test problems in are... types of operati... tremely low concen- ...use distinct and dis- ...and odor in water ...and shellfish caught ...ated water: ...lems in which natu- phenols in drinking ...en identified as the ...of kidney ailments, ...in some areas of

...profes- sor of chemical engineering, and Dr. E. Kendal Pye, assistant professor of biochemistry, at the University of Pennsylvania, the co-principal investigators of the project, said that phenolic pollutants are difficult to detect, they cause odor and taste problems, they pose serious health problems in some countries, and they inhibit the natural biological

...concentrations of phenols (1.5 and .5 grams per liter, respectively, as opposed to the .001 milligrams per liter limit set by the U.S. Public Health Service for drinking water).

It is the highly concentrated phenols in these effluents that the University of Pennsylvania group hopes to degrade into less noxious compounds through the use of enzymes

...late, or catalyze, reactions distinguishes enzymes from other proteins.

Chemical engineers and biochemists on the project, supported by a grant of $215,000 from the National Science Foundation, will make a multi-pronged attack on problems related to the practical use of enzyme systems focusing on their use

capable of catalyzing the ... phenol. Once a good source is found, these will study ways of growi... ticular micro-organism will produce the maximu... of enzyme. A key prob... area is to produce large... of the enzyme.

• Investigate me... recovery and purificati...

GL01408

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FOR RELEASE: Immediate
Mail: June 4, 1974
NSF 74-168

DEEP WELL AT MONTANA SITE TO TEST POTENTIAL OF GEOTHERMAL ENERGY SOURCE

Drilling began this week in old mining country near Marysville, Montana, to determine whether a usable source of geothermal energy exists there.

If the answer is yes, there is the promising prospect that the site itself offers a generous reserve of energy which can be turned to electricity on a commercial scale.

A yes answer would give hope also that other such sources are waiting to be discovered in the western United States and might provide a large contribution to the nation's domestic energy supply.

The "spudding in," the first bite of the drill for a well going down more than a mile, follows more than a year of exploratory research to assess the nature and size of a formation of hot rock and its subsurface characteristics. The project has been funded from the beginning by the National Science Foundation.

The site, 10 to 12 square miles in area, attracted attention upon discovery there of an abnormally high heat flow from the earth, without the geysers, steam, hot springs, or volcanic residues usually associated with such a heat source below.

To scientists, the circumstances suggested the presence beneath the surface of a young intrusive rock mass, sufficiently hot and close to the surface to produce what the researchers call the Marysville "geothermal anomaly."

The possiblility that what may be found at Marysville may exist elswhere in the west arises from the fact that the western United States is geologically newer than the eastern part and more likely to hold such sites.

The Marysville intrusive, if confirmed, would be the first of its kind penetrated by a drill. The hypothesis pictures a process wherein molten rock formed in the mantle of the earth made its way through the crust without venting at the surface, presenting a formation at an accessible depth which has cooled sufficiently to harden, but is still hot.

When the drilling results become available, it will be known if the site is hot and wet; hot, dry and fractured; or hot, dry and not fractured. Fracture of the rock is important because fracturing permits greater surface area of hot rock to be in contact with injected water for greater efficiency in producing steam. Methods usable in converting the heat to electricity depend on the answer.

The working assumption is that the rock is hot; 700° to 800°F at 6000 ft. depth. If the rock is wet, the task will be to harness its steam. If the rock is wet, the task will be to harness its steam. If it is dry and fractured, the task will be to introduce water from the surface and harness the resulting steam. If the rock is dry and unfractured, various methods of fracturing can be tried to make it permeable to injected water. In any case, electric power would be obtained by getting steam from the rock and running it through a turbo-generator. The steam would then be condensed and recycled into the rock formation.

The Marysville project began as the result of basic research. Because of the power generating potential and economic implications for other areas, the work has been carried into applied research. Dr. David D. Blackwell, of Southern Methodist University, carrying on geophysical studies supported by the Research Directorate of the National Science Foundation, discovered "an astonishingly high heat flow" through measurements in shallow wells in the Marysville mining district. Exploratory evaluation which followed, sponsored by the Foundation's Research Applications Directorate, developed strong evidence for the hypothesis which the drilling this summer will test.

There is some opinion that the Marysville thermal anomaly may result from steam trapped near a deeper intrusive. If this is so, it suggests a conclusion, regarded by the research team as exceedingly important, that hidden steam fields may be more common than heretofore thought.

-more-

In addition to deep well drilling in the summer of 1974, geoscience studies will include completion of geological mapping, heat flow analysis from eight additional 200-feet wells, further micro-earthquake studies, and surveys of variations in magnetic and electric current manifestations as indicators of subsurface structure.

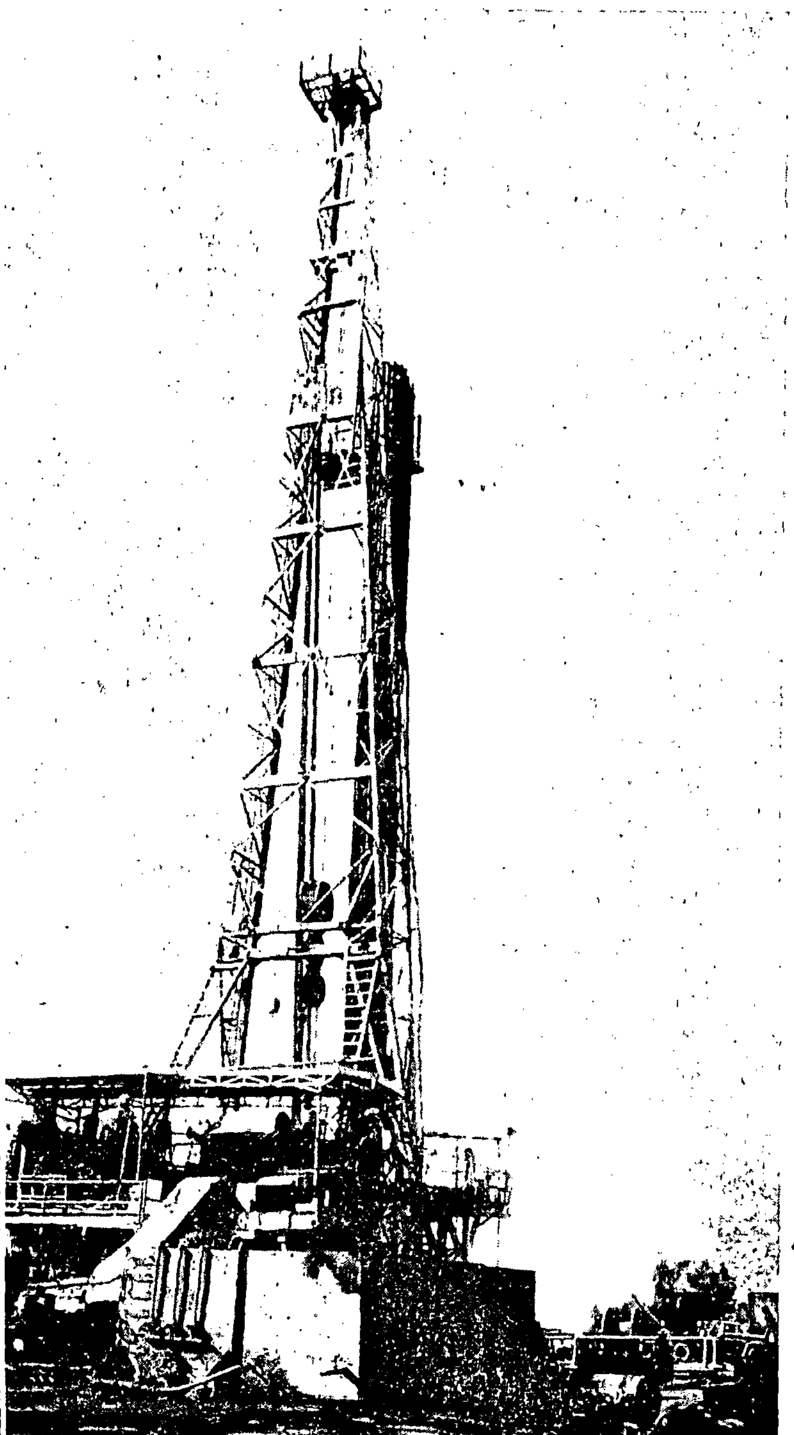
The total funding for the 30-month project is programmed at $2,448,500. Battelle Memorial Institute, Richland, Washington, is the grantee institution, and the Principal Investigator is Donald H. Stewart.

Participating in the work are Southern Methodist University, Dr. Blackwell; Rogers Engineering Co., San Francisco, James D. Kuwada; Systems, Science and Software, La Jolla, California, Dr. Russell E. Duff; and the University of Utah, Dr. Stanley H. Ward.

-END-

Dr. Ward
from World Oil, vol. 177 #7

How geothermal wells are drilled and completed



John Cromling, Drilling Engineer, Big Chief Drilling Co., Oklahoma City, Okla.

10-second summary

Unusual and costly operating problems have been solved in perfecting techniques to drill and complete steam and hot brine wells. This article presents detailed information on surface and downhole drilling equipment; casing design; mud and cement programs, and completion procedures.

Big Chief Drilling Co. has developed unique methods and equipment for drilling and completing geothermal wells in California's Imperial Valley and in the Geysers area, 75 miles north of San Francisco in Sonoma County. These are the two areas in the United States where active geothermal development is underway.

Abnormally high temperatures to 500° F, very hard drilling and excessive erosion of downhole and surface equipment are a few of the problems which make geothermal wells relatively expensive. A 3,000-foot Imperial Valley completion costs about $125,000 and a 5,000-foot well about $200,000. In the Geysers area, a 7,000-foot well costs some $350,000. However, wells are profitable to the producer. A Geysers well capable of producing 200,000 pph of steam is comparable in value to a 250-bpd oil well.

Imperial Valley wells produce hot brine while superheated steam is produced from Geysers area wells. As a result, drilling and completion techniques vary between areas. This article outlines methods and equipment now used successfully in both places.

DRILL SITES

Imperial Valley locations usually are not a problem since terrain is nearly flat. Drilling water is readily ob-

FIG. 1—Big Chief Drilling Co. is drilling for geothermal energy in the Imperial Valley and Geysers areas of California. Imperial Valley wells produce hot brines, while Geysers wells produce dry superheated steam.

tained from irrigation canals which cross the valley.

Geysers area locations cause problems because of rugged, mountainous terrain. Often, drill sites are constructed as small as possible due to economic reasons and blasting is often required for location clearing. Normal drill sites cost as much as $10,000 and some as high as $40,000.

Some operators use surface spring water for drilling operations, but the main water source has been a creek. On some remote locations, water must be hauled by truck.

Natural borehole drift also is considered before selecting a location. All these factors tend to increase location costs and in some cases reduce efficiency of the rig.

DRILLING RIGS

Most Imperial Valley rigs are rated for 3,000-7,000 feet. The preferred rig usually consists of a 250,000-pound derrick to handle the liner, the largest hook load, with 300-hp drawworks powered by a 450-hp engine. Independent mud pumps are driven by 500-hp engines. Drill string is usually 3½-inch drill pipe and 6-inch drill collars.

Geysers area wells require drawworks and drilling engines of at least 1,000 hp and two 600-hp mud pumps.

The 17½-inch Geysers surface hole requires high pump output. The rotating system must tolerate excessive torque and shock loading. Rotary clutch, shaft and chains are susceptible to damage and must be properly designed to match the job. Direct drive between the power train and rotary table should be avoided. This is accomplished by using fluid couplings on the compound or an independent rotary drive which absorbs shocks transmitted through the system.

CASING DESIGN

Normally, 20-inch conductor is set at about 110 feet in Imperial Valley wells by a rat hole rig.

A 1,050-foot, 17½-inch surface hole is drilled for 13⅜-inch 48 ppf H-40 surface pipe with buttress connections. The string is a normal design except for buttress connections needed to overcome heat expansion stresses (Fig. 2).

A 7⅞-inch hole then is drilled to TD, varying from 2,600 to 6,000 feet. This small hole has the advantages of:

- Drilling faster
- Lower bit costs
- Better surveying
- Lower stabilization costs
- Easier testing.

If the well is a potential producer, the pilot hole is opened to 10⅝-inch to the necessary depth.

Production string is usually 8⅝-inch (Fig. 2) and a combination 36 ppf J-55 slotted liner and 32 ppf J-55 blank liner. Hung at about 900 feet, the liner acts as a slip joint to allow for thermal expansion prior to cementing and permits larger hole sizes in the upper portion to accommodate downhole pumps used to produce hot brine from the well.

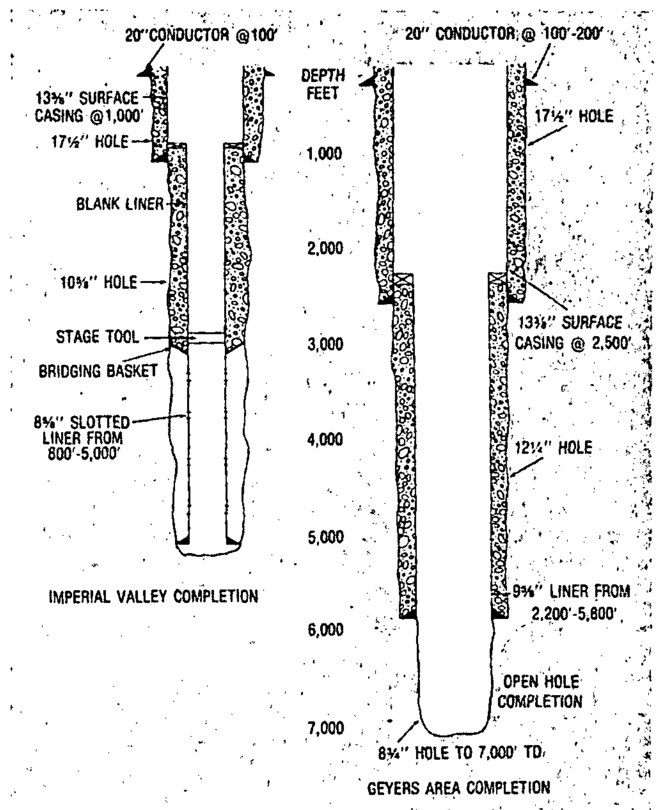


FIG. 2—Imperial Valley wells are completed with 8⅝-inch liners. A slotted section, run on bottom of a blank section, is set through the productive interval. Geysers area wells are completed open-hole. A 9⅝-inch liner is set just above the steam zone prior to drilling the well in.

In the Geysers area, 20-inch conductor is set at 100-200 feet. A 17½-inch surface hole then may be drilled in one pass or a 12¼-inch pilot hole may be drilled and opened to 17½ inches (Fig. 2). Sometimes the latter procedure reduces over-all bit and stabilizing costs, and the probability of drill string failures.

Surface pipe is usually 13⅜-inch K-55 61 ppf with buttress connections for heat expansion. Surface strings are set at 1,000-2,500 feet, depending on local geology. Purpose of the surface string is to case off numerous shallow water flows, unstable serpentine and fractured graywacke.

A 12¼-inch hole is drilled below surface casing to just above the anticipated steam zone to accommodate a 9⅝-inch K-55 36 and 40 ppf buttress liner. This liner shuts off deep water flows and covers as much open hole as possible prior to drilling into the steam zone. A much cleaner well is provided thus protecting production equipment from unnecessary erosion.

An 8¾-inch hole then is drilled to TD and the well is completed open hole.

MUD SYSTEMS

Fresh water gel-lignite muds are commonly used in the Imperial Valley. Lignite acts as a thinning agent, counteracts high temperature effect and reduces viscosity by preventing clay particles from uniting. Normally, mud weight is 75 ppcf (10 ppg) with funnel viscosity of 35-40 seconds. Solids content, kept to a minimum, aids drillability by reducing heat-carrying capacity of mud.

No high pressure zones are encountered and mud weight is maintained for hole stability. Lost circulation is not a serious problem, but it is advisable to wait a few hours after experiencing a loss to allow the formation to heal. Both lost circulation material and cement have been used to regain circulation.

The critical factor in the mud system is the high temperature of circulating mud. Most Imperial Valley holes have BHTs near 500° F and circulating temperatures of 200° F. On extremely hot wells, a cooling tower is used to reduce circulating temperature 30°-40° F, enough to keep the mud in a usable fluid state.

Geysers drilling fluid is usually a low solids gel, tannathin and fresh water system, which has proven most practical because of excessive lost circulation. As temperature increases with depth, mud dehydrates and become viscous. Steps then must be taken to counteract increased viscosity so that a usable drilling fluid is maintained. It is advantageous to use a large, high speed shale shaker, desander and desilter to remove drilled solids. Also, pits must be cleaned each tour and sometimes more often to maintain a low solids system, particularly while drilling 17½-inch hole.

Cooling towers normally are not used in the Geysers, but large fans may be installed to cool the 200° F mud 20°-30° as it crosses shale shaker screens.

Severe lost circulation occurs in large fractured intervals. Cottonseed hulls (12 pounds/barrels) may be used to heal the zone, but cement is sometimes necessary.

Where possible, Geysers wells may be air drilled to increase drilling rate and reduce lost circulation. Often, air cannot be used in top hole sections because of water zones. However, it is necessary to air drill steam intervals to avoid damaging the well.

BITS

One first stage bit will usually drill 17½-inch surface hole at 50-70 fph in the Imperial Valley, depending on hole conditions. Weight and rpm are not critical because of soft formations. Hydraulics dictate drilling rate, which is regulated to maintain hole stability.

A 7⅞-inch pilot hole is drilled to TD using first stage bits. This portion drills almost as fast as hole stability and drilling conditions will allow. Normally, a bit will drill 1,000 feet in about 20 hours. If the hole is potentially productive, it is opened to 10⅝-inch using a hole opener. The opener will penetrate about twice as fast as initial drilling, with no problems other than occasional lost circulation. Generally, Imperial Valley formations drill very fast with a minimum bit cost.

Shallow formations in the Geysers are hard. A second stage steel mill tooth bit is required for spudding. All available drill collar weight must be used and the rotary must be turned at a speed which allows the bit to run smooth. Faulted and fractured formations cause the bit to jump and bounce unless weight and rpm are coordinated properly. Often, higher drilling rates are sacrificed to preserve the bit and surface drilling equipment.

Carbide insert bits commonly are used at about 1,000 feet and drill at 20 fph in the surface hole. If necessary, 12¼-inch pilot hole can be opened to 17½-inch using bits or hole openers, with bits more economical and safer. Generally, 17½-inch hole is opened three times as fast as the 12¼-inch was drilled if hydraulics and drill collar sizes are optimum.

Hole below surface casing is drilled with insert bits but sometimes a third stage tooth bit is required. Cost per foot of hole drilled recently has been reduced using insert bits in this section of hole. Drilling rates are 10-20 fph with mud and 10-35 fph with air, where applicable. Hole below the liner drills at 25-75 fph with air and insert bits.

Geysers drilling programs vary greatly and every well must be drilled as a wildcat due to variations of local faulting and lithology.

GEYSERS DRILLING PROBLEMS

Hard abrasive rocks, fracturing and complex faulting cause crooked holes in the Geysers area. But the problem can be reduced if the surface location is picked to take advantage of natural drift. Ultra-packed hole assemblies and large OD drill collars reduce dogleg severity to the 2° per 100-foot range. Deviation build up at 3° per 1,000 feet is normal and presents no problems if dogleg severity is minimal.

Sometimes, optimum locations are not feasible due to rough terrain, thus restricting total bottom hole displacement of the well bore, or requiring the well to be directionally drilled at considerable expense. As much as $100,000 can be added to total well cost on difficult jobs. Directional work should be performed as shallow as possible due to hard formations and detrimental effects of high downhole temperatures on directional tools. A bit normally will be worn out in 30 feet or less while drilling at high rpm associated with mud motors.

Drill strings also are subjected to severe conditions in the Geysers. Hard fractured graywacke and chert in 17½-inch hole contribute to excessive torque and bouncing of drill pipe. In some cases, torque has been so great that it is virtually impossible to turn the bit with any degree of success while using as little as 40,000 pounds drilling weight. Many twist-offs and failures occur in this portion of the hole.

Drilling 12¼-inch hole is similar except that it is smaller, there is less whipping action in tool joints and temperatures are higher. Formations are essentially graywacke, chert and serpentine stringers.

The worst hole is that part drilled with air. Near bottom, steam may enter the hole. Steam plus air causes severe erosion of drill pipe tool joints, due to hard abrasive cuttings traveling at high annular velocities. Depending on steam production, return velocities range from 6,000-10,000 fpm. Tool joints can almost be cut off the drill pipe and hardband can be completely erased. Thus, drill pipe must be inspected before each well to guard against failures.

Often over 50% of a drill string is useless after drilling one geothermal well in the Geysers area. Drill collars are usually inspected on a weekly basis during drilling.

Drill strings are considered expendable, especially drill pipe. Drill collar joint fatigue, due to bending stresses and harmonic vibrations, is accelerated 10-20 times, compared to most areas. Drill pipe and drill collar maintenance, including discarded drill pipe, is about $25,000-$35,000 per well.

CEMENT

The most succesful slurry used in the Imperial Valley is a 1:1 ratio of premixed neat and perlite cement with 4% gel. A 150-barrel cool water flush precedes cement to allow for high temperatures. The 8⅝-inch liner is cemented in stages using a DV tool and bridging baskets to protect the slotted section.

Another popular slurry has been a 1:1 ratio of neat and perlite with 40% silica flour (to prevent compressive strength retrogression) and a friction reducer.

To guard against surface casing parting, cement is circulated back to surface. Casing and cement coefficients of thermal expansion are nearly identical, thus cement and casing will expand together.

Cementing Geysers wells is similar to cementing deep gas or oil wells with high BHTs. Conductor is cemented with a slurry of Class G and $CaCl_2$. Surface casing slurry is a 2:1 ratio of Class G and Litepoz with 30% silica flour and retarder. To reduce pumping time down 13⅜-inch casing and because of limited water storage available, cementing is through drill pipe using a "stab in" type float collar.

Liner slurry is a 1:1 mixture of Class G and Litepoz with 30% silica flour, retarders and friction reducers. This slurry is exposed to higher temperatures and more retarders are used, plus some friction reducer additives.

Sometimes, drilling fluid gels due to heat and pressure as the liner is run. Highly gelled or partially solidified mud can cause bridging, making it necessary to squeeze the liner top. A retrievable packer is set in the 13⅜-inch immediately above the liner hanger and cement is pumped through liner hanger ports down the liner annulus. About 50% of Geysers area wells require liner top squeezing.

BOP EQUIPMENT

BOP equipment is subjected to extreme damage from heat and abrasion. A recommended stack (Fig. 3) from bottom to top consists of:

1. Casing head with flanged wing outlets containing internal plug receptacles which allow changing wing valves without killing the well.

2. Full opening gate valve with stainless trim, later used as a permanently installed production valve.

3. Wear flange to protect the valve while drilling.

4. Two sets of ram BOPs to shut-in the well for repairs on the banjo box or blooey line.

5. A banjo box (modified QRC body to which the blooey line is attached) which is subjected to severe erosion as steam and cuttings are diverted out the blooey line.

6. A double set of ram BOPs, which allow the well to be shut-in while testing or circulating through the blooey line.

7. Rotating head, for stripping in and out of the hole while air drilling or when steam is being produced.

8. A blooey line, as large as surface casing, is laid in a straight line to minimize cutting action. A muffler on the end of the line controls dust and noise.

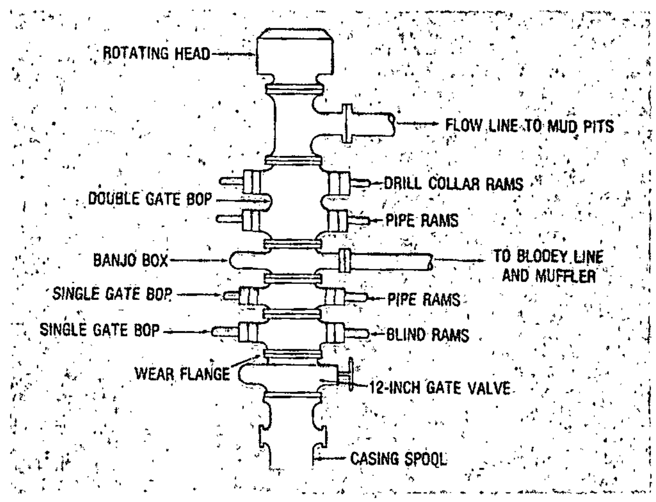


FIG. 3—Special BOP equipment is used on all geothermal wells. A full opening gate valve, installed just above the casing spool, later is used as a production valve. When testing, the banjo box is used to divert steam and cuttings out the blooey line. Ability to strip in and out of the hole is provided by a rotating head.

Rubber products in BOP equipment get soft and expand while in contact with steam, but turn hard and brittle as they cool. Ram rubbers are normally ruined after one well. High temperature rotating head rubbers usually last for one round trip while producing steam when drilling into steam zones. Water is injected under the rotating head to help preserve the rubber.

BOPs must be inspected and repaired before each well.

COMPLETIONS

In Imperial Valley wells, 8⅝-inch liner is run and cemented. BOPs then are removed, the master gate valve is installed and BOPs re-installed for drilling out. Mud system is usually changed to salt or brine water to clean out cement and wash the slotted liner. After washing, the well is essentially completed. Rig is moved off and production tree installed. Average cost of a 3,000-foot well in the Imperial Valley is about $125,000 while a 5,000-foot well costs about $200,000.

In the Geysers area, wells are first tested with drill pipe in the hole using an orifice plate in the blooey line to determine if the well is producing the desired amount of steam. Drill pipe is pulled and wells are again blown for about 4 hours after which they tend to stabilize, giving accurate tests. If a well is satisfactory at this time, it is shut-in and steam is vented through a ½-inch line to prevent steam condensation which could kill the well.

After moving the rig off location, production equipment is installed. Since completions are open hole and no logs are run, they are quick and uncomplicated.

Some problems arise during the last trip out of the hole, when great quantities of steam are being produced. Most BOP failures occur at this time. A typical steam well in the Geysers area costs about $350,000 to drill and complete. ■

About the author

JOHN CROMLING *gained oil field experience working as a roughneck in Alaska and as a drill pipe inspector in South Texas prior to receiving his B.S. degree in petroleum engineering from the University of Oklahoma in 1970. After graduation, Mr. Cromling joined Big Chief Drilling Co. as an engineering trainee and worked on several rigs throughout the United States. He later became associated with geothermal drilling operations in California as Big Chief's drilling engineer. Mr. Cromling is a member of SPE-AIME.*

WHI DE

S. H. Ward

metamorphosis progressed. *R. pipiens* tadpoles had only the 4.3*S* component in its red blood cells and did not show the heavier 7.0*S* component; the adult *X. laevis* had only the 4.3*S* component initially, but apparently formed a limited amount of the 7.0*S* hemoglobin when the lysate of the red cells was stored under refrigeration for several days. Average molecular weights indicated 68,000 for the hemoglobin of *R. grylio* tadpoles and 68,000 and 136,000 for the two principal components for the frogs of this species.

Certain of the red blood cell components detected in the ultracentrifuge were separated by starch-block electrophoresis in sufficient quantities for further study and identification. The small amount (less than 10 percent) of the 2.7*S* and the predominant (more than 90 percent) 4.3*S* ultracentrifuge components of the red cells of the *R. grylio* tadpole corresponded respectively to the slower and faster moving bands visible on starch-block electrophoresis of the lysate. The 4.3*S* and 7.0*S* components of the red cells from the *R. grylio* adult corresponded to the faster and slower moving electrophoretic bands, respectively. When present in the cells of the adult, the 10*S* to 11*S* component is eluted with the band of 7.0*S* material. With respect to relative electrophoretic mobility, the slower (2.7*S*) tadpole component migrates at about the same rate as the faster (4.3*S*) frog component.

Amino acid analyses were made on the globins from the best available preparations of tadpole and frog hemoglobins. For the tadpole, analyses were obtained on two pooled lysates which had been centrifuged at 20,000*g* and one pooled sample of electrophoretically purified hemoglobin with comparable results. For the frog, amino acid data are averaged from analyses of the supernatant solution from the centrifugation at 20,000*g* of the washed, lysed red blood cells of three adults. The frog hemoglobin analyses thus include the 4.3*S*, 7.0*S*, and any 10*S* to 11*S* hemoglobins and any other component present in these lysates. Other protein components present are believed to be negligible. The globins were precipitated with a mixture of HCl and acetone, and hydrolyzed by refluxing with 6*N* HCl for 18 hours. Amino acid analyses expressed as residues per 68,000*g* by the Moore-Stein technique (*8*) for tadpole and frog were, respectively: arginine 18, 26; lysine 30, 34; histidine 29, 41; aspartic acid 53, 39; glutamic acid 44, 36; methionine 2, 5; and ½ cystine 0 to 1, 7 to 8. There was a significant increase in dibasic amino acids and a decrease in dicarboxylic amino acids in the transition of tadpole to frog. Also very striking is the increase of half-cystine residues in general agreement with the observations of Riggs (*5*). The changes in amino acid composition are in accord with the experimentally observed differences in rates of migration of these hemoglobins on both starch and paper (see Table 1, properties g, h, and k). It is evident that there is an extensive alteration in amino acid composition of hemoglobin chains during metamorphosis.

Spectrophotometric studies confirmed the absence of any differences in the visible region of the spectrum (*4*). Frog red blood cell lysates resisted methemoglobin formation less readily than did lysates from tadpole cells under identical conditions of storage. A large increase in absorption at 540 mμ compared to 570 mμ and the appearance of the 625 mμ peak characteristic of methemoglobin was observed. The ultraviolet spectrum shows a decrease in the intensity of the tryptophan band at about 289 to 291 mμ during metamorphosis accompanied by a shift to longer wave length characteristic of fetal to adult hemoglobins (*9*).

The now numerous differences in tadpole and frog hemoglobins are summarized in Table 1. Our data would indicate there are at least two principal hemoglobins in the adult *R. grylio* and one in the tadpole. In these experiments the 7.0*S* component does not appear to be interconvertible with the 4.3*S* fraction as evidenced by separate sedimentation experiments with varying protein concentration and increasing ionic strength. The sedimentation patterns for adult *R. grylio* and *R. catesbeiana* are the same whether observed one hour or five days after bleeding, in contrast to adult *X. laevis* samples. Furthermore, the individual components isolated electrophoretically have never given evidence of dimerization or splitting to form the component removed by electrophoresis even after storage for more than 30 days at 5°C. Since there are two or more hemoglobins, this poses some interesting questions regarding their biosynthesis; for example, whether the 7.0*S* hemoglobin, which presumably is an octamer, contains any peptide chains in common with any of the chains of the 4.3*S* tetramers (*10*).

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17 December 1962

Geothermal Brine Well: Mile-Deep Drill Hole May Tap Ore-Bearing Magmatic Water and Rocks Undergoing Metamorphism

Abstract. *A deep geothermal well in California has tapped a very saline brine extraordinarily high in heavy metals and other rare elements; copper and silver are precipitated during brine production. Preliminary evidence suggests that the brine may be pure magmatic water and an active ore-forming solution. Metamorphism of relatively young rocks may also be occurring within accessible depths.*

A geothermal well has been drilled recently in Southern California into a geologic environment that can only be described in spectacular terms. The well was drilled for geothermal power near Niland, close to the Salton Sea in the Imperial Valley, during the winter of 1961–62. It is 5232 feet deep (*1*) and is the deepest well in the world today in the high-temperature hot spring areas. In the lower half of the hole, temperatures are too high to measure with available equipment, but they are at least 270°C and may even reach 370°C. For comparison, the previous maximum temperature reported for hot spring areas is 295°C, observed at Waiotapu, New Zealand, in a 3000-foot drill hole (2).

The well taps a very saline brine which has an unusually high potassium content, and perhaps the highest lithium and heavy-metal content known for natural waters. During a production test, the brine deposited in discharge pipes material astonishingly high in silver, copper, and some other scarce elements normally concentrated in ore deposits. Considerable evidence favors the geologically fascinating possibility that this brine is man's first sample of an "active" ore solution of the type that probably formed many of the world's economic concentrations of ore metals in the geologic past. Moreover, this brine may originate at greater depths as a water-rich fluid residue from crystallization in the magma chamber that also supplied the recent rhyolite and obsidian volcanoes of the area. If this is so, the brine is an undiluted magmatic water that can be sampled and studied in detail for the first time.

Equally fascinating is the possibility that temperatures in the lower part of the hole are so high that transformation of young sedimentary rocks into metamorphic rocks is taking place within depths accessible for scientific study. These metamorphic processes are considered to occur at "normal" earth temperatures only at depths below 25,000 to 30,000 feet, beyond present limits for direct study.

The Salton Sea is on the northern extension of the downwarped or downfaulted trough of the Gulf of California. The southernmost recognized branches of the great San Andreas fault of California extend into the area. The general geology of the area has been mapped by Dibblee (3); a geophysical study by Kovak and others (4) extends up from the south just to the geothermal area. Both reports indicate great structural depression of the trough in the last 10 or 20 million years. An estimated 10 to 20 thousand feet of relatively young sedimentary rocks lie on rocks of pre-Tertiary age, as confirmed in part by oil-test holes up to 12,000 feet deep. Gravity data indicate a local gravity high for the thermal area. This gravity high could be explained by upfaulting of a sliver of relatively heavy pre-Tertiary rocks between branches of the San Andreas fault, but it is perhaps equally well explained by local transformation of young light rocks into heavier rocks. For such changes there is normally a decrease in pore space and a decrease in water content, and new minerals are formed in response to high temperature or pressure; chemical changes other than change in water content may also occur.

Dibblee (3) has mapped a northeast-striking line of pumiceous rhyolite and obsidian domes of Quaternary age that lie in and near the geothermal area at the southern end of the Salton Sea, but the northeastern dome—Mullet Island—is not shown on Dibblee's map. The domes, as well as nearby hot springs, mud volcanoes, and shallow wells drilled for CO_2, have been described briefly by others (5).

The chemical composition of this extraordinary brine is known quantitatively for only a few components but estimates of the order of magnitude of the concentrations have been made for many other components. Some serious analytical problems are already apparent, and others are expected. A sample of the deep brine was collected from a 3000-gallon water-steam separator of the test system at the end of the 3-month production test. The sample was collected carefully in an attempt to obtain a sample representative of nonerupted brine at depth; the valves were closed on the separator while the proper proportions of brine and high-pressure steam were maintained, and the mixture was then cooled and the steam condensed. Some gas remained as a vapor phase, so the original composition could not be duplicated exactly.

Analyses of the gases (6) show 80 to 93 percent (by volume) of CO_2, methane, and other gases; H_2S, of special interest, was reported to be 0.35 percent in a sample collected 1 June 1962, but was not detected in samples collected 4 July and 8 August.

A partial analysis of the water sample (in parts per million by weight) includes (6): Na, 54,000; K, 23,800; Li, 321; Ca, 40,000; total halides as Cl, 184,000; evaporated residue (180°C), 332,000; specific gravity at 20°C, 1.262. Semiquantitative spectrographic analysis (6) of the evaporated residue indicates the following concentrations, computed in parts per million of the original water: Fe, 3000; Mn, 1000; Ag, 2; B, 500; Ba, 200; Cr, 0.5; Cu, 20; Ni, 2; Pb, 100; Sr, 2000; and Zn, 500. Each figure given is intended only as an indication of the order of magnitude of these concentrations. Many are far higher than reported concentrations in other natural waters (excepting acid mine waters).

This brine, as identified by its major components, is an NaCaCl or NaCaKCl type.

The water of most spring systems associated with volcanism is dominantly of surface origin; when rocks are fractured and permeability permits, the water circulates deeply and is heated by conduction in the high heat-flow environment. Additional heat and perhaps a few percent of magmatic water with dissolved substances are supplied near the base of circulation, and the hot mixture rises in the core of a huge convection system, with little loss in temperature until pressures near the surface are low enough for the water to boil. Thus the typical system has a very high rate of temperature increase from the surface downward for the upper few hundred to a thousand feet or more. The depth of the zone of boiling depends on the temperature of the rising water (7). At some depth and temperature characteristic of each spring system, temperatures tend to level off downward, with little further increase at greater explored depths. The Niland system, however, probably has little physical movement of water except perhaps from a magma chamber upward into the brine reservoir where it has presumably displaced water of lower density that formerly occupied the available pore spaces; original ground temperatures before the drilling seem to have been controlled primarily by rock conduction and have shown a nearly straight-line increase with depth.

Pressures within the system are about 25 percent higher than hydrostatic pressures would be for pure water having the same temperature distribution at similar depth (5, 8); normal dilute meteoric water cannot circulate downward against such pressures. In addition, extremely high salinity and high concentrations of elements such as potassium, lithium, and the heavy metals are very unlikely to occur in a dynamic convection system that requires a large supply of scarce elements. For these reasons, and in contrast to most thermal spring systems, we consider seriously only certain kinds of water of deep origin to explain the brine in the Niland system.

The chemical characteristics of different kinds of saline water of deep origin, as presently understood, have been reviewed recently (9). The deep

Niland brine is not clearly any one of these previously recognized types. Present limited evidence, namely the very high brine temperature and the unusually high content of potassium, lithium, and other rare elements, suggests a magmatic type not previously recognized with certainty in hot spring areas. This type presumably is so saline and heavy, and so low in volatile components other than H_2O that it ordinarily remains deep within each volcanic system and rarely if ever appears at the surface in high concentration in hot springs. If such a magmatic water does exist, it is similar in its major components, sodium, calcium, and chloride, to the dominant type of very saline connate (fossil) brine of the earth's oilfields of pre-Tertiary age (*9*). But the Niland water differs greatly from these connate waters: the content of potassium and lithium is extraordinarily high, and there is a virtual absence of sulfate. Marine and nonmarine salt deposits can also develop end-stage brines high in potassium and somewhat high in lithium, but these types are normally very high in magnesium and sulfate and low in calcium and heavy metals. The concentrations of cesium, rubidium, bromide, iodide, the heavy metals, and the isotopes of hydrogen and oxygen are of particular interest. These components and the ratio of each to its geochemically most closely related major element (such as Cs/Na and Br/Cl) are becoming very useful in distinguishing waters of different origins (*9*).

If the brine is of magmatic origin and is rising upward into porous rocks and displacing less-dense water of some other origin, a density-stratified interface probably exists at some unknown height above the first casing perforations at 4900 feet; the brine reservoir is probably the local source of heat in the area. Temperatures should increase with depth toward this source of heat but they will then either attain a maximum or will increase less rapidly with increasing depth below the brine interface, depending upon the details of the water circulation within the brine reservoir. On the other hand, if the brine is one of the several nonmagmatic types also being considered, it is being heated entirely from below by thermal conduction, presumably from the magma chamber that was the source of the rhyolite and obsidian domes of the area. For any of these nonmagmatic origins, temperatures probably continue to rise as depth increases through the brine reservoir, although not by a straight-line relationship if thermal conductivities of the rocks differ by very much.

Of significance also in ascertaining the origin of the water is the nature of dark material deposited from the brine during the 3-month production test. The total quantity of the deposit precipitated in the 275-foot-long horizontal discharge pipe from the well was not measured, but it was so thick at the discharge end that cleaning was required at 1-month intervals (*10*). A rough calculation indicates that 5 to 8 tons were precipitated during the 3 months.

A fire assay of the deposit (*6*), reported a silver content of 381 ounces per ton, or nearly 1.2 percent, and a gold content of 0.11 ounce per ton. A semiquantitative spectrographic analysis of a piece of deposit collected about 100 feet from the discharge end of the pipe is shown in Table 1. The sample from the discharge end has an almost equally high content of heavy metals, and the thin deposit from the well has an even higher content. Natural waters have never before been observed to precipitate such high concentrations of silver and copper; other notable concentrations of elements that are rare or widely dispersed in ordinary rocks are arsenic, boron, beryllium, bismuth, gallium, lead, and antimony. Calculations indicate that 1 to 3 ppm of copper and 0.1 to 0.3 ppm of silver were precipitated from the water to form the pipe deposits. These quantities are in the order of 10 percent of original concentrations indicated by spectrographic analysis for the whole brine.

A "whole-rock" x-ray diffraction analysis of the pipe deposit shows chiefly amorphous material with a high iron background. Most of the low x-ray peaks in the record are very close to those of bornite, a copper-iron sulfide abundant in many copper deposits. Several other peaks have not yet been identified.

The mineral assemblages of rocks, when buried to great depths and heated up to earth temperatures normal for such depths, change to new mineral assemblages called metamorphic rocks. All such rocks that geologists have studied in the past were formed ten million years ago or more, and at great depths in the earth. Where they are now exposed at and near the earth's surface, extensive uplift and erosion of the original overlying cover has occurred to reveal them. Evidence for the begin-

Table 1. Semiquantitative spectrographic analysis of dark deposit in pipes from brine of the deep well (6). Results are reported in percentage to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, and so forth, which represents approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results includes the quantitative value about 30 percent of the time. The following elements were below the limits of detection: Au, Cd, Ce, Hf, Hg, La, Li, Mo, Nd, P, Pt, Pa, Re, Sc, Ta, Te, Th, Tl, U, W, Y, Zn, Zr.

Element	Percentage	Element	Percentage	Element	Percentage
Si	Major	Ag	2	Ga	0.02
Al	0.7	As	0.15	Ge	0.001
Fe	7	B	0.15	Ni	0.0001
Mg	0.015	Ba	0.015	Pb	0.02
Ca	0.7	Be	0.07	Sb	0.3
Na	1	Bi	0.005	Sn	0.0007
K	1	Co	0.0001	Sr	0.007
Ti	0.0015	Cr	0.0002	V	0.0005
Mn	0.5	Cu	~20*	Yb	0.0002

* This exceptionally high copper content, determined by 1000× dilution, has been confirmed by x-ray fluorescence by W. W. Brannock, who also determined by the same method that the sulfur content was approximately 8 percent.

Table 2. Summary of characteristics of drill core from geothermal wells at Niland.

Approximate depth (ft)	Bulk specific gravity	Minerals present*
4477	2.47	Chlorite, K-feldspar, K-mica, quartz, albite†
4484	2.53	K-feldspar, quartz, chlorite, K-mica, albite†
4662‡	2.52	Quartz, K-feldspar, chlorite, albite, pyrite§
4917	3.18	Epidote, quartz, some feldspar or unknown or both, pyrite‖
4923	2.62	Quartz, chlorite, albite, epidote, pyrite

* In approximate order of decreasing abundance, as determined by whole-rock x-ray diffractometer, and by microscope inspection of thin section. † Epidote and pyrite in veinlets. ‡ From Sportsman No. 1 well of Joseph I. O'Neill and associates, about ¼ mile ESE of the deep well (Imperial Irrigation District No. 1 well) and drill to depth of 4729 feet. § Veinlets of quartz and pyrite without epidote. ‖ Epidote constitutes 60 percent or more of the rock.

ning stages of active metamorphism has been looked for in oil-test wells that are drilled 20,000 feet and more below the surface where "normal" temperatures are in the order of 200°C; however, such evidence has not yet been found. Recent conclusions (*11*) are that "low-grade" metamorphic rocks, with minerals such as chlorite, epidote, and albite, first form normally at depths in the order of 25,000 to 30,000 feet, where temperatures are probably near 250°C.

Five specimens of drill core have been studied in some detail, and the data are summarized in Table 2. All five specimens were originally shale or siltstone, but they now contain minerals characteristic of the greenschist or chlorite grade of metamorphism. The pre-Tertiary basement of the Salton Sea Basin is considered (*3, 4*) to be 10,000 to 20,000 feet below the surface throughout most of the structural trench, and relatively young rocks of Pliocene age dominate the upper 5000 to 10000 feet. If this general picture is correct, the low-grade metamorphic rocks of the drill core must be either old basement rocks that have been upfaulted locally as a sliver between branchs of the San Andreas fault, or they are rocks of relatively young Tertiary age that are now being metamorphosed because of high temperatures at these lesser depths.

Some geologists will be of the opinion that mineral changes in this environment should be called "hydrothermal alteration" (commonly produced by the action of ore-depositing waters) rather than "metamorphism." Hydrothermal alteration is normally characterized by new hydrous minerals, and by a decrease in specific gravity of the altered rocks. Metamorphism, on the other hand, normally consists of the formation of new mineral assemblages stable at higher temperatures and pressures than former assemblages; specific gravities usually increase with metamorphism, and water content decreases. In this sense the deep Niland rocks are metamorphic, even though the brines may have brought about some net chemical change.

The age and origin of the metamorphic rocks of the drill core are not determinable with certainty from the present limited data, but several lines of evidence favor the theory of active metamorphism of relatively young rocks.

The data of Table 2 suggest that the grade of metamorphism is increasing as the depth increases within the short interval from 4477 to 4923 feet more rapidly than might be expected for normal old metamorphic rocks. Epidote was found only in veinlets in the two pieces of drill core nearest the surface, but it is abundant in the lower core as a replacement for other silicate minerals. The specific gravity of the drill core in general increases rather rapidly with increased depth, as geologists might expect from a localized rapid downward increase in grade of metamorphism. For comparison elsewhere in the same structural trough (*4*), the drill core from 0 to 4000 feet in depth has an average bulk specific gravity of 2.37; 4000 to 8000 feet, 2.44; and 8000 to 12,000 feet, 2.47. Probably the most significant point in favor of active metamorphism, however, is the fact that wherever bedding is discernible in the five core specimens, it was essentially horizontal, as evidenced by relations to the originally vertical sides of the drill core. In contrast to this, old metamorphic rocks usually have been upfaulted and tilted extensively, and original bedding is only horizontal by coincidence.

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References and Notes

1. The well was drilled by Joseph I. O'Neill and associates of Midland, Texas, who have given permission to publish this preliminary report. We are grateful for the courage and skill required to drill so deeply into the fantastic environment of the Niland area.
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6. Analysis of the gases by Truesdail Laboratories, Los Angeles; analysis of water sample by Robert Schoen; semiquantitative spectrographic analyses of the residue of water sample by Robert Mays; fire assay of the deposit by Smith Emery Co., Los Angeles, for O'Neill Geothermal; x-ray fluorescence determination of copper by W. Brannock; semiquantitative spectrographic analysis of dark deposits in pipes from brine (Table 1) by Chris Heropoulis and Harry Bastron.
7. H. Craig, G. Boato, D. E. White, *Proc. 2nd Conf. Nuclear Processes in Geologic Settings* (Natl. Acad. Sci.–Natl. Res. Council, Washington, 1956), pp. 29–38; D. E. White, *Bull. Geol. Soc. Am.* 68, 1637 (1957); ——, United Nations Conf. on New Sources of Energy (1961), preprint; I. G. Donaldson, *J. Geophys. Res.* 67, 3449 (1962).
8. The 5232-foot well, when standing open, is filled below 58 feet from the land surface with brine that is about 25 percent heavier than pure water at 20°C and is probably similarly heavier at higher temperatures.
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10. Data from Robert Lonnquist, Rogers Engineering Company, who carried out the production test and collected the samples that are being studied (1962). Their average specific gravity is close to 2.5.
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11 January 1963

Low Malignancy of Rous Sarcoma Cells as Evidenced by Poor Transplantability in Turkeys

Abstract. *Homologous and isologous transfers of Rous sarcoma cells in turkeys indicate that growth of the implanted cells contributes little, if at all, to the formation of these neoplasms. Infection of normal host cells by virus appears to be, at least in this species, the major factor in the induction and progressive growth of Rous sarcomas.*

It is well known that Rous sarcoma can be produced in chickens by implantation of tumor cells or injection of cell-free filtrates of the tumor tissue. Tumor production by cell transfer could be the result of either malignant growth of the implanted cells themselves or infection and growth of host cells initiated by virus released from the implanted cells, or a combination of both. There is evidence that in chickens proliferation of the implanted cells does occur in certain instances (*1*). However, preliminary data obtained in our laboratory (*2*) clearly indicated that in turkeys virus was much more important than cells for the induction and progressive growth of these tumors.

In the studies we report now (*3*), large numbers of intact and viable tumor cells, obtained by trypsinization of virus-induced turkey sarcomas, were implanted into the wing web of large numbers of turkeys. These experiments were conducted as follows: 7-day-old Beltsville white turkeys of both sexes were injected subcutaneously in the left wing web with 0.2-ml amounts of standard Rous sarcoma virus that had been prepared from chicken tumor tissue (*4*). Tumors were produced by injection of 10^4 to 10^6 pock-forming

GEOTHERMAL

~~K. L. Cook~~

Rec'd from Isherwood Mar 1/7?

STUDT, F.E. (1961)

United Nations Conference on New Sources of Solar Energy, Rome, 1961.

Solar energy, wind power and geothermal energy [papers]

GEOPHYSICAL PROSPECTING IN NEW ZEALAND'S HYDROTHERMAL FIELDS

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Summary

1. Hydrothermal fields differ so greatly in character and environment that geophysical methods meet with varying success in prospecting for steam or hot water. In some cases there is difficulty in applying geophysical techniques and in others there is difficulty in interpretation.

2. Owing to the permeability of the rocks, most New Zealand fields yield wet steam and little work has been done on dry steam fields. The permeability of the rocks also results in usable hot water being often found by drilling close to the hot springs or fumaroles, so that much small scale exploitation has been possible without the help of prospecting. Geophysics has been employed in mapping the limits of such fields, but its main uses have been in the study of the geological background, or in the attempt to penetrate beneath the shallow reservoir to locate deeper aquifers or feed channels.

3. Gravity surveys are primarily used to indicate the basement structure and are not very detailed, but minor positive anomalies have been found, coinciding with some fields, which probably indicate intrusive rocks genetically associated with the hot water.

4. The basement rocks are only weakly magnetised, and magnetic surveys therefore indicate the distribution of magnetic rocks within the overburden. Detailed surveys are of value, since hydrothermal alteration converts the magnetite in the rocks to pyrite, thus weakening the magnetic field. This has enabled useful deductions to be made about the source of the Wairakei hot water.

5. Resistivity surveys, designed to map the distribution of hot water at the water table, have been successful in uniform geological conditions, but the interpretation is liable to be complicated by porosity and salinity variations. Deep penetration is hampered by the shielding effect of hot water near the surface.

6. Seismic refraction surveys have located cap rocks in some fields. Reflection work at Wairakei showed very low seismic velocities, suggesting steam in the rocks in place of water, and dry steam has since been tapped in this area. Seismic work in hydrothermal fields is handicapped by very high natural noise levels and energy dissipation.

7. Early attempts at well-logging showed promise of locating producing horizons by comparing natural potential logs run under standing and flowing conditions. Similar work on deeper and hotter holes is prevented by the inability of insulated cables to withstand the physical and chemical conditions in geothermal drillholes.

$\Delta G = -nFE$

$-n23E$

$\Delta G =$ [illegible]

$2H_2O \rightarrow 2H_2$

HINTS FOR IMPROVED PROBE ANALYSIS

by D. M. Kerrick

Samples and Standards - Selection and Preparation

1. Perhaps the most important advice to a novice is to initially obtain analyses on only a few samples, before computing the results. Invariably your first attempt will yield unsatisfactory results (for one or more reasons given in this list). If you have a lot of probe work ahead, the most satisfactory procedure is alternate your probe time with free periods, using the latter for computing the results of previous analyses. For example, don't make the mistake of analyzing pyroxene in 50 samples for Mg and Fe and *then* for Ca and Si only to find later that your results are unsatisfactory - this is costly and very disappointing.
2. Select standards that are similar in composition to your samples *unless* the standards are poorly characterized. In the latter case it is best to obtain more reliable standards that are less similar in composition to your samples. We have a large number of standards, some are more reliable than others. Contact D. M. Kerrick for advice on the selection of specific standards for your analytical problem. If you cannot find a reliable standard that is similar in composition to your samples, obtain standards which contain *more* of each element than your samples.
3. It is *very important* to have a good polish on your samples - a little extra effort in obtaining a top-notch polish often makes the difference between good and mediocre quantitative analyses. Ask Lee Eminhizer about polishing procedures and for an evaluation of the quality of polish on your specimens.
4. It is important that the surface of your specimen is perpendicular to the electron beam. Make sure your probe mount is such that the polished surface

is not tilted (a good test is to examine the reflectivity with the reflected light microscope). Extended polishing time can lead to significant relief differences between hard and soft substances in the same mount - the resulting surface irregularity will result in a lack of perpendicularity between the surface of the specimen and the impinging beam. Ask Lee Eminhizer about the most efficient polishing procedure so as to avoid excessive polishing time.

5. It is best to have the same thickness of carbon coat on standards and samples (although preliminary research in our lab suggests that appreciable variations in the thickness of the carbon coat are not important). We have a device to monitor carbon coat thickness - Lee Eminhizer is well-experienced in the operation of this instrument.
6. Polished thin sections are extremely useful, since you can work with both transmitted and reflected light. A normal covered thin section can easily be made into a polished thin section by placing the section on a piece of dry ice (obtainable from the stockroom), prying off the cover slip after about 15 sec. (use a razor blade), and then wiping off all exposed lakeside with an acetone-soaked Kimwipe. The specimen is then ready for polishing.

Probe Operation

1. It is important to assure that the machine is steady before analysis - carefully saturate the filament and align the electron gun.
2. At all times the beam must be centered with the crosshairs of the microscope. Throughout your analysis this alignment should be repeately checked by observing a fluorescent specimen (e.g. quartz, feldspar, or Al in the A.R.L. standard) or by letting the beam hit epoxy leaving a

small pit (in the latter, minimize the time in which the beam is impinging on the specimen, since the plastic is evaporated causing contamination).

3. The beam diameter should be kept as small as possible so that you can avoid inclusions, cracks, etc. However, with a narrow beam (or large sample current) you may get burn-off of light elements (especially Na). To check for burn-off, obtain repeated 10 sec. counts on the same spot - if there is burn-off, you will see a decrease in counts of a particular element with time. If burn-off occurs, increase the beam diameter and/or decrease the sample current.
4. Watch for drift - this will be obvious when comparing successive average counts on the same standard. If drift is greater than about 5 percent of the total counts (between two successive standardizations) it is best to reanalyze. Drift corrections are not advised.
5. Focus is <u>extremely</u> critical. It is imperative that you develop a reproducible technique for focusing on both standards and samples. The best way to focus is to observe the fluorescent spot produced by the beam, and to change the focus to minimize the spot size. Obviously, this technique is useful only for fluorescent minerals (e.g. feldspars, carbonates, soxic pyroxenes). If your specimens and standards do not fluoresce, carefully adjust the focus so as to make the smallest surface imperfections (scratches, pits) as clear as possible. Initially check the reproducibility of your focusing by refocusing and recounting several times on the same spot.
6. Throughout your analysis, continually check the sample current - it should always be steady. Fluctuating sample current will (in most cases) indicate that your analysis will be unsatisfactory. In this case check your mount

for obvious conductivity problems (e.g. Ag paint contact broken), or put another carbon coat on your sample. Poor conductivity usually indicates that the carbon coat is too thin. Saturation with respect to sample current is not instantaneous after opening the flag. Close examination of the meter will reveal that the sample current will quickly climb to a value near saturation and then slowly creep up a unit or so (i.e. .001 μa) to the saturation position. Wait until the sample current meter indicates saturation before you start counting.

7. Dead time arises when the count rate is so high that the counting system cannot process all of the pulses produced by the detectors. In this case the counting system will register fewer counts than should actually be recorded. Dead time arises above about 15,000 counts/10 sec. for spectrometer #1 and about 10,000 counts/10 sec. for spectrometer #2; thus, keep your counts well below these values to avoid dead time problems. A simple test for dead time is to plot counts vs. sample current - the resulting line will be linear up to an inflection point, above which dead time becomes a factor.

8. Avoid analyzing very small particles. An article by Page et al. (on file) shows that with particles less than about 20 microns across, the irradiated volume is larger than the particle - in this case you would be producing X-radiation from the particle as well as the surrounding matrix. Obviously, this is to be avoided. The diameter of the irradiated volume is larger than the diameter of the electron beam. In this context it is also important to avoid analyzing right next to the edge of a large grain since the irradiated volume may incorporate an adjacent phase.

9. In a specimen with several crystals of the same phase, obtain analyses on several different crystals in order to evaluate the compositional variation from one crystal to the next. Also, check for compositional zoning (especially in feldspars, garnets, epidote, and amphibole) by analysis of the core and rim compositions. If zoning is apparent, make a traverse across the crystal to obtain the zoning profile. If you want a full analysis of the core and rim compositions of a zoned crystal you will have to return to the same spot - thus, make a sketch of the crystal showing places where analysis were taken.

10. In most specimens it is necessary to have a marking system to distinguish the various types of minerals, or to indicate specific grains you want to analyze (e.g. zoned crystals). The most helpful method is to mark specific grains with ink - a Hunt 104 pen provides a small ink mark that is useful for even fine-grained specimens. See D. M. Kerrick for hints on this marking technique. Traverses (e.g. for zoning) can be marked with an ink line.

11. With polished thin sections, a useful "trick" for selecting areas that are both well polished and free of inclusions or cracks is to adjust the transmitted and reflected light intensities so that the suitable areas show up as bright zones - the areas where inclusions occur, or where the polish is poor, will be relatively poorly illuminated. Ask D. M. Kerrick to show you this technique.

Computation

1. In many cases, partial probe analysis provides a quick method of quantitative analysis. Common phases such as plagioclase and olivine are routinely analyzed with only partial analysis of the two elements which

show mutual substitution (e.g. Mg and Fe in olivine). J. V. Smith and co-workers have published numerous papers describing this method for common rock-forming minerals (we have these papers on file). This method hinges on having well-characterized standards. We have a suitable suite of plagioclase and olivine standards for partial probe analysis. See D. M. Kerrick for specifics on this method.

2. For complete major element analyses of relatively simple solid solutions (e.g. olivine, plagioclase, epidote) it is helpful to start by analyzing the two elements which show reciprocal variation (e.g. Fe and Al in epidote). In this way you will be able to observe the reciprocal variation by comparing the relative counts on the two elements. This provides a rough way to estimate the composition of the phase and to check for compositional zoning; furthermore, reciprocal variation in the counts is an important indication that your analysis will be successful. If reciprocal variation does not occur then you should stop and evaluate what is wrong with your analytical procedure.

3. For most major element analyses (except for sulfides) we use the scheme developed by Bence and Albee (paper on file) for reducing the probe data to oxide proportions. You <u>must</u> have a <u>complete</u> major element analysis for this computation. The program uses parameters (α-factors) for correcting the count ratio between standards and samples; in order to derive a correct α-factor for each element it is necessary to furnish the count data for <u>all</u> major elements (except oxygen).

4. When initiating an analysis it is advisable to select two or three standards for a particular element. In so doing you can select count data from alternate standards should your initial computation prove unsatisfactory. Furthermore, it is useful to compare the results obtained by

using several different standards (hopefully, the results will agree). Once a given set of standards is selected, it is advisable to stick with these for future analysis of the same minerals in other samples.

5. Probe analysis is accurate to ± 2 wt. %; thus, oxide totals should be within 100 ± 2%. This is a necessary (but not sufficient) test for the accuracy of your analysis - it is possible that the oxide proportions are wrong and get your analysis fortuitously totals to near 100 wt. %. However, faith in your analysis will considerably increase if, in a large number of samples, the oxide totals are close to 100%. Another test is to look at the structural formula (given to you in the computer print-out). For example, you would have much more reliance in a pyroxene that had a structural formula of: $Ca_{1.0}$ $(Mg, Fe)_{1.0}$ $Si_{2.0}O_6$ than one that comes out as: $Ca_{.6}$ $(Mg, Fe)_{.8}$ $Si_{2.2}O_6$.

1.50

1.562

Th	Mα 2	1.5712	1.5663
	Mα 1	1.5663	1.4920
		.049	.0743
	MB	1.4920	

8 .05

1.492
.018
1.474

8 | 1.050
.006

U MAR 1.4797 ?

Daru

POSTULATED DGE DEVELOPMENT SCENARIOS

FOR

ELECTRIC GENERATING CAPACITY BY SITE

EXAMPLE - DRAFT COPY

DRAFT

TABLE 1-1

POSTULATED DOE GEOTHERMAL DEVELOPMENT SCENARIOS[1]

PROSPECT	GENERATING CAPACITY INSTALLED EACH YEAR										
	Pre-1983	1983	1984	1985	1986	1987	1988	1989	1990	Post-1990	TOTAL
CALIFORNIA & HAWAII											
Brawley, CA	—	50	—	50	—	100	100	100	100	500	1,000
Coso Hot Springs, CA	—	—	—	50	50	50	150	150	150	—	600
East Mesa, CA	—	—	—	50	—	—	50	—	—	—	100
Geysers, CA (liquid-dominated	—	—	—	100	100	100	100	100	100	400	1,000
Geyers, CA (steam)	1678	160	220	110	—	—	—	—	—	—	2,168
Glass Mt., CA	—	—	—	—	—	—	—	—	50	—	50
Heber, CA	—	50	—	50	—	100	100	—	—	700	1,000
Lassen, CA	—	—	—	—	—	50	—	—	50	—	100
Mono-Long Valley, CA	—	—	—	50	—	100	—	—	100	—	250
Puna, HI	—	—	—	—	—	—	—	—	50	850	900
Salton Sea, CA	—	50	—	100	75	75	100	100	100	1400	2,000
Surprise Valley, CA	—	—	—	—	50	—	50	100	100	1700	2,000
NORTHWEST											
Alvord, OR	—	—	—	—	—	50	—	—	50	200	300
Baker Hot Springs, WA	—	—	—	—	—	—	—	—	50[2]	—	—
Bruneau-Grandview, ID	—	—	—	—	—	50	—	—	100	3000	3,150
Mt. Hood, OR	—	—	—	—	—	—	—	—	50[2]	—	—
Raft River, ID	—	—	—	—	—	—	50	—	50	—	100
Vale Hot Springs, OR	—	—	—	—	—	—	50	—	50	700	800
Weiser-Crane Creek, ID	—	—	—	—	—	—	50	—	100	850	1,000
West Yellowstone, MT	—	—	—	—	—	—	—	—	50[2]	—	—
SOUTHWEST											
Brady Hot Springs, NV	—	50	—	—	50	—	100	—	100	700	1,000
Beowawe, NV	—	50	—	—	50	—	50	—	100	750	1,000
Chandler, AZ	—	—	—	—	50	—	—	—	100	80	230
Cove Fort-Sulfurdale, UT	—	—	—	50	—	50	—	50	50	1300	1,500
Leach, NV	—	—	—	—	—	50	—	—	50	1400	1,500
Roosevelt Hot Springs, UT	—	50	—	—	50	—	50	—	100	750	1,000
Safford, AZ	—	—	—	—	—	50	—	—	—	50	100
Steamboat Springs, NV	—	—	—	50	—	—	50	—	100	—	200
Thermo, UT	—	—	—	—	—	—	50	—	—	450	500
Valles Caldera, NM	—	50	—	—	100	—	100	—	100	1150	1,500
GULF COAST[3]											
Acadia Parish, LA	—	—	—	—	—	50	—	—	50	250	350
Brazoria, TX	—	—	—	—	25	—	100	100	200	1800	2,225
Calcasieu Parish, LA	—	—	—	—	—	50	—	—	50	250	350
Cameron Parish, LA	—	—	—	—	—	50	—	—	50	400	500
Corpus Christi, TX	—	—	—	—	—	50	—	—	50	1550	1,650
Kenedy County, TX	—	—	—	—	—	50	—	—	50	200	300
Matagorda County, TX	—	—	—	—	—	50	—	—	50	400	500
Cumulative Power On Line	1678	2188	2408	3068	3668	4793	6093	6793	9143	30923	30,923

[1] Pilot plants are not included in this table.

[2] MITRE-assumed plant capacities for analysis.

[3] These geopressured sites are postulated to produce 29,315 MW thermal equivalent of methane by 1985.

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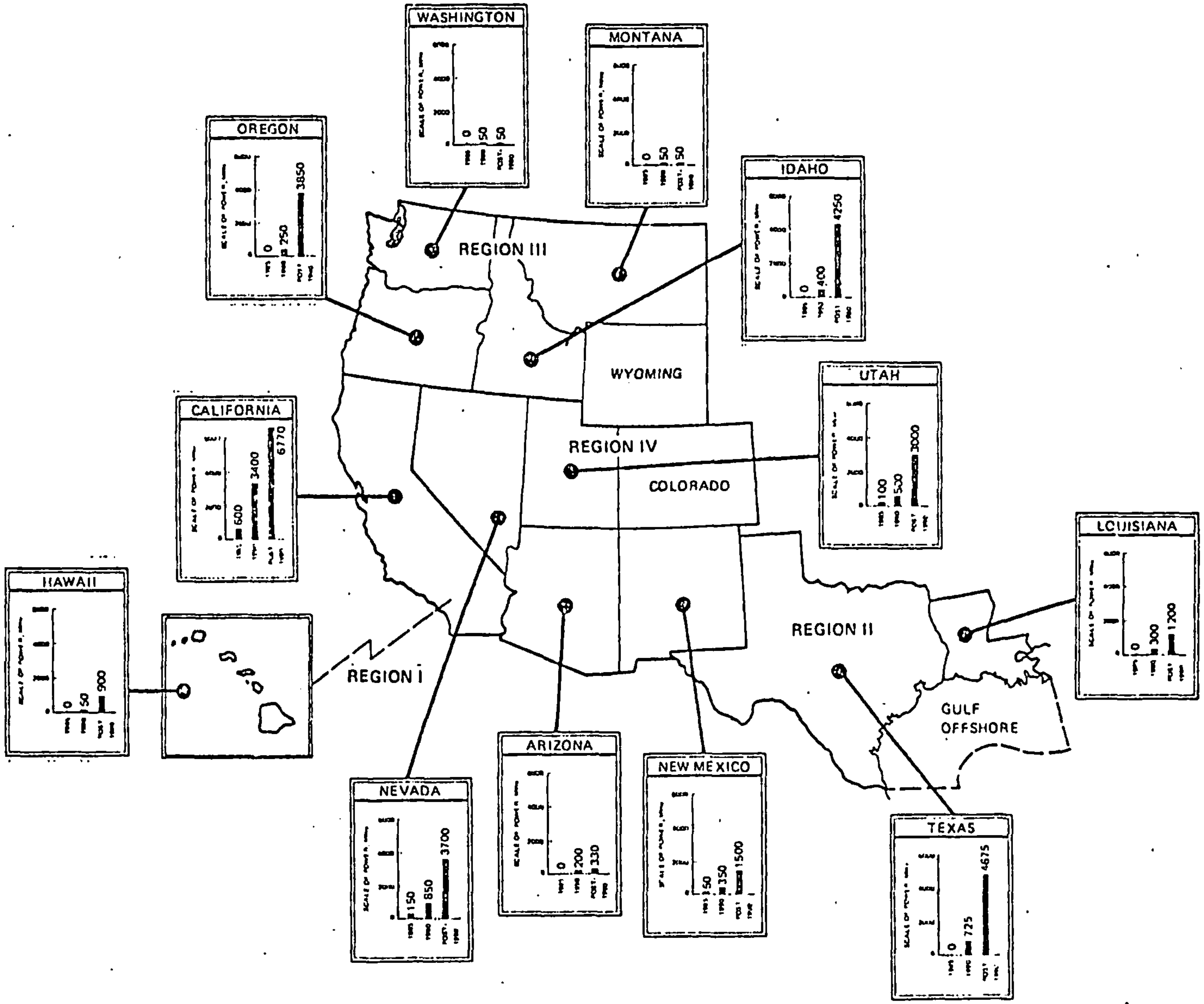

FIGURE 1-1
POSTULATED GROWTH OF INSTALLED GEOTHERMAL ELECTRIC CAPACITY

EXAMPLE

DEVELOPMENT SCENARIO - ROOSEVELT HOT SPRINGS, UTAH

<u>Draft Copy</u>

ROOSEVELT HOT SPRINGS, UTAH

Postulated Development Scenario

PLANT NUMBER	INSTALLED CAPACITY (MWe)	PLANT ON-LINE DATE
1	50	1983
2	50	1986
3	50	1988
4	100	1990
SUBSEQUENT PLANTS	750	1991-1998
TOTAL	1000	to 1998

Estimates of Resource Characteristics

RESOURCE CHARACTERISTIC		ESTIMATE
Subsurface Fluid Temperature (°C)	Range:	204-260
	Best Estimate:	230
Total Dissolved Solids (PPM)		7,800
Electric Energy Potential (MWe 30 Years)		100
Overlying Rock	Medium-Hard:	Sediments, metamorphics, and volcanics
Depth to Top of Reservoir (Meters)		830
Land Status		
Total KGRA acres		29,791
Total Federal acres		24,592[1]
Federal acres leased		24,592
Total State and private acres		5,199
State and private acres leased		No data

[1] All Federal land in the KGRA was offered in the Federal lease sales. Through first and second offerings, nearly all has been leased. The site is now unitized, and Phillips Petroleum Company is the operator of the land holdings, according to recent information from DOE/DGE.

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Development Status and Activity

Thermal Power Company, a subsidiary of Natomas Company, has completed a joint venture well which was drilled to 382 meters (1254 feet). Preliminary testing demonstrated a well-head pressure of 25 kg/cm^2 (355 lbs./sq. inch) and temperature of 222°C (132°F). Projected total mass flow capability of well is one million lb/hr of steam and hot water.

Phillips Petroleum Company reports that an 823-840 meter (2700-2800 foot) test well had an initial flow rate of 90,700 kg/hr (200,000 lb/hr) of steam at 204°C (400°F). Phillips has now completed 10 production wells and is negotiating with several potential hydrothermal users including the City of Burbank, Utah Power & Light Company, and other firms interested in nonelectric applications such as hybrid coal power plant/geothermal process heat uses.

Thermal Power Company plans to build a larger test facility to determine more precisely the electric generating capability potential. Thermal Power holds options to drill on an additional three sections of geothermal leaseholds in the Roosevelt fields. Two wells drilled in 1976, at the site of a significant new field discovery the year before, were both successful producers. One was 1860 meters (6100 feet) deep and the other only 380 meters (1250 feet) deep. The latter produced steam at 300 feet, 700 feet, and 1200 feet and a total mass flow of about one million lb/hr.

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Major Development Problems

No major development problems are currently evident at the Roosevelt Hot Springs hydrothermal site. However, technological areas which could entail a moderate risk include:

- fluid disposal — why
- high silica content of brine — why
- cooling water availability/subsidence. — why

Postulated Development Scenario: Status and Implications

First Commercial-Scale Plant: 50 MWe in 1983

Based on the number of developers and the recent field activity at Roosevelt Hot Springs, this appears to be one of the more attractive candidates for development. Phillips Petroleum Company holds Federal leases on which Utah Power Company is planning to build an electric generating plant. The resource temperatures indicate a commercial effectiveness of installing a flash conversion process at this site. As shown in Figure 26-1, the first 50-MWe plant is scheduled to go on line in 1983. Accordingly, the commitment to develop must be made in 1978 and plant final designs must be ready by 1980. Moreover, any technological RD&D, in order to be incorporated in the design specifications and installations must be completed by 1980. Figure 26-2 shows the scheduled activities of principal participants in the development of all the plants at the Roosevelt Hot Springs prospect.

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FIGURE 26-1

DEVELOPMENT SCHEDULE FOR FIRST PLANT: ROOSEVELT HOT SPRINGS, UTAH

OPERATING ENTITIES	ACTIVITY	RECIPIENTS	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
BLM	Issue STC Permit	Developer	ASSUMED COMPLETED										
USGS	Issue Drilling Permits	Developer	ASSUMED COMPLETED										
BLM	Process EIA/EIS	CEQ	ASSUMED COMPLETED										
County Gov't	Issue Land Use Permit	Developer	ASSUMED COMPLETED										
Developer	Preliminary Geophysical Exploration		ASSUMED COMPLETED										
Developer	Exploratory Drilling and Reservoir Assessment		ASSUMED COMPLETED										
Developer	Develop Utility Interest		ASSUMED COMPLETED										
Developer Utility	Feasibility Study		ASSUMED COMPLETED										
Producer/Developer) and Utility	Financial Negotiations		—	—									
Producer	Site Selection			—									
Producer/ Utility	Design			—	—								
Producer/ Utility	Prepare Master Development Plan	BLM, USGS		—	—								
Utility	Prepare Environmental Data Statement	BLM, FPC, State, County		—	—								
Producer/ Utility	Commitment to Development			△									
BLM, FPC, State, USGS	Certify Plant and Site, Issue Permits	Producer & Utility			—	—							
USGS	Process EIA/EIS (Drilling)	CEQ			—	—							
FPC	Process EIA/EIS (Plant)	CEQ			—	—							
FPC	Process EIA/EIS (Transmission Line)	CEQ			—	—							
Producer	Development Drilling					—	—	—					
Utility	Plant Construction					—	—	—	—				
Utility	Install Transmission Line (96.5km)						—	—	—				

FIGURE 26-1

FIGURE 26-2

DEVELOPMENT SCHEDULE FOR ALL PLANTS: ROOSEVELT HOT SPRINGS, UTAH

OPERATING ENTITIES	ACTIVITY	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Owner	Lease Land, Issue Prospecting Permit											
County	Process Environmental Report - Pre-lease Issue Land Use Permit Process Environmental Report - Drilling											
State	Process Environmental Report, Lease Land Issue Prospecting/Exploration Permits Issue Drilling Permits Certify Plant and Site - Issue Permits Process Environmental Reports - Drilling, Plant Construction, Transmission Lines											
Developer	Exploration and Reservoir Evaluation Commit to Development Prepare Master Development Plan Development Drilling											
Utility	Commit to Development Prepare Environmental Data Statement and Master Development Plan Construct Plant, Install Transmission Lines Power on Line											
DOI/USGS	Issue Drilling Permit Process EIA/EIS - Drilling											
DOI/BLM	Process EIA/EIS, Lease Land Issue STG Drilling Permit Certify Plant and Site, Issue Permits											
DOI/USFS	Process EIA/EIS, Lease Land Issue STG Drilling Permit											
FPC	Certify Plant and Site, Issue Permits Process EIA/EIS - Plant & Transmission Line											
BIA	Process EIA/EIS, Lease Land Issue Drilling Permits											

FIGURE 26-2, Concluded

DEVELOPMENT SCHEDULE FOR ALL FALNTS: ROOSEVELT HOT SPRINGS, UTAH

OPERATING ENTITIES	ACTIVITY	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Owner	Lease Land, Issue Prospecting Permit											
County	Process Environmental Report - Pre-lease Issue Land Use Permit Process Environmental Report - Drilling											
State	Process Environmental Report, Lease Land Issue Prospecting/Exploration Permits Issue Drilling Permits Certify Plant and Site - Issue Permits Process Environmental Reports - Drilling, Plant Construction, Transmission Lines											
Developer	Exploration and Reservoir Evaluation Commit to Development Prepare Master Development Plan Development Drilling											
Utility	Commit to Development Prepare Environmental Data Statement and Master Development Plan Construct Plant, Install Transmission Lines Power on Line	50 ▲		100 ▲	100 ▲ 5	100 ▲	100 ▲	100 ▲	100 ▲	100 ▲	100 ▲	50 ▲ 12
DOI/USGS	Issue Drilling Permit Process EIA/EIS - Drilling											
DOI/BLM	Process EIA/EIS, Lease Land Issue STG Drilling Permit Certify Plant and Site, Issue Permits											
DOI/USFS	Process EIA/EIS, Lease Land Issue STG Drilling Permit											
FPC	Certify Plant and Site, Issue Permits Process EIA/EIS - Plant & Transmission Line											
BIA	Process EIA/EIS, Lease Land Issue Drilling Permits											

<u>Development Problems</u>. There are a number of site-related technological problems of moderate concern. The reservoir/return formation is fractured volcanic, capped with medium-to-hard overlying rock and, consequently, its ability to absorb return flows of return flows of brine over extended operating times is in question.

In addition, although quantitative data have not been well established for silica content in produced brines, there are some indications that silica carryover and scaling may be problems at the Roosevelt Hot Springs site. Similarly, maintaining long-term flows from production wells could be a significant consideration.

Environmental concerns are relevant, particularly regarding potential land settlement in that locale: recent withdrawals from (nearer-surface) aquifers have resulted in observed subsidences of six feet. The possible impacts of seismic excitation are also a moderate concern.

Surface water for evaporative cooling is generally unavailable in the region. This water shortage may not be a problem should the underground brine-receiving formations be able to tolerate a slight deficit in reinjection (i.e., based on tradeoffs in cooling versus subsidence and reservoir depletion).

<u>Economic Analysis</u>. The projected economics of electrical generation at the Roosevelt Hot Springs geothermal power prospect are presented in Table 26-I.

TABLE 26-I

ECONOMIC ANALYSIS: ROOSEVELT HOT SPRINGS, UTAH

FLASH SYSTEM , 50 MW ELECTRIC PLANT

FIRST PLANT ON LINE DATE : 1983

TEMPERATURE IN CENTIGRADE DEGREES (BEST ESTIMATE) : 230
WELL DEPTH IN METERS : 1300
BRINE SALINITY : LOW
OVERLYING ROCK TYPE : MEDIUM HARD
SPECIFIED WELL FLOW RATE (KGM./HR.) : 363000
THE COST PER PRODUCTION WELL IS NOT SPECIFIED : THE DEFAULT COST PER PRODUCTION WELL ($) = 533136.2
THE COST PER INJECTION WELL IS NOT SPECIFIED : THE DEFAULT COST PER INJECTION WELL ($) = 533136.2

PRODUCER FINANCIAL DATA

DEBT FRACTION :	0.30
ANNUAL INTEREST RATE ON DEBT (FRACTION) :	0.08
REQUIRED RATE OF RETURN ON EQUITY (FRACTION) :	0.20
PROPERTY TAX RATE (FRACTION) :	0.01
REVENUE TAX RATE OR ROYALTY (FRACTION) :	0.10
EFFECTIVE TOTAL INCOME TAX RATE (FRACTION) :	0.50
EFFECTIVE INVESTMENT TAX CREDIT (FRACTION) :	0.04
ESCALATION FACTOR FOR O&M COSTS :	0.05
ESCALATION FACTOR FOR ENERGY COSTS :	0.05
ESCALATION FACTOR FOR CAPITAL COSTS :	0.05
LIFE SPAN OF PRODUCTION WELLS (YEARS) :	10.00
LIFE SPAN OF INJECTION WELLS (YEARS) :	10.00
LIFE SPAN OF PRODUCER PLANT (YEARS) :	20.00
START UP COST MULTIPLIER :	1.081

UTILITY FINANCIAL DATA

DEBT FRACTION :	0.50
ANNUAL INTEREST RATE ON DEBT (FRACTION) :	0.08
REQUIRED RATE OF RETURN ON EQUITY (FRACTION) :	0.12
PROPERTY TAX RATE (FRACTION) :	0.01
REVENUE TAX RATE OR ROYALTY (FRACTION) :	0.0
EFFECTIVE TOTAL INCOME TAX RATE (FRACTION) :	0.50
EFFECTIVE INVESTMENT TAX CREDIT (FRACTION) :	0.04
ESCALATION FACTOR FOR O&M COSTS :	0.05
ESCALATION FACTOR FOR ENERGY COSTS :	0.05
ESCALATION FACTOR FOR CAPITAL COSTS :	0.05
LIFE SPAN OF UTILITY PLANT (YEARS) :	30.00
ULTIMATE CAPACITY FACTOR :	0.80
START UP COST MULTIPLIER :	1.038

* NUMBER OF WELLS , CAPITAL COSTBASIS AND O&M COSTS , AND REVENUE REQUIREMENTS WITHOUT ANY R&D IMPACTS *

CAPITAL COSTBASIS (1977 $M)

7 PRODUCTION WELLS :	4.492	
6 INJECTION WELLS :	3.850	
PRODUCER PLANT EXCLUDING WELLS :	4.708	
REPLACEMENT PRODUCTION WELLS :	3.836	
REPLACEMENT INJECTION WELLS :	3.288	
REPLACEMENT PLANT :	2.077	
TOTAL FOR PRODUCTION FIELD :		22.253
GENERATING PLANT :		24.113
TOTAL :		46.366

O&M COSTS (1977 $M/YR.)

PRODUCER		
GENERAL :	0.224	
WELL :	0.069	
DEEP WELL PUMP :	0.0	
SPENT BRINE TREATMENT :	0.0	
CHEMICAL & MECHANICAL CLEANING :	0.0	
TOTAL :		0.294
UTILITY		
GENERAL :	0.703	
CHEMICAL & MECHANICAL CLEANING :	0.0	
TOTAL :		0.703

** REVENUE REQUIREMENTS **

PRODUCER : 13.744 MILLS/KWHR
UTILITY : 7.016 MILLS/KWHR
* TOTAL : 20.760 MILLS/KWHR *

ROOSEVELT H.S. , NEVADA
(CONTINUED)

* R&D IMPACTS FOR PLANT NO. 1 - ON LINE DATE : 1983 *

R&D COMPONENT	ANTICIPATED CHANGE (%)	CHANGE IN REVENUE REQUIREMENTS (MILLS/KWHR)
CAPITAL COST PER PRODUCTION WELL	-5.00	-0.2576
CAPITAL COST PER INJECTION WELL	-5.00	-0.2208

** REVENUE REQUIREMENTS WITH ALL THE R&D IMPACTS INCLUDED. **

PRODUCER : 12.266 MILLS/KWHR
UTILITY : 7.016 MILLS/KWHR
* TOTAL : 19.283 MILLS/KWHR *

* SENSITIVITY OF COST OF ELECTRICITY (FROM PLANT NO. 1 , R&D IMPACTS INCLUDED) *

RESOURCE & OPERATING PARAMETERS	MILLS/KWHR
HIGH RESOURCE TEMPERATURE ESTIMATE (260 DEGREES CENTIGRADE)	15.330
LOW RESOURCE TEMPERATURE ESTIMATE (200 DEGREES CENTIGRADE)	33.178
HIGH CAPACITY FACTOR VALUE : 0.85	18.148
LOW CAPACITY FACTOR VALUE : 0.60	25.710
EXPENSING OF INTANGIBLE DRILLING COSTS (70.0% OF WELL COSTS EXPENSED)	17.812
DEPLETION ALLOWANCE (22.0% OF GROSS INCOME)	16.873
INVESTMENT TAX CREDIT (26.2% GROSS, 15.0% EFFECTIVE)	18.198

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ROOSEVELT H.S. , NEVADA
(CONTINUED)

* R&D IMPACTS FOR PLANT NO. 2 - ON LINE DATE : 1986 *

R&D COMPONENT	ANTICIPATED CHANGE (%)	CHANGE IN REVENUE REQUIREMENTS (MILLS/KWHR)
NUMBER OF PRODUCTION WELLS	-3.00	-0.7358
CAPITAL COST PER PRODUCTION WELL	-12.00	-0.6181
CAPITAL COST PER INJECTION WELL	-12.00	-0.5298
CAPITAL COST OF GATHERING SYSTEM	-10.00	-0.0649
CAPITAL COST OF DISTRIBUTION SYSTEM	-10.00	-0.0254
CAPITAL COST OF TURBINE GENERATOR	-3.00	-0.0728
CAPITAL COST OF PROCESS MECHANICAL (UTILITY)	-10.00	-0.0270
LIFE SPAN OF PRODUCTION WELLS	20.00	-0.3758
LIFE SPAN OF INJECTION WELLS	100.00	-0.9828
START UP COST MULTIPLIERS	(PRODUCER: -4.16 , UTILITY: -2.12)	-0.7208

** REVENUE REQUIREMENTS WITH ALL THE R&D IMPACTS INCLUDED. **

PRODUCER : 10.264 MILLS/KWHR
UTILITY : 6.770 MILLS/KWHR
* TOTAL : 17.034 MILLS/KWHR *

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ROOSEVELT H.S. , NEVADA
(CONTINUED)

* R&D IMPACTS FOR PLANT NO. 3 - ON LINE DATE : 1988 *

R&D COMPONENT	ANTICIPATED CHANGE (%)	CHANGE IN REVENUE REQUIREMENTS (MILLS/KWHR)
NUMBER OF PRODUCTION WELLS	-3.00	-0.7358
CAPITAL COST PER PRODUCTION WELL	-12.00	-0.6181
CAPITAL COST PER INJECTION WELL	-12.00	-0.5298
CAPITAL COST OF GATHERING SYSTEM	-10.00	-0.0649
CAPITAL COST OF DISTRIBUTION SYSTEM	-10.00	-0.0254
CAPITAL COST OF TURBINE GENERATOR	-3.00	-0.0728
CAPITAL COST OF PROCESS MECHANICAL (UTILITY)	-10.00	-0.0270
LIFE SPAN OF PRODUCTION WELLS	20.00	-0.3835
LIFE SPAN OF INJECTION WELLS	100.00	-0.9958
START UP COST MULTIPLIERS	(PRODUCER: -4.16 , UTILITY: -2.12)	-0.7208

** REVENUE REQUIREMENTS WITH ALL THE R&D IMPACTS INCLUDED. **

PRODUCER : 10.247 MILLS/KWHR
UTILITY : 6.790 MILLS/KWHR
* TOTAL : 17.017 MILLS/KWHR *

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ROOSEVELT H.S. , NEVADA
(CONTINUED)

* R&D IMPACTS FOR PLANT NO. 4 - ON LINE DATE : 1990 *

R&D COMPONENT	ANTICIPATED CHANGE (%)	CHANGE IN REVENUE REQUIREMENTS (MILLS/KWHR)
NUMBER OF PRODUCTION WELLS	-3.00	-0.7358
CAPITAL COST PER PRODUCTION WELL	-20.00	-1.0302
CAPITAL COST PER INJECTION WELL	-20.00	-0.8830
CAPITAL COST OF GATHERING SYSTEM	-10.00	-0.0649
CAPITAL COST OF DISTRIBUTION SYSTEM	-10.00	-0.0254
CAPITAL COST OF TURBINE GENERATOR	-3.00	-0.0728
CAPITAL COST OF PROCESS MECHANICAL (UTILITY)	-10.00	-0.0270
LIFE SPAN OF PRODUCTION WELLS	20.00	-0.3835
LIFE SPAN OF INJECTION WELLS	100.00	-0.9958
START UP COST MULTIPLIERS	(PRODUCER: -4.16 , UTILITY: -2.12)	-0.7208

** REVENUE REQUIREMENTS WITH ALL THE R&D IMPACTS INCLUDED. **

PRODUCER : 9.672 MILLS/KWHR
UTILITY : 6.770 MILLS/KWHR
* TOTAL : 16.442 MILLS/KWHR *

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The levelized busbar cost of flash-conversion electricity[1] from this site is estimated to be 20.8 mills/kWh using currently available technology. Accounting for anticipated cost reductions from the RD&D program, the first commercial-scale plant at this site, postulated to come on line in 1983, is expected to have a levelized busbar energy cost of 19.3 mills/kWh.

It is assumed that geothermal electric plants in this region will be competing primarily against new western coal-fired power plants. The levelized busbar cost of electricity from these sources is expected to be about 20.0 mills/kWh in 1985, rising to 20.6 mills/kWh in 1990 under assumptions of the National Energy Plan scenario for escalation of coal prices.

The costs of electricity (with RD&D benefits) at this prospect are therefore competitive without the advantage of Federal subsidies.

Subsequent Plants

The second plant at Roosevelt, also a 50-MWe plant, is scheduled to go on line in 1986. Its construction must commence in 1984, the design must be completed in 1984, and the commitment to develop this expanded capacity must be made by 1982. With a required RD&D cutoff time of 3 years before power on line, no operating experience will be

[1] See Chapter 2 for a detailed description of the computer print-out and assumptions and data used in this analysis.

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available for Plant 2 from any of the new 1983 plants, including Roosevelt Hot Springs Plant 1. The projected cost of electricity from Plant 2 is 17.0 mills/kWh (Table 26-I). Plant 3 will realize benefits from the same RD&D contributions and, since it will be the same size as Plant 2, will have similar power production costs.

Plant 4, 100-MWe capacity in 1990, will benefit from further RD&D impacts (Table 26-I) and will produce electricity at a favorable 16.4 mills/kWh.

GLENN H. GARDNER

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DEPARTMENT OF ENERGY

APR 13 1978

NOTICE OF PROGRAM INTEREST (NPI)
FOR SPECIAL PROJECTS

Up to $600,000 will be made available to the Energy Extension Service (EES) pilot states to conduct special projects during the EES pilot program operation. Unsolicited proposals to be funded by the Special Projects Program will benefit the pilot states by strengthening the EES pilot program network and helping lay the groundwork for the national EES program.

In general, the Special Projects Program will fund activities that (1) enhance the technical capabilities of state EES programs; (2) facilitate the sharing of information among pilot states and other states; and (3) offer regional or multistate approaches to delivering program services and implementing market factors feedback (MFF) activities.

Each submitted proposal should explore methods, approaches, or ideas in support of the EES Special Projects program that (a) do not unnecessarily duplicate work already underway or contemplated by the Department of Energy (DOE), and (b) are not already known by DOE, or (c) have previously unrecognized merit or value. Specifically, DOE will consider for possible funding those proposals that meet the following restrictions and conditions.

1. Only unsolicited proposals from the ten EES pilot state programs will be considered; each pilot state may submit more than one proposal. They must be signed by the state official whose signature appears on the face page of the state's EES Grant Document or by an official designated in writing by this signatory to act on EES matters. Proposals submitted by non-EES program affiliates are eligible for consideration if they are submitted by a participating state as a project under an existing EES pilot grant and are signed as described above.

2. Projects must benefit more than one pilot state by developing tangible products or services that can be used by other states in the pilot program.

3. Funds cannot be used simply to expand an individual state program.

4. Each project budget generally should not exceed $75,000.

5. Funds awarded cannot replace or supplant funding from other sources now provided for similar activities; rather, they must supplement such funds.

6. Projects must be completed or have achieved significant results by the end of the pilot program (3/31/79).

7. Projects must not detract from efforts required to execute the current EES pilot program.

8. Projects must be consistent with the purposes and requirements of the EES program as defined in the PRDA and grant documents - e.g., no research and development or demonstrations to establish the feasibility of energy technologies.

Unsolicited proposals must be received on or before May 5, 1978, 5:00 P.M., to be considered for funding. Selections of the proposals will take place within 60 days after this date.

DOE reserves the right to support or not support any or all proposals submitted, in whole or in part, and assumes no responsibility for any costs associated with specific proposal preparation.

Ten (10) copies of each proposal should be mailed, and any questions referred, to:

Glenn Gardner
Special Projects Manager
Energy Extension Service
U.S. Department of Energy
20 Massachusetts Avenue, N.W.
Washington, D.C. 20545
(202) 376-1967

Each proposal should be marked:

"EES Special Project Proposal"

Any resulting EES grant modification awarded pursuant to this NPI will be subject to the conditions, regulations, and stipulations contained in the State's current EES grant documents, the ERDA Procurement Regulations 9-4.950, and the ERDA Federal Assistance Manual (see 42 Federal Register 27630).

The Department of Energy will obtain comments on proposal abstracts and/or the full proposals from a group at non-pilot states. However, the decision on which proposals to fund will be made soley by the Department of Energy.

Specific information on proposal preparation formats is attached.

CONTENTS OF UNSOLICITED PROPOSALS

No particular format need be followed for the submission of proposals. However, a proposal should, as a minimum, cover the points set forth below in the order indicated. Elaborate proposals or presentations are neither necessary nor desirable. In this connection, the proposer should bear in mind that DOE is under no obligation with respect to the costs of preparing any proposal. Ten copies of the proposal should be submitted.

A formal unsolicited proposal is a detailed document which must be signed by an authorized official as noted in the NPI. This document forms the basis for both further technical evaluation and for possible grant modifications. Each proposal should contain the following elements:

1. Cover Sheet
2. Abstract
3. Narrative
4. Cost Proposal (should be a document that is separable from original proposal).

Cover Sheet

Each proposal must have a cover sheet providing the information set forth in the sample in Appendix A.

Abstract

At the beginning of each proposal, there should be a concise abstract of 200-300 works stating the basic purpose, summary of work, and expected end results of the proposed effort.

Narrative

Each proposal should contain a narrative in which the relevance of the proposed work to DOE/EES Special Projects Program is discussed and a clear statement of the proposed work plan is presented. The qualifications of the proposer should be delineated.

The following points should be specifically addressed:

1. Purpose and Objective - State briefly the primary purpose, general objective and expected end result of the proposal, such as:

    (1) State the problem or problems the proposed special project will contribute to solving, and the anticipated contribution of the project to that solution.

(2) Enumerate the specific objectives of the project and specify the questions which the project will try to answer.

(3) State the expected consequences of successful completion of the project for the EES program.

(4) Discuss the existing interest by potential beneficiaries or users.

2. Statement of Work - Give full and complete technical details of the procedures that will be followed throughout the scope of work. Describe the work to be performed and services to be rendered, phase by phase in a sequence that will permit DOE to determine the success of the accomplishments at the end of any phase, and relate these to any phase which follows. Indicate the scope and methods of management support planned in order to fully execute the work. Provide an estimated period of time in which to accomplish the objectives of the proposal or have achieved significant results by 3/31/79, and indicate criteria by which success of the project can be evaluated. It is advisable to indicate the phasing of the project on an appropriate time-milestone basis.

3. Organization, Facilities, and Qualifications - As applicable, make the following representations with respect to the organization, facilities, and qualifications for performing the work or services set forth herein:

a. It is ______________________ organized and existing under the
(type of organization)
laws of the State of____________, having its principal office and place of business in the city of____________ in the state of_______________.

(1) If a corporation, list the officers authorized to commit the company.

(2) If a partnership, list the names and addresses of all partners.

b. It regularly employs __________persons.

(1) It is (is not) categorized as a "minority business" enterprise.

(2) It is (is not) categorized as a "small business" enterprise.

c. Work proposed will be performed at the contractor's place of business located at___________________________.

d. It has available qualified personnel for the performance of the work or services called for within the time specified, except as follows: (detail as necessary)

e. It (is currently) (has been) engaged in work or services of the type required herein and is fully qualified for the performance of the work or services hereunder as the result of its experience in the field involved.

f. If a contract is awarded as a result of this proposal, it is the intention of the proposer to subcontract the following work or services:

Work, Services, or Major Equipment Purchases to be Subcontracted	Cost*	Prospective** Subcontractor(s)
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g. It has (has not) employed or retained a company or person (other than a full-time employee) to solicit or secure this contract, and agrees to furnish information relating thereto as requested by the contracting officer.

h. It has (has not) the necessary financial capacity, working capital, and other resources to perform the contract without assistance from any outside source. (If not, indicate the amount required and the anticipated source.)

5. Other Information - Provide the following:

a. Names, titles, and resumes of principal investigator and key technical personnel and percent of time each will be spending on the special project.***

b. Describe briefly the location, facilities, and special equipment available to perform the work outlined in the proposal.

c. List additional locations, facilities and special equipment required to perform the work outlined in the proposal.

d. The submission of a proposal to other prospective sponsors, concurrently with its submission to the DOE, will not prejudice DOE review of such proposal. In this regard, the following information should be furnished:

---

* Indicate basis, whether actual competitive price quotations, catalog prices, or other.
** Indicate method of selection, competitive or selected source.
*** Note: This information is also required on the budget sheet shown in Appendix B.

(1) State whether the proposal has been submitted to any other prospective sponsor(s), including other Federal agencies. If so, indicate to whom, when, and where, and the proposed total cost of such other submission(s).

(2) State whether any portion of the work outlined in the proposal is presently being supported by any other sponsor(s) or by the proposer.

(3) State whether any prior work related to the present proposal was sponsored and, if so, indicate the information as in (1) above.

Cost Estimate

An estimate of the cost of all the proposed work or total program, as appropriate, with breakdowns by task and by Government fiscal year, should be submitted. A sample format which is adequate for DOE's needs is set forth in Appendix B.

APPENDIX A

Sample Cover Sheet

UNSOLICITED PROPOSAL

Submitted to

Department of Energy

State

Address

For

Title of Proposal

State Contact

Name & Address of Project Manager if Different From Above

Signature of Authorized State Official as Noted in NPI

Sample Budget

From (beginning date) to (ending date)
REIMBURSABLE OR COST SHARING PORTION

	Estimated Requirements	
	First Year	Second Year
1. Salaries and Wages	$ XXXX	$ XXXX
Scientific Discipline Personnel		
Principal Investigator, R. Roe, Assoc. Prof.—100% of time for 2 summer months @ $XXXX per month	XXXX	XXXX
J. Doe, Post-Doctorate Asst.—100% of time for 3 summer months @ $XXXX per month	XXXX	XXXX
2 Graduate Assistants @ $XXXX per calendar year—50% of time for 12 months	XXXX	XXXX
Support Personnel	XXXX	XXXX
Secretary		
2 Dishwashers		
Social Security and Retirement	XXX	XXX
2. Equipment	$ XXXX	$ XXXX
XYZ Machine	XXX	0
Electronic Equipment	0	XXX
Power Supply	XXX	0
3. Travel	$ XXX	$ XXX
Domestic	XXX	XXX
Foreign	XXX	XXX
4. Other Direct Costs	$ XXX	$ XXX
Supplies and Materials (indicate significant items or items of a special nature)	XXX	XXX
Publications	XXX	XXX
Machine Shop Services	XXX	XXX
Computer Services	XXX	XXX
5. Indirect charges XX.X% of salaries or other base	XXXX	XXXX
Total Project Costs	$XXXXX	$XXXXX
Percentage and Amount to be Contributed by (Name of Institution) —%	$ XXXX	$ XXXX
Percentage and Amount Requested of ERDA —%	$ XXXX	$ XXXX

The beginning and ending dates for the period covered by the budget should be included. If commitments for personnel, supplies or equipment have to be made prior to the beginning date, a statement to this effect should be included in the proposal.

Salaries of scientific personnel should be identified by the individual's name and title, social security number, and monthly academic rate of pay.

Fraction of time or effort personnel will devote to the project should be shown.

List each piece of scientific or technical equipment to be purchased or fabricated. Where this is not practical, equipment may be grouped in general categories. Any general purpose equipment must be listed individually.

The need for individual pieces of equipment should be explained in the portion of the proposal describing the work to be undertaken.

Purpose of the travel should be explained in the proposal.

The budget may include costs of publishing in recognized scientific journals including the cost of a reasonable supply of reprints.

Indicate percent and expenditures to which applied—also indicate name of cognizant audit and negotiation agencies.

Under special research support agreements, the Institution will be required to furnish an annual after-the-fact certified statement showing the actual total cost during the prior agreement year.

Institution's contributions may be made by contributing particular items without cost to the ERDA or by agreeing to pay a specified percent of the total cost of the project.

If the budget includes estimates of total costs to complete the project, indicate the amounts required each year.

Some organizations include these and other general purpose items of expense in their indirect costs. In such cases, the items should not be duplicated by listing the items as a direct cost.

If the cost of the later stages of the project cannot be accurately estimated, only the costs of the first year need be included in the budget.

ITEMS EXCLUDED FROM COST SHARING TO BE CONTRIBUTED BY THE CONTRACTOR
(Dollar amounts are not required if the item(s) to be contributed can be described using quantitative terms such as hours, pounds, etc.)

CONTRACTOR CONTRIBUTION OF PRINCIPAL INVESTIGATOR
Principal investigator, R. Roe
50% of time for 9 month academic year.
(Do not show dollar amounts under this category. When all or a part of the principal investigator's time is shown in this section, overhead and salary related costs for that portion of time may not be included in Reimbursable or Cost Sharing Portion above.)

NOTE: ERDA is now DOE.

August 14, 1974

United States Geological Survey
Geothermal Research Program
Fiscal Year 1975

INTRODUCTION

The U.S. Geological Survey Geothermal Research Program is a multidisciplinary effort whose objective is to understand the factors that control the nature and distribution of geothermal resources in the United States and thus to provide reliable, documented estimates of the magnitude of these resources. The program of work for FY-75 falls into six broad categories:

1.	Location of geothermal target areas and estimation of national resources	33%
2.	Science and technology for determining the energy potential of specific geothermal reservoirs	29%
3.	Geothermal exploration technology	20%
4.	Energy potential of deep parts of geothermal reservoirs	3%
5.	Geochemical control of reservoir permeability	4%
6.	Environmental impact of geothermal extraction (earthquakes, subsidence, groundwater disturbance)	11%
		100%

The Geothermal Research Program encompasses a broad spectrum of geological, geochemical, geophysical, and hydrological activities, and accordingly is set up not as a line activity but as a program that can draw upon the specialized talent of existing organizational units within Geologic Division and Water Resources Division. Under the "lead division" concept, the program is coordinated by L. J. Patrick Muffler under the direction of Richard S. Fiske (Chief, Office of Geochemistry and Geophysics, Geologic Division). Donald E. White, as senior U.S.G.S. scientist in geothermal research, is advisor to Muffler and Fiske. Geothermal investigations carried out in Water Resources Division are coordinated by Lee C. Dutcher, seismic investigations by Peter L. Ward, and geothermal investigations in Regional Geophysics Branch by Gordon P. Eaton. Approximately 24% of the Geothermal Research Program is designated for research contracts and grants. This extramural part of the program is directed by Donald W. Klick, who also provides liaison in the Washington D. C. area with other agencies having geothermal programs.

The Geothermal Research Program is organized and managed separately from the leasing activities of Conservation Division of the USGS. However, many data generated by the Geothermal Research Program bear directly on the land classification and lease evaluation activities of Conservation Division. Accordingly, the Geothermal Research Program is coordinated with the classification and evaluation needs and does provide geothermal data to support the lease-related activities of Conservation Division.

Until 1971, the U.S.G.S. had no specifically funded program of geothermal resource studies, although investigations of hot springs and hydrothermal systems had been carried out (primarily by Donald E. White) since 1945 as part of the ongoing Geologic Division program in energy and mineral resources. Expansion of the USGS Geothermal Research Program since first authorized by Congress in FY-72 is shown below.

FY-71	$205,000 (part of ongoing "base" program)
FY-72	$665,000
FY-73	$2,255,000
FY-74	$2,975,000 (includes $300,000 from National Science Foundation for program acceleration and $120,000 from Atomic Energy Commission for investigations at Raft River, Idaho)
FY-75	$9,009,000

This last figure does not include $1,805,000 requested by the U.S.G.S. in FY-75 for land classification, lease evalution, and lease supervision.

REGIONAL GEOTHERMAL EVALUATION

Five efforts in the Geothermal Research Program are aimed at a synoptic overview of geothermal phenomena in the United States, with the goal of synthesizing diverse geological, geochemical, geophysical, hydrological, and economic data into an understanding of the nature and distribution of geothermal resources of various grades. Each of these efforts is based in a different subdiscipline and approaches the problem from a different perspective.

1. A regional volcanological study by Robert L. Smith, Herbert R. Shaw, and Robert G. Luedke.

2. A study based on heat flow and other regional geophysics by William H. Diment and Thomas C. Urban.

3. Studies of hot-springs and thermal waters by Donald E. White.

4. Analysis of remote sensing and other synoptic geophysical data (personnel not certain)

5. Collection of geothermal resource data and analysis in terms of mineral economics, technological factors, and institutional constraints (Office of Resource Analysis; personnel not certain)

GEOLOGIC INVESTIGATIONS

Reconnaissance Studies

1. Geothermal reconnaissance of Oregon (Norman S. MacLeod)

2. Geothermal reconnaissance of the northern Great Basin (Richard K. Hose)

3. Geothermal reconnaissance of Alaska (Thomas P. Miller)

4. Geothermal reconnaissance of the Snake River plain (Paul L. Williams)

5. Geothermal reconnaissance of the young volcanic areas around the Colorado Plateau (Peter W. Lipman)

Studies of Specific Geothermal Areas

1. Long Valley, California, with emphasis on the post-caldera volcanic history (Roy A. Bailey, Robert P. Koeppen, and Frederick A. Wilson)

2. The Clear Lake volcanic field, California (B. Carter Hearn and Julie M. Donnelly)

3. Pre-Tertiary geology of the Geysers-Clear Lake Area (Robert J. McLaughlin)

4. Geology of the Coso Mountains, California (Wendell A. Duffield; cooperative effort with the U.S. Navy)

5. Studies of the San Francisco volcanic field, Arizona. Areal geology and petrology by Edward W. Wolfe, Robert L. Christiansen, George E. Ulrich, and Richard B. Moore. Studies of ultramafic nodules by E. Dale Jackson and Howard G. Wilshire

6. Geology of the Weiser area, Idaho (David H. McIntyre)

7. Geology of the Raft River area, Idaho (Paul L. Williams, Kenneth L. Pierce, David H. McIntyre; in cooperation with the Atomic Energy Commission)

8. Geology of the Quaternary volcanics of the Yellowstone region (Robert L. Christiansen)

9. Geology of Yellowstone thermal areas. Areal studies by L. J. Patrick Muffler, Donald E. White, and Keith E. Bargar. Petrology of drill core by Melvin H. Beeson, Keith E. Bargar, Terry E. C. Keith, and L. J. Patrick Muffler.

10. Geology of the upper Arkansas River valley (Glenn R. Scott)

GEOPHYSICAL INVESTIGATIONS

Electrical Investigations

1. Dipole-bipole resistivity surveys supplemented by Schlumberger soundings (William D. Stanley, Dallas B. Jackson, and Adel A. R. Zohdy). Surveys in many areas, including Yellowstone Park, The Geysers, Raft River etc.

2. Telluric investigations (Don R. Mabey and James E. O'Donnell)

3. Self-potential surveys and interpretation (Donald B. Hoover and David V. Fitterman)

4. Continuing refinement of techniques for interpreting resistivity surveys (Adel A. R. Zohdy)

Electromagnetic Investigations

1. Audio-frequency magnetotelluric (AMT) surveys (Donald B. Hoover)

2. Magnetotelluric surveys (William D. Stanley and James E. O'Donnell)

3. Geomagnetic soundings (James N. Towle)

4. Controlled source eletromagnetic surveys (personnel uncertain)

5. Theoretical electromagnetic research (Frank C. Frischknecht, Raymond D. Watts, and Walter L. Anderson)

Seismic Investigations

1. Studies of teleseismic P-delays and attenuation phenomena to identify and define magma chambers (H. M. Iyer, A. M. Pitt, and Don W. Steeples)

2. Development of a portable network of about 100 seismometers plus data processing system for use in teleseismic and attenuation studies (Peter L. Ward, John H. Healy, and Herbert Mills)

3. Analysis and interpretation of seismic noise surveys run in FY-74 (H. M. Iyer)

4. Delineation of the Kilauea, Hawaii magma chamber through use of expanded seismograph and levelling nets (Peter L. Ward and Rex V. Allen)

5. Microearthquake monitoring in the Imperial Valley, The Geysers, San Francisco Mountains, and Yellowstone Park (H. M. Iyer and A. M. Pitt)

6. Development of a new system for deep crustal refraction studies (David P. Hill and John H. Healy)

7. Shallow refraction surveys (Hans D. Ackermann)

8. Laboratory measurements of compressional and shear velocities in crustal rocks (some partly melted) to 10 kb and 1000°C (Louis Peselnick and Roger Stewart)

Heat Flow Investigations

Heat flow studies are carried out by a group consisting of Arthur H. Lachenbruch, John H. Sass, William H. Diment, Thomas P. Urban, Thomas H. Moses, and Robert J. Monroe. Part of the effort is in studies of broad regions, in particular the Battle Mountain High in northern Nevada, the high lava plateaus of Oregon, and the zone of heat-flow transition at the east side of the Sierra Nevada. In addition, detailed studies of conductive and convective heat transport are being carried out at The Geysers and at Long Valley, California.

Gravity and Magnetic Surveys

Gravity and aeromagnetic surveys are being carried out in numerous areas, in part in support of geologic investigations and in part for regional tectonic and volcanic analysis. Areas currently being investigated by Don R. Mabey, Gordon P. Eaton, Donald L. Peterson, Andrew Griscom, Lindreth E. Cordell, William F. Isherwood, Ronald R. Wahl, and David L. Williams include The Geysers and Long Valley in California, the Snake River Plain in Idaho, the belt of young volcanic rocks around the Colorado Plateau, Yellowstone National Park, the San Francisco volcanic field in Arizona, and several areas in central Oregon.

Remote Sensing

1. Continued development of the thermal inertia model for extracting geothermal signal from thermal noise, with field experiments at Raft River, Idaho, and Norris Geyser Basin in Yellowstone Park (Kenneth Watson and others)

2. Study of surface thermal emission and infrared imagery at Long Valley, California (Jules D. Friedman)

3. Continued development of the passive microwave technique, with field surveys at Long Valley, California and Raft River, Idaho (Anthony W. England)

Borehole Logging

Continuing effort by W. Scott Keys and Richard H. Merkel to develop high-temperature borehole logging devices and to test them in simulated and in field conditions.

GEOCHEMISTRY

Geothermal Waters

1. Sampling of fluids from hot springs and wells followed by chemical analysis for major and minor constituents is carried out by Ivan Barnes, Robert H. Mariner, John B. Rapp, Theresa S. Presser, and others. Major sampling efforts in FY-75 will be in The Geysers-Clear Lake area of California, in western Montana, and in the belt of volcanic rocks around the Colorado Plateau.

2. Use of major-element contents and ratios as geothermometers to estimate minimum subsurface temperatures (Robert O. Fournier and Alfred H. Truesdell)

3. Development of methods that use the fractionation of isotopes (eg., ^{18}O between $SO_4^{=}$ and H_2O; ^{13}C between CH_4 and CO_2) to estimate subsurface temperatures (Alfred H. Truesdell and William F. McKenzie)

4. Interpretation of water compositions in terms of reaction with associated minerals (Ivan Barnes)

5. Analysis and interpretation of dilution and dissipation of trace elements discharged in geothermal waters (Everett A. Jenne)

Experimental Mineralogy and Petrology

1. Laboratory experiments on the hydration status of aqueous silica species and the system $NaCl-KCl-CaCl_2-H_2O$ with and without quartz (Robert O. Fournier, Randall S. Babcock, and J. M. Thompson)

2. Laboratory studies on aqueous silica species and on ferrous and calcium silicate complexes in solution (John L. Haas)

3. Theoretical and laboratory studies of the kinetics of igneous processes (Lawrence M. Cathles)

Thermodynamic properties

1. Laboratory determination of the pressure-volume-temperature relations of geothermal brines (Robert W. Potter)

2. Calorimetric studies to determine the thermodynamic properties of phases relevant to the possible plugging of geothermal reservoirs (Richard A. Robie and Bruce S. Hemmingway)

3. Evaluation and correlation of thermodynamic data (James R. Fisher)

4. Collection and evaluation of thermodynamic data for aqueous species (Charles L. Christ)

Isotope Studies

1. Potassium-argon dating of igneous rocks from geothermal areas (G. Brent Dalrymple, Marvin A. Lanphere, Edwin H. McKee, and Harald H. Mehnert)

2. Studies of stable isotopes (O, C, H) in geothermal waters and minerals (James R. O'Neil)

3. Studies of stable isotopes in Yellowstone Park, with emphasis on ^{34}S relationships (Robert O. Rye)

HYDROLOGIC INVESTIGATIONS

Reconnaissance Studies of Hot-Water Systems

1. Hydrologic reconnaissance of selected geothermal systems in northern Nevada, including Double, Fly Ranch, Gerlach, Brady's, Leach, Buffalo Valley, and Sulphur Hot Springs (Franklin H. Olmsted and F. Eugene Rush)

2. Hydrologic reconnaissance of selected geothermal systems in southern Oregon (Edward A. Sammel). Initial emphasis is being placed on the Klamath Falls and Newberry areas.

3. Tentative plans for geothermal reconnaissance in Utah, Hawaii, Montana, and Colorado.

Detailed Studies of Hot-Water Systems

1. Detailed study of the hydrology of Long Valley, California (Robert E. Lewis)

2. Detailed study of the hydrology of the Jemez Mountains, New Mexico (Frank W. Trainer), in part in cooperation with Los Alamos Scientific Laboratories.

3. Collection and collation of hydrologic data from the Imperial Valley, California (William F. Hardt)

4. Collection of hydrologic data from shallow auger holes and intermediate-depth test wells in Raft River area, Idaho (E. G. Crosthwaite)

Hydrologic Support

1. Rotary drilling (using USBR equipment) to depths of 300 to 1500 feet, in support of hydrologic studies listed above.

2. Auger and rotary drilling to depths of 10 to 150 feet, in support of hydrologic studies listed above.

3. Development and testing of packer and tracer systems for use in determining hydrologic properties in hot drillholes (Eugene Shuter)

4. Determination of hydrologic properties of core at the drill site using a truck-mounted laboratory (Francis S. Riley)

5. Borehole logging of holes drilled for hydrologic purposes (W. Scott Keys and Richard H. Merkel)

Modelling and Physics of Hydrothermal Systems

1. Development of a two-phase mathematical model to simulate the production history of a hot-water geothermal system (James W. Mercer)

2. Application of mathematical models to the Imperial Valley geothermal system (Raymond E. Miller)

3. Adaptation of a model developed by Lawrence Livermore Laboratory to geothermal systems and use of the model in interpreting the hydrologic and thermal data from Long Valley and one or more Nevada areas (Michael L. Sorey)

4. Laboratory experiments and theoretical studies of how high temperature gradients effect multi-phase flow of fluids (Akio Ogata)

5. Experimental investigations of the feasibility of increasing productivity of hydrothermal systems by inducing hydraulic fractures in poorly permeable rock (John D. Bredehoeft)

6. Analysis of production behavior of hot-water and dry-steam geothermal wells (Manuel Nathenson)

Geopressured Reservoirs

1. Continuing mapping of selected parameters (extent of geopressured sands; water salinity; temperature; location of faults and folds) using data from deep oil wells in the Gulf Coast of Texas and Louisiana (Paul H. Jones, Raymond H. Wallace, John B. Wesselman)

2. Analysis of whether high rates of fluid production from geopressured aquifers can be maintained for periods of 20 years (S. S. Papadopulos)

3. Analysis of the economic feasibility of recovering kinetic, thermal, and combustion energy from Gulf Coast geopressured reservoirs (Thomas Maddock, III)

4. Investigations of the geochemistry of geopressured fluids and the changes in fluid composition, dissolved methane content, and clay mineralogy that may occur under high production rates (staffing uncertain)

5. Development of a quantitative model of representative geopressured aquifer, including analysis of pressure changes and land subsidence that might result from large-scale production (staffing uncertain)

Hot-Dry Rock

1. Investigation of the feasibility of economic extraction of heat from multiple hydraulic fractures in slanted drill holes. Initial effort is being devoted to a) fracture geometry, dimensions, shape and width as a function of stresses and injection medium (David D. Pollard), and b) analysis of flow paths between holes intersecting fractures (Manual Nathenson)

2. Experimental investigations of the change in permeability as water is flushed through hot granite (James D. Byerlee)

Subsidence

Ben E. Lofgren is continuing cooperation with various Federal, State and local agencies as well as private industry to monitor ground movements in the Imperial Valley, in order to detect any possible subsidence due to geothermal development. A similar net with both horizontal and vertical control is monitored at The Geysers, California. Evaluation of monitoring needs is being undertaken for Raft River and Bruneau-Grandview, Idaho, Long Valley, California, and the Gulf Coast, leading to new monitoring nets in selected parts of these areas.

GRANTS AND CONTRACTS

The grants and contracts part of the USGS Geothermal Research Program is designated to supplement the in-house research effort, and accordingly will be closely coordinated with the research carried out by USGS personnel. Proposals will be evaluated on the basis of technical content, relevance to geothermal resource evaluation, and compatibility with the USGS in-house geothermal program. In addition, the USGS geothermal grants and contracts effort will be coordinated with the parallel geothermal resource program of the National Science Foundation. Responsibility for the USGS geothermal grants and contracts lies with Donald W. Klick.

PERSONNEL

Name	Organizational Unit	Headquarters
Hans D. Ackermann	Regional Geophysics Branch	Denver
Rex V. Allen	Earthquake Tectonics Branch	Menlo Park
Walter L. Anderson	Regional Geophysics Branch	Denver
Randall S. Babcock	Experimental Geochemistry and Mineralogy Branch	Menlo Park
Roy A. Bailey	Field Geochemistry and Petrology Branch	Reston
Keith E. Bargar	Field Geochemistry and Petrology Branch	Menlo Park
Ivan Barnes	Water Resources Division	Menlo Park
Melvin H. Beeson	Field Geochemistry and Petrology Branch	Menlo Park
John D. Bredehoeft	Water Resources Division	Reston
James D. Byerlee	Earthquake Tectonics Branch	Menlo Park
Lawrence M. Cathles	Experimental Geochemistry and Mineralogy Branch	Reston
Charles L. Christ	Experimental Geochemistry and Mineralogy Branch	Menlo Park
Robert L. Christiansen	Field Geochemistry and Petrology Branch	Menlo Park
E. G. Crosthwaite	Water Resources Division	Boise, Idaho
Lindreth E. Cordell	Regional Geophysics Branch	Denver
G. Brent Dalrymple	Isotope Geology Branch	Menlo Park
William H. Diment	Earthquake Tectonics Branch	Menlo Park
Julie M. Donnelly	Field Geochemistry and Petrology Branch	Berkeley, Calif. (Univ. Calif.)
Wendell A. Duffield	Field Geochemistry and Petrology Branch	Menlo Park
Lee C. Dutcher	Water Resources Division	Menlo Park
Gordon P. Eaton	Regional Geophysics Branch	Denver
Anthony W. England	Regional Geophysics Branch	Denver
James R. Fisher	Experimental Geochemistry and Mineralogy Branch	Reston

PERSONNEL

Name	Organizational Unit	Headquarters
Richard S. Fiske	Office of Geochemistry and Geophysics	Reston
David V. Fitterman	Regional Geophysics Branch	Denver
Robert O. Fournier	Experimental Geochemistry & Mineralogy Branch	Menlo Park
Jules D. Friedman	Regional Geophysics Branch	Denver
Frank C. Frischknecht	Regional Geophysics Branch	Denver
Andrew Griscom	Regional Geophysics Branch	Menlo Park
John L. Haas	Experimental Geochemistry & Mineralogy Branch	Reston
William F. Hardt	Water Resources Division	Garden Grove, Calif.
John H. Healy	Seismology Branch	Menlo Park
B. Carter Hearn	Field Geochemistry and Petrology Branch	Reston
Bruce S. Hemmingway	Experimental Geochemistry and Mineralogy Branch	Reston
David P. Hill	Seismology Branch	Menlo Park
Donald B. Hoover	Regional Geophysics Branch	Denver
Richard K. Hose	Western Mineral Resources Branch	Menlo Park
William F. Isherwood	Regional Geophysics Branch	Denver
H. M. Iyer	Seismology Branch	Menlo Park
Dallas B. Jackson	Regional Geophysics Branch	Denver
E. Dale Jackson	Earthquake Tectonics Branch	Menlo Park
Everett A. Jenne	Water Resources Division	Menlo Park
Paul H. Jones	Water Resources Division	Bay St. Louis, Mississippi
Terry E. C. Keith	Field Geochemistry and Petrology Branch	Menlo Park
W. Scott Keys	Water Resources Division	Denver
Donald W. Klick	Office of Geochemistry and Geophysics	Reston

PERSONNEL

Name	Organizational Unit	Headquarters
Arthur H. Lachenbruch	Earthquake Tectonics Branch	Menlo Park
Marvin A. Lanphere	Isotope Geology Branch	Menlo Park
Robert E. Lewis	Water Resources Division	Garden Grove, Calif.
Peter W. Lipman	Central Environmental Branch	Denver
Ben E. Lofgren	Water Resources Division	Sacramento, Calif.
Don R. Mabey	Regional Geophysics Branch	Denver
Thomas Maddock, III	Water Resources Division	Reston
Norman S. MacLeod	Western Mineral Resources Branch	Menlo Park
Robert H. Mariner	Water Resources Division	Menlo Park
David G. McIntyre	Central Environmental Branch	Denver
Edwin H. McKee	Western Mineral Resources Branch	Menlo Park
William F. McKenzie	Experimental Geochemistry and Mineralogy Branch	Menlo Park
Robert J. McLaughlin	Western Environmental Branch	Menlo Park
Harald H. Mehnert	Isotope Geology Branch	Denver
James W. Mercer	Water Resources Division	Reston
Richard H. Merkel	Water Resources Division	Denver
Raymond E. Miller	Water Resources Division	Washington D.C.
Thomas P. Miller	Alaskan Geology Branch	Anchorage
Herbert Mills	Seismology Branch	Menlo Park
Richard B. Moore	Astrogeologic Studies Branch	Flagstaff
Thomas H. Moses	Earthquake Tectonics Branch	Menlo Park
L. J. Patrick Muffler	Office of Geochemistry and Geophysics	Menlo Park
Robert J. Munroe	Earthquake Tectonics Branch	Menlo Park

PERSONNEL

Name	Organizational Unit	Headquarters
Manuel Nathenson	Field Geochemistry and Petrology Branch	Menlo Park
James E. O'Donnell	Regional Geophysics Branch	Denver
Akio Ogata	Water Resources Division	Denver
Franklin H. Olmsted	Water Resources Division	Denver
James R. O'Neil	Isotope Geology Branch	Menlo Park
S. S. Papadopulos	Water Resources Division	Reston
Louis Peselnick	Earthquake Tectonics Branch	Menlo Park
Donald L. Peterson	Regional Geophysics Branch	Denver
Kenneth L. Pierce	Central Environmental Branch	Denver
A. M. (Mitch) Pitt	Seismology Branch	Menlo Park
David D. Pollard	Earthquake Tectonics Branch	Menlo Park
Robert W. Potter	Experimental Geochemistry and Mineralogy Branch	Reston
Theresa S. Presser	Water Resources Division	Menlo Park
John B. Rapp	Water Resources Division	Menlo Park
Francis S. Riley	Water Resources Division	Denver
Richard A. Robie	Experimental Geochemistry and Mineralogy Branch	Reston
F. Eugene Rush	Water Resources Division	Carson City, Nevada
Robert O. Rye	Isotope Geology Branch	Denver
Edward A. Sammel	Water Resources Division	Menlo Park
John H. Sass	Earthquake Tectonics Branch	Menlo Park
Glenn R. Scott	Central Environmental Branch	Denver
Herbert R. Shaw	Experimental Geochemistry and Mineralogy Branch	Berkeley, Calif.
Eugene Shuter	Water Resources Division	Denver

PERSONNEL

Name	Organizational Unit	Headquarters
Robert L. Smith	Field Geochemistry and Petrology Branch	Reston
Michael L. Sorey	Water Resources Division	Menlo Park
William D. (Dal) Stanley	Regional Geophysics Branch	Denver
Don W. Steeples	Seismology Branch	Menlo Park
Roger Stewart	Earthquake Tectonics Branch	Menlo Park
J. M. (Mike) Thompson	Experimental Geochemistry and Mineralogy Branch	Menlo Park
James N. Towle	Regional Geophysics Branch	Denver
Frank W. Trainer	Water Resources Division	Albuquerque, N.M.
Alfred H. Truesdell	Experimental Geochemistry and Mineralogy Branch	Menlo Park
George E. Ulrich	Astrogeologic Studies Branch	Flagstaff, Ariz.
Thomas P. Urban	Earthquake Tectonics Branch	Menlo Park
Ronald R. Wahl	Regional Geophysics Branch	Denver
Raymond H. Wallace	Water Resources Division	Bay St. Louis, Mississippi
Peter L. Ward	Seismology Branch	Menlo Park
Raymond D. Watts	Regional Geophysics Branch	Denver
Kenneth E. Watson	Regional Geophysics Branch	Menlo Park
John B. Wesselman	Water Resources Division	Bay St. Louis, Mississippi
Donald E. White	Field Geochemistry and Petrology Branch	Menlo Park
Howard G. Wilshire	Astrogeologic Studies Branch	Menlo Park
Edward W. Wolfe	Astrogeologic Studies Branch	Flagstaff, Ariz.
David L. Willaims	Regional Geophysics Branch	Denver
Paul L. Williams	Central Environmental Branch	Denver
Frederick A. Wilson	Field Geochemistry and Petrology Branch	Washington
Adel A. R. Zohdy	Regional Geophysics Branch	Denver

July 28, 1975

United States Geological Survey
Geothermal Research Program
Fiscal Year 1976

INTRODUCTION

The U.S. Geological Survey Geothermal Research Program is a multidisciplinary effort whose objective is to understand the factors that control the nature and distribution of geothermal resources in the United States and thus to provide reliable, documented estimates of the magnitude of these resources as an aid in the development of a national energy policy. The program of work for FY-76 falls into five broad categories:

1.	National geothermal resource assessment	32%
2.	Exploration technology	21%
3.	Energy potential of geothermal reservoirs	31%
4.	Environmental impact (earthquakes, subsidence, groundwater disturbance)	12%
5.	Geochemical control of reservoir permeability	4%
		100%

The Geothermal Research Program encompasses a broad spectrum of geological, geochemical, geophysical, and hydrological activities, and accordingly is set up not as a line activity but as a program that can draw upon the specialized talent of existing units within Geologic Division and Water Resources Division. Under the "lead division" concept, the program is coordinated by L. J. Patrick Muffler under the direction of Richard S. Fiske (Chief, Office of Geochemistry and Geophysics, Geologic Division). Donald E. White, as senior U.S.G.S. scientist in geothermal research, is advisor to Muffler and Fiske. Geothermal investigations carried out in Water Resources Division are coordinated by Frank W. Trainer. Approximately 20% of the Geothermal Research Program is designated for research contracts and grants. This extramural part of the program is directed by Donald W. Klick, who also provides liaison in the Washington D. C. area with other agencies having geothermal programs.

The Geothermal Research Program is organized and managed separately from the leasing activities of Conservation Division of the USGS. However, many data generated by the Geothermal Research Program bear directly on the land classification and lease evaluation activities of Conservation Division. Accordingly, the Geothermal Research Program is coordinated with the classification and evaluation needs and provides geothermal data to support the lease-related activities of Conservation Division.

Until 1971, the U.S.G.S. had no specifically funded program of geothermal resource studies, although investigations of hot springs and hydrothermal systems had been carried out (primarily by Donald E. White) since 1945 as part of the ongoing Geologic Division program in energy and mineral resources. Expansion of the U.S.G.S. Geothermal Research Program since first authorized by Congress in FY-72 is shown below.

FY-71	$205,000 (part of ongoing "base" program)
FY-72	$665,000
FY-73	$2,255,000
FY-74	$2,975,000 (includes $300,000 from National Science Foundation for program acceleration and $120,000 from Atomic Energy Commission for investigations at Raft River, Idaho)
FY-75	$9,309,000 (includes $343,000 from Energy Research and Development Administration for 1975 geothermal resource estimation)
FY-76	$9,114,000

This last figure does not include $1,987,000 requested by the U.S.G.S. in FY-76 for land classification, lease evaluation, and lease supervision. Of this $1,987,000 approximately $320,000 is used for geophysical surveys conducted on Federal land prior to competitive lease sales.

REGIONAL GEOTHERMAL EVALUATION

Four efforts in the Geothermal Research Program are aimed at a synoptic overview of geothermal phenomena in the United States, with the goal of synthesizing diverse geological, geochemical, geophysical, hydrological, and economic data into an understanding of the nature and distribution of geothermal resources of various grades. Each of these efforts is based in a different subdiscipline and approaches the problem from a different perspective.

1. A regional volcanological study by Robert L. Smith, Herbert R. Shaw, and Robert G. Luedke.

2. Studies of hot-springs and thermal waters by Donald E. White.

3. Collection of geothermal resource data (James A. Calkins and JoAnn Cobb).

4. Analysis of geothermal resource data in terms of producibility, mineral economics, technological factors, and institutional constraints (Donald E. White, Manuel Nathenson, L. J. Patrick Muffler, and John C. Lucking).

GEOLOGIC INVESTIGATIONS

Reconnaissance Studies

1. Geothermal reconnaissance of Oregon (Norman S. MacLeod).

2. Geothermal reconnaissance of Alaska (Thomas P. Miller).

3. Geothermal reconnaissance of the Snake River Plain (Steven S. Oriel, Harold J. Prostka, Mel A. Kuntz, Kenneth L. Pierce, and Harry R. Covington).

4. Statistical characterization of geothermal areas in the Basin and Range province (David L. Williams).

5. Continued mapping of selected parameters (extent of geopressured sands; water salinity; temperature; location of faults) using data from deep oil wells in the Gulf Coast (Raymond H. Wallace, John B. Wesselman, and Richard Taylor).

Studies of Specific Geothermal Areas

1. Long Valley, California, with emphasis on the post-caldera volcanic history (Roy A. Bailey, Robert P. Koeppen, and Frederick A. Wilson).

2. The Clear Lake volcanic field, California (B. Carter Hearn and Julie M. Donnelly).

3. Pre-Tertiary geology of The Geysers/Clear Lake Area (Robert J. McLaughlin).

4. Geology of the Coso Mountains, California (Wendell A. Duffield and Charles R. Bacon; cooperative effort with the U.S. Navy and the Energy Research and Development Administration).

5. Studies of the San Francisco volcanic field, Arizona. Areal geology and petrology by Edward W. Wolfe,George E. Ulrich, Richard B. Moore and Richard F. Holm.

6. Geology of the Raft River are, Idaho (Paul L. Williams, Kenneth L. Pierce, Steven S. Oriel, and Harry R. Covington; in cooperation with the Energy Research and Development Administration.

7. Geology of the Quaternary volcanics of the Yellowstone region (Robert L. Christiansen)

8. Geology of Yellowstone thermal areas. Areal studies by L. J. Patrick Muffler, Donald E. White, and Keith E. Bargar. Petrology of drill core by Melvin H. Beeson, Keith E. Bargar, Terry E.C. Keith, and L. J. Patrick Muffler.

Studies of Specific Geothermal Areas continued:

9. Geology of the thermal areas in and around Lassen National Park (Penelope A. Bowen)

10. Geology of Mt. Shasta (Robert L. Christiansen)

GEOPHYSICAL INVESTIGATIONS

Electrical and Electromagnetic

1. Refinement of DC resistivity methods (Dallas B. Jackson and A. A. R. Zohdy).

2. Development of transient electromagnetic sounding methods (William D. Stanley, James N. Towle, and Dallas B. Jackson).

3. Telluric surveys (James E. O'Donnell).

4. Development of magnetotelluric sounding methods for the determination of regional geothermal potential (William D. Stanley).

5. Determination of upper crustal and mantle conductivity using magnetic variometer arrays (James N. Towle and David V. Fitterman).

6. Development of self-potential techniques for geothermal exploration (Donald B. Hoover).

7. Development of tensor audio-frequency magnetotelluric techniques for geothermal exploration (Donald B. Hoover).

8. Development of techniques and computer programs for electromagnetic modeling and the inversion of electromagnetic data (Walter L. Anderson).

Seismic Investigations

1. Studies of teleseismic P-delays and attenuation phenomena to identify and define magma chambers at Yellowstone Park, The Geysers, Coso Mountains, San Francisco Mtn. (Arizona), and Mt. Drum (Alaska). (H. M. Iyer and A. M. Pitt).

2. Development of a portable network of about 100 seismometers (CENTIPEDE array) plus data processing system for use in teleseismic and attenuation studies (Paul Reasonberg, Anthony Marshall, and Peter Stevenson).

3. Delineation of the Kilauea, Hawaii magma chamber through use of expanded seismograph and tiltmeter nets (Fred W. Klein and Rex V. Allen).

Seismic Investigations continued:

4. Microearthquake monitoring in the Imperial Valley, The Geysers, and Yellowstone Park (A. M. Pitt and Gary S. Fuis).

5. Development of a new system for deep crustal refraction studies (David P. Hill, John H. Healy, David H. Warren, Jay Dratler, and Robert M. Hazelwood).

6. Shallow refraction surveys (Hans D. Ackermann).

7. Laboratory measurements of compressional and shear velocities in crustal rocks (some partly melted) to 10 kb and 1000°C (Louis Peselnick and Roger Stewart).

Heat Flow Investigations

Heat flow studies are carried out by a group consisting of Arthur H. Lachenbruch, John H. Sass, William H. Diment, Thomas P. Urban, Thomas H. Moses, and Robert J. Monroe. Part of the effort is in studies of broad regions, in particular the Battle Mountain High in northern Nevada, the high lava plateaus of Oregon, and the zone of heat-flow transition at the east side of the Sierra Nevada. The remaining effort consists of detailed studies of conductive and convective heat transport are being carried out at The Geysers and at Long Valley, California. In addition, the Pallman (chemical) method of determining mean annual ground temperatures is being evaluated by Irving Friedman.

Gravity and Magnetic Surveys

1. An investigation of the system of young volcanic centers along the east side of the Sierra Nevada (D. L. Williams, W. F. Isherwood, M. F. Kane).

2. Structural setting of the Snake River Plain including detailed studies of subsurface structure of the Raft River Area (D. R. Mabey, T. G. Heldenbrand).

3. Regional structure of the Colorado Plateau margin and its associated young volcanics, in particular San Francisco Mountains (R. R. Wahl, G. P. Eaton).

4. Development of analytical methods for application in geothermal areas (Bimal K. Bhattacharyya, T. G. Hildenbrand).

5. A group of less comprehensive investigations being carried out in Oregon, Alaska, Calif., New Mexico and Yellowstone National Park (L. E. Cordell, W. F. Isherwood and A. Griscom).

Remote Sensing

1. Continued development of the thermal inertia model for extracting geothermal signal from thermal noise, with field experiments at Raft River, Idaho, and Norris Geyser Basin in Yellowstone Park (Kenneth Watson and others).

2. Study of surface thermal emission and infrared imagery at Long Valley, California (Jules D. Friedman).

3. Continued development of the passive microwave technique (Anthony W. England).

Borehole Logging

Continued effort by W. Scott Keys and others to develop high-temperature borehole logging devices and to test them in simulated and in field conditions.

Miscellaneous

1. Various gravity, magnetic, electrical and electromagnetic surveys in Known Geothermal Resource Areas (KGRA's) to provide data for pre-sale evaluation of Federal lands leased competitively for geothermal resource development (Don R. Mabey, Carol W. Wilson, Lindreth E. Cordell, Donald B. Hoover, D. B. Jackson, H. E. Kaufman, James E. O'Donnell, Donald L. Peterson, William F. Isherwood, and Joseph Rosenbaum).

2. Determination of physical properties of rocks under geothermal conditions (Gary R. Olhoeft).

3. Tiltmeter studies for the detection of subsurface magma bodies at Yellowstone (M. Darroll Wood) and Kilauea (Arnold Okamura).

GEOCHEMISTRY

Geothermal Waters

1. Sampling of fluids from hot springs and wells followed by chemical analysis for major and minor constituents is carried out by Robert H. Mariner, John B. Rapp, Theresa S. Presser, J. M. Thompson and others.

2. Use of major-element contents and rations as geothermometers to estimate minimum subsurface temperatures (Robert O. Fournier and Alfred H. Truesdell).

3. Development of methods that use the fractionation of isotopes (eg., ^{18}O between $SO_4^=$ and H_2O; ^{13}C between CH_4 and CO_2) to estimate subsurface temperatures (Alfred H. Truesdell and William F. McKenzie).

Geothermal Waters continued:

4. Interpretation of water compositions in terms of reaction with associated minerals (Ivan Barnes).

5. Analysis and interpretation of dilution and dissipation of trace elements discharged in geothermal waters (Everett A. Jenne and Robert C. Stauffer).

6. Investigations of the geochemistry and membrane-filtration properties of the Gulf Coast geopressured systems (Yousif K. Kharaka).

Experimental Mineralogy and Petrology

1. Laboratory experiments on the hydration status of aqueous silica species and the system $NaCl-KCL-CaCl_2-H_2O$ with and without quartz (Robert O. Fournier, Randall S. Babcock, and J. M. Thompson).

2. Laboratory studies on aqueous silica species and on ferrous and calcium silicate complexes in solution (John L. Haas).

Thermodynamic properties

1. Laboratory determination of the pressure-volume-temperature relations of geothermal brines (Robert W. Potter).

2. Calorimetric studies to determine the thermodynamic properties of phases relevant to the possible plugging of geothermal reservoirs (Richard A. Robie and Bruce S. Hemmingway).

3. Evaluation and correlation of thermodynamic data (James R. Fisher).

4. Collection and evaluation of thermodynamic data for aqueous species (R. M. Siebert and Charles L. Christ).

5. Evaluation of heats of fusion of common normative minerals (Stephen D. Ludington).

Isotope Studies

1. Potassium-argon dating of igneous rocks from geothermal areas (G. Brent Dalrymple, Marvin A. Lanphere, and Edwin H. McKee).

2. ^{14}C dating of carbon layers in young volcanic sequence (Meyer Rubin).

3. Application of thermoluminescence to dating of volcanic rocks from Long Valley, California (Rodd May).

4. Studies of stable isotopes (O, C, H) in geothermal waters and minerals (James R. O'Neil).

Isotope Studies continued:

5. Studies of stable isotopes in Yellowstone Park, with emphasis on ^{34}S relationships (Robert O. Rye).

HYDROLOGIC INVESTIGATIONS

Reconnaissance Studies of Hot-Water Systems

1. Northern Nevada, including Double, Fly Ranch, Gerlach, Brady's Leach, Buffalo Valley, and Sulphur Hot Springs (Franklin H. Olmsted).

2. Southern Oregon (Edward A. Sammel). Initial emphasis is being placed on the Klamath Falls and Newberry areas.

3. Western Utah (F. Eugene Rush).

4. Western Montana (Robert B. Leonard).

5. Appalachian mountains (W.A. Hobba and J. C. Chemerys).

Detailed Studies of Hot-Water Systems

1. Collection and collation of hydrologic data from the Imperial Valley, California (William F. Hardt).

2. Collection of hydrologic data from shallow auger holes and intermediate-depth test wells in Raft River area, Idaho (E. G. Crosthwaite).

3. Hydrology of the Coso Mountains, Ca. (W. R. Moyle).

4. Completion of a study of the discharge hydrology of the Jemez Mountains, New Mexico (Frank W. Trainer).

5. Long Valley, (Michael L. Sorey and Franklin H. Olmsted).

Hydrologic Support

1. Auger and rotary drilling to depths of 1500 feet, in support of hydrologic studies listed above (Glen Blevins).

2. Development and testing of packer and tracer systems for use in determining hydrologic properties in hot drillholes (Eugene Shuter).

3. Determination of hydrologic properties of core at the drill site using a truck-mounted laboratory (Francis S. Riley).

4. Borehole logging of holes drilled for hydrologic purposes.

Modelling and Physics of Geothermal Systems

1. Development of a multi-phase finite-element models to simulate the production history of hot-water geothermal systems (James W. Mercer and Charles R. Faust).

2. Development of multi-phase finite difference models of geothermal systems (Allen F. Moench).

3. Adaptation of a single-phase finite difference model developed by Lawrence Livermore Laboratory to geothermal systems and use of the model in interpreting the hydrologic and thermal data from Long Valley and various areas in Nevada (Michael L. Sorey).

4. Laboratory experiments and theoretical studies of how high temperature gradients effect multi-phase flow of fluids (Akio Ogata and William Herkelrath).

5. Application of mathematical models to the Imperial Valley geothermal system (Raymond E. Miller).

6. Application of mathematical models to the Raft River geothermal system (W. D. Nichols).

7. Development of multi-dimensional finite difference models to simulate flow from the Gulf Coast geopressured reservoirs (Peter C. Trescott and Edward Callender).

8. Analysis of production behavior to hot-water and dry-steam geothermal wells (Manuel Nathenson).

Hot-Dry Rock

1. Investigation of the feasibility of economic extraction of heat from multiple hydraulic fractures in slanted drill holes. Initial effort is being devoted to fracture geometry, dimensions, shape and width as a function of stresses and injection medium (David D. Pollard and Chi Yu King).

2. Laboratory studies of hydrofracture as a function of confining pressure, differential stress, and fluid injection rate (James D. Byerlee).

3. Experimental investigations of the change in permeability as water is flushed through hot granite (James D. Byerlee).

Subsidence

Ben E. Lofgren is continuing cooperation with various Federal, State and local agencies as well as private industry to monitor ground movements in the Imperial Valley, in order to detect any possible subsidence due to geothermal development. A similar net with both horizontal and vertical control is monitored at The Geysers, California. New monitoring nets and horizontal control nets are monitored at the Raft River, Idaho and the Coso Mountains, California. Evaluation of monitoring needs in the Gulf Coast is being undertaken.

GRANTS AND CONTRACTS

The extramural portion of the U.S.G.S. Geothermal Research Program is designed to support and to supplement the in-house research effort and accordingly close liaison is established with the research carried out by U.S.G.S. personnel. In addition, the U.S.G.S. grants and contracts are closely coordinated with the appropriate elements of the Division of Geothermal Energy of the Energy Research and Development Administration as lead agency for Federal geothermal programs. Unsolicited proposals can be submitted at any time and if of utmost priority, they can be funded on an individual basis throughout the fiscal year. Most proposals, however, should be submitted in response to a public announcement issued in early Fall with a closing date for receipt of proposals sometime in mid-December. The proposals are evaluated as a group on the basis of 1) scientific quality of the work proposed, 2) capabilities of the principal investigator and his research team, 3) reasonableness of the resources budgeted for the proposed work, and 4) relevance to the U.S.G.S. in-house geothermal program. The grants and contracts implemented in FY-75 fall into three general categories. Slightly more than half are in exploration technology, about a third in regional assessment, and the remainder in resource characterization. They are:

Grantee/Contractor	Title
University of Arizona (Paul Damon)	Geochronology of the San Francisco Volcanic Field
Batelle Pacific Northwest Laboratories (William McSpadden)	Research to Examine the Cause of the Geothermal Anomaly in the Deep Well at Marysville, Montana
Brown University (Joseph Kestin)	Thermophysical Properties of Water Substance and of Aqueous Solutions
University of California at Berkeley (H. Frank Morrison)	Delineation of Geothermally Active Regions in Southern Idaho with Gravity and Magnetic Data
University of California at Berkeley (H. Frank Morrison and John Clarke)	Improved Low Frequency Electromagnetic Prospecting System for Geothermal Exploration Utilizing a DC Squid Magnetometer
University of California at Riverside (W. A. Elders and P. R. L. Browne)	Comprehensive Laboratory Study of Samples from Natural Hydrothermal Systems

Grantee/Contractor	Title
California State University (Roswitha B. Grannell)	Detailed Gravity Surveys of the Brady's Hot Springs - Soda Lake and the Buffalo-Jersey-Lower Reese River Valley Areas, Nevada
Colorado Geological Survey (Richard H. Pearl)	Geochemical and Hydrological Parameters of Geothermal Systems in Colorado
Colorado State Division of Water Resources (John Romero)	Relationship between Geothermal Resources and Ground Water in Colorado
ENSCO, Inc. (Edward A. Page)	Improved Techniques for the Detection of Geothermal Sources from Seismic Activity
ENSCO, Inc. (Walter Hernandez)	New Signal Processing Methods for Magnetotellurics
University of Florida (Douglas L. Smith)	Heat Flow and Radioactive Heat Generation Studies in Southeastern United States
Florida State University (J. K. Osmond and J. B. Cowart)	Radioactivity Series Isotopic Disequilibrium in Geothermal Waters
Montana State University (Robert A. Chadwick)	Geothermal Reconnaissance of Southwestern Montana
University of New Mexico (Gary P. Landis)	Evaluation of Geothermal Potential of the Basin and Range Province of New Mexico
Occidental College (Spencer H. Wood)	Eruptive Chronology of Holocene Volcanoes, Long Valley-Mono Basin Geothermal Areas, Eastern California
Oregon State Department of Geology and Mineral Industries (Donald A. Hull)	Heat Flow Study of the Brothers Fault Zone, Oregon
University of Oregon and Oregon State University (Richard Couch and Howard Baker)	Geophysical Investigations of the Vale-Owyhee Geothermal Region, Malheur County, Oregon
University of Oregon and Oregon State University (Richard Couch and Howard Baker)	Geophysical Investigations of the Cascade Range in Central Oregon

Grantee/Contractor	Title
Oregon State University (Richard Couch)	Analysis of Geophysical Data Pertaining to the Vale K.G.R.A.
Stanford University (David M. Boore)	Evaluation of Intermediate Period Seismic Waves as an Exploration Tool for Geothermal Areas
Stanford University (Robert L. Kovach and Amos M. Nur)	Seismic Reflection Investigations in the Beowawe, Nevada Geothermal Area
University of Texas at Dallas (Mark Landisman)	Geomagnetic Variometer Arrays as an Exploration Technique for Conductive Geothermal Sites
University of Texas at Dallas (Mark Landisman)	Evaluation of Broad Band Multi-Separation Crossed Dipole Electrical Technique for Geothermal Exploration
University of Utah (Stanley H. Ward)	Geophysics Applied to Detection, Delineation and Evaluation of Geothermal Resources

GLENN H. GARDNER

ENERGY EXTENSION SERVICE
ROOM 5110
20 MASS. AVE. N.W.
WASHINGTON, D. C. 20545
DEPARTMENT OF ENERGY (202) 376-1967

... cannot replace or supplant funding from other sources now provided for similar activities; rather, they must supplement such funds.

6. Projects must be completed or have achieved significant results by the end of the pilot program (3/31/79).

will contribute to solving, and the anticipated contribution of the project to that solution.

(2) It is (is not) categorized as a "small business" enterprise.

c. Work proposed will be performed at the contractor's place of business located at__________________________.

* Indicate basis, whether actual competitive price quotations, catalog prices, or other.
** Indicate method of selection, competitive or selected source.
*** Note: This information is also required on the budget sheet shown in Appendix B.

(1) State whether the proposal has been submitted to any other prospective sponsor(s), including other Federal agencies. If so, indicate to whom, when, and where, and the proposed total cost of such other submission(s).

(2) State whether any portion of the work outlined in the proposal is presently being supported by any other sponsor(s) or by the proposer.

(3) State whether any prior work related to the present proposal was sponsored and, if so, indicate the information as in (1) above.

Cost Estimate

An estimate of the cost of all the proposed work or total program, as appropriate, with breakdowns by task and by Government fiscal year, should be submitted. A sample format which is adequate for DOE's needs is set forth in Appendix B.

APPENDIX A

Sample Cover Sheet

UNSOLICITED PROPOSAL

Submitted to

Department of Energy

State

Address

For

Title of Proposal

State Contact

Name & Address of Project Manager if Different From Above

Signature of Authorized State Official as Noted in NPI

Appendix B

Sample Budget

From (beginning date) to (ending date)
REIMBURSABLE OR COST SHARING PORTION

The beginning and ending dates for the period covered by the budget should be included. If commitments for personnel, supplies or equipment have to be made prior to the beginning date, a statement to this effect should be included in the proposal.

Salaries of scientific personnel should be identified by the individual's name and title, social security number, and monthly academic rate of pay.

Fraction of time or effort personnel will devote to the project should be shown.

List each piece of scientific or technical equipment to be purchased or fabricated. Where this is not practical, equipment may be grouped in general categories. Any general purpose equipment must be listed individually.

The need for individual pieces of equipment should be explained in the portion of the proposal describing the work to be undertaken.

Purpose of the travel should be explained in the proposal.

The budget may include costs of publishing in recognized scientific journals including the cost of a reasonable supply of reprints.

Indicate percent and expenditures to which applied—also indicate name of cognizant audit and negotiation agencies.

Under special research support agreements, the institution will be required to furnish an annual after-the-fact certified statement showing the actual total cost during the prior agreement year.

Institution's contributions may be made by contributing particular items without cost to the ERDA or by agreeing to pay a specified percent of the total cost of the project.

If the budget includes estimates of total costs to complete the project, indicate the amounts required each year.

Some organizations include these and other general purpose items of expense in their indirect costs. In such cases, the items should not be duplicated by listing the items as a direct cost.

If the cost of the later stages of the project cannot be accurately estimated, only the costs of the first year need be included in the budget.

	Estimated Requirements First Year	Estimated Requirements Second Year
1. Salaries and Wages	$ XXXX	$ XXXX
Scientific Discipline Personnel		
Principal Investigator, R. Roe, Assoc. Prof.—100% of time for 2 summer months @ $XXXX per month	XXXX	XXXX
J. Doe, Post-Doctorate Asst.—100% of time for 3 summer months @ $XXXX per month	XXXX	XXXX
2 Graduate Assistants @ $XXXX per calendar year—50% of time for 12 months	XXXX	XXXX
Support Personnel	XXXX	XXXX
Secretary		
2 Dishwashers		
Social Security and Retirement	XXX	XXX
2. Equipment	$ XXXX	$ XXXX
XYZ Machine	XXX	0
Electronic Equipment	0	XXX
Power Supply	XXX	0
3. Travel	$ XXX	$ XXX
Domestic	XXX	XXX
Foreign	XXX	XXX
4. Other Direct Costs	$ XXX	$ XXX
Supplies and Materials (indicate significant items or items of a special nature)	XXX	XXX
Publications	XXX	XXX
Machine Shop Services	XXX	XXX
Computer Services	XXX	XXX
5. Indirect charges XX.X% of salaries or other base	XXXX	XXXX
Total Project Costs	$XXXXX	$XXXXX
Percentage and Amount to be Contributed by (Name of Institution) —%	$ XXXX	$ XXXX
Percentage and Amount Requested of ERDA —%	$ XXXX	$ XXXX

ITEMS EXCLUDED FROM COST SHARING TO BE CONTRIBUTED BY THE CONTRACTOR
(Dollar amounts are not required if the item(s) to be contributed can be described using quantitative terms such as hours, pounds, etc.)

CONTRACTOR CONTRIBUTION OF PRINCIPAL INVESTIGATOR
Principal investigator, R. Roe
50% of time for 9 month academic year.
(Do not show dollar amounts under this category. When all or a part of the principal investigator's time is shown in this section, overhead and salary related costs for that portion of time may not be included in Reimbursable or Cost Sharing Portion above.)

NOTE: ERDA is now DOE.

High-temperature heat pumps for industry

RON FERRIS
Product Specialist
Westinghouse Canada Limited
Oakville, Ontario

ABSTRACT

The Westinghouse Templifier™, using heat pump principles, recovers low-grade waste heat in the 60°F to 160°F temperature range and amplifies it to usable levels of up to 220°F. Coefficients of performance (C.P.O.) normally encountered are from 3.0 to 6.0, with capacities from 200,000 to 10 million Btu/hr.

Introduction

Heat pumping is not a new technology; however, it is only in the past few years that the cost effectiveness of electrically driven heat pumps is becoming more evident. Rapidly escalating prices and dwindling supplies of fossil fuels have re-directed attention to heat pumps as an alternative method of heat transfer.

The acceptance and reliability of residential and commercial air-to-air heat pumps for space heating has grown considerably, because technological advancements have occurred to eliminate the technical problems which have impeded the performance of such pumps, especially for low-ambient operation.

Industrial uses for water-to-water heat pumps present many potential applications for process heat requirements in addition to space heating. They have in the past been uneconomical due to the relatively low cost of other fuels compared to electricity.

The technology and equipment for higher-temperature (140 to 220°F) heat pumps is already in existence and is being demonstrated in many parts of North America. Since 1975, low-temperature waste heat sources, such as cooling tower systems, have been used in conjunction with heat pumps for hot water production and space heating. These same concepts can be applied to lower-temperature sources to amplify the temperature to a usable level or increase the amount of energy that can be usefully extracted from a limited resource.

Keywords: Equipment, Maintenance, Heat pumps, Templifier, Heating, Energy conservation.

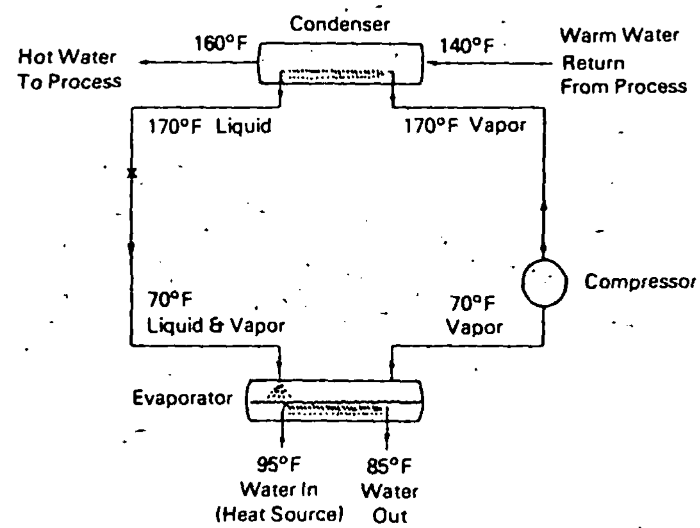

FIGURE 1. Templifier schematic diagram: 95°F heat source temperature; 160°F hot water delivered.

The Industrial Templifier™

Recent developments by Westinghouse Electric Corporation in the area of high-temperature heat pumps offer viable alternatives to the use of fossil fuels by providing economical heat recovery and amplification from low-grade waste effluents in the 60° to 120°F range.

The Templifier™ (short for *temperature-amplifier*) utilizes a non-reversible heat pump principle and works at higher temperature levels, incorporating larger compressors and different refrigerants than are currently used in residential/commercial air-to-air heat pumps.

Available refrigerants for use in the Templifier limit the maximum delivery temperature to about 230°F.

Cycles and Efficiencies

By recovering energy in the available resource and amplifying the temperature by means of the compression cycle, useful heat can be delivered into a process fluid.

For example, a Templifier extracts three units of heat from a waste heat source, adds one unit of electric power through the compressor to accomplish the amplifying and delivers four units of useful heat output.

The coefficient of performance (C.O.P.) in this case would be:

$$\frac{\text{4 units of useful energy OUT}}{\text{1 unit of purchased energy IN}} = \text{4 C.O.P.}$$

Figure 1 shows the cycle diagram with a 95°F source entering the Templifier evaporator. Heat from this source is absorbed by the unit's working fluid vapour, which is then increased both in temperature and pressure by the compressor.

The high-temperature working fluid is then passed to the unit condenser, where the heat is transferred to the process stream. The condensed working fluid is expanded back to the evaporator to complete the cycle.

A typical C.O.P. of the cycle operating at these temperatures is about 4.5.

Figure 2 shows the two-stage increases of compressor configuration normally required for over 85°F, between the source water and delivery hot water temperatures.

Figure 3 shows the achievable delivery temperature curves based on cooling the inlet source temperature 10°F. The vertical scale shows the expected C.O.P.s, ranging from 3 to 6.

The normal temperature amplification range is about 85°F (delivery temperature minus leaving source temperature), which would require a single-stage compressor. Temperature increases of more than 85°F would require the use of a two-compressor configuration, as shown in Figure 2.

Application and System Considerations

For industrial uses the applications are extremely varied, but there are a number of basic considerations to contend with, as follows:

1. Obviously, we need a source of waste heat in liquid form- the higher the temperature the better.
2. A simultaneous need for heat in fluid form must also be met, unless thermal storage can be provided at either end.
3. Compatibility of the various source fluids with shell and tube-type heat exchangers, as used with the Templifier, is necessary.
4. Utilization of some primary direct heat exchangers would be necessary should the source temperature level be higher than that of the fluid to be heated.
5. For economic reasons, it is preferred to have as many operational hours per year as possible.

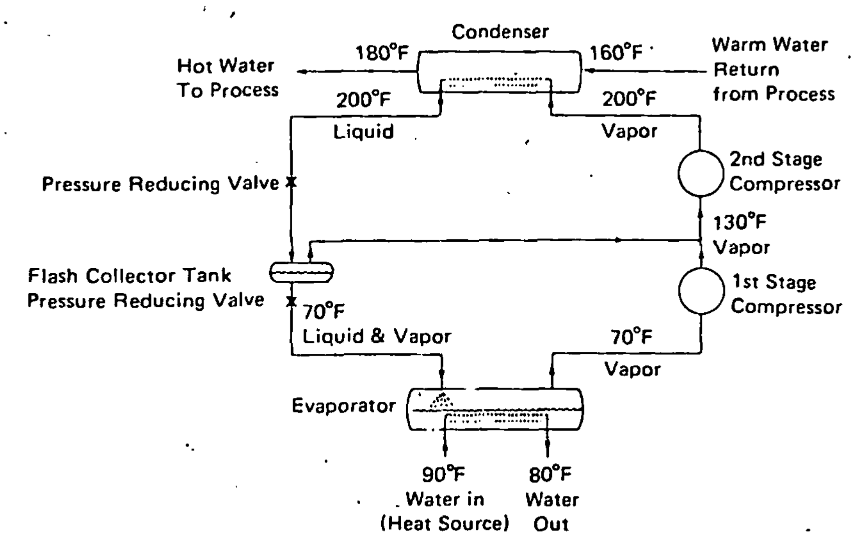

FIGURE 2. Templifier schematic diagram—two-stage compression: 90° heat source temperature; 180°F hot water delivered.

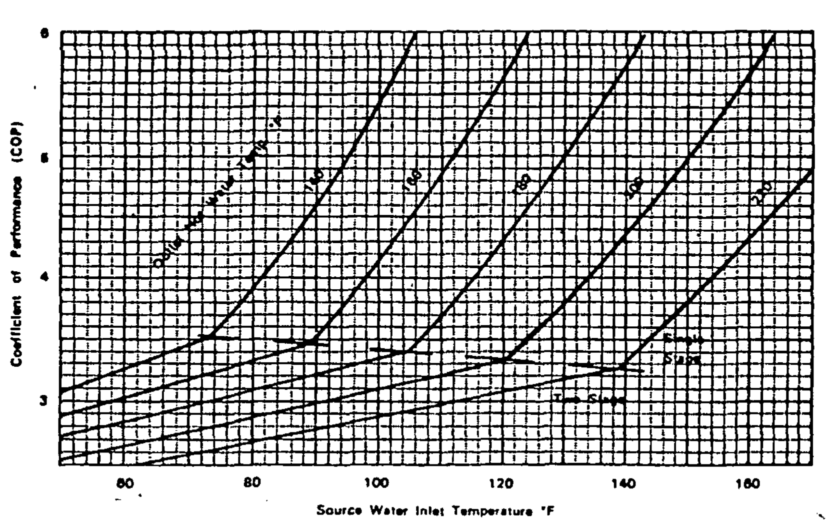

FIGURE 3. Achievable delivery temperature curves.

Preliminary Economic Considerations

A typical example might be considered here wherein a heating load could be represented by boiler feed make-up water for a 125,000-lb/hr boiler operating for 8700 hrs/year.

Let us assume that a 40 per cent make-up is required, which would represent a make-up flow of 100 gpm (U.S.). The available heat source is a waste stream or body of water at 60°F in plentiful supply, and the make-up water is entering at 40°F and is heated to approximately 110°F. Comparing the operating costs of oil versus the electric Templifier to illustrate a preliminary economic evaluation, and based on providing this 3.5 million Bty/hr capacity, it would appear as follows:

Should No. 6 oil (180,000 Btu/imp. gal.) be used, priced at \$0.40/Imp. gal. with a conversion system efficiency of 0.75:

Oil costs =

$$\frac{\$0.40 \times 3.5 \times 10^6 \text{ Btu/hr}}{180{,}000 \text{ (Btu/gal.)} \times 0.75 \text{(Eff.)}} = 8700 \text{ hrs} = \$90{,}200/\text{yr.}$$

For the Templifier, operating at a C.O.P. of 5.33 (Fig, 3), with power available at \$0.015/KWH:

Electricity costs =

$$\frac{\$0.015 \times 3.5 \times 10^6 \text{ Btu/hr}}{5.33 \text{ C.P.O.} \times 3412 \text{ Btu/KW}} = \$25{,}200/\text{yr.}$$

This shows a potential savings of \$65,000 per year. With an estimated installed cost of \$120.000, a simple (cost/savings) payback of 1.85 years in calculated.

From this preliminary evaluation, assuming that the potential falls within the payback parameters established by the user (normally the input data would be refined for specific selection and performance), a detailed financial analysis could be prepared to incorporate cost of capital, maintenance, fuel cost escalation, etc., to establish the return on investment over any time period.

Conclusion

Although some applications appear unattractive for short-term industrial investment, however, with the current fuel escalation rates and potential shortages now appearing, the electric-driven heat pump offers economical alternatives which should be considered.

Perhaps one of the current opportunities is the conservation aspect, considering that the displacement of oil and gas is mutually beneficial to all.

DIST. 6 MEETING ON WESTERN CANADIAN COAL—VANCOUVER—FEB. 14-15

Appendix A - Field Operation

Five orthogonal component, surface EM field measurements (E_x, E_y, H_x, H_y, H_z) were made of the micropulsation fields at each site in the overall frequency range of approximately 0.002 to 100 Hz. This range was covered by five overlapping bands as described in Table B-1.

Figure A-1 shows the field sensor configuration used. The positive x axis is directed to magnetic north, in a right-hand coordinate system. The E-field sensors are electrode lines using 100 square inch lead electrodes with a usual spacing of 600 feet. The H-field sensors are Geotronics induction magnetometers - model MTC-4SS for H_x and H_y, and Model MTC-6SS for H_z.

The instrument van contains the recording system of Geotronics manufacture, consisting of the MTE-4 three-channel E-field preamplifier, the MTH-4 three-channel H-field preamplifier, the MTC-2 calibrator, the MTF-16 filter-post amplifier, and the MTDR-2 digital recorder. A 6-channel Brush chart recorder is used for field monitoring of the signals.

A five-man crew is used, consisting of the crew chief and instrument man, alternate instrument man, and a three-man site layout team including a surveyor.

Proper field technique, which is of extreme importance in MT recording, has been developed by Geotronics personnel through 15 years of MT experience and is stressed throughout the survey. System noise and data quality checks are made routinely. All sensors are buried about 12 inches or more deep and all cables buried or weighted to reduce wind noise and improve thermal stability. While one site is being recorded, an alternate set of sensors is installed at the next site, and an adequate time (a few hours) is allowed for stabilization, including thermal and magnetic stabilization of the magnetometers and contact potential stabilization of the electrodes.

Field tapes are sent back to Geotronics daily (when conditions permit) so that preliminary analysis can be done to assess signal quality while the field crew is still in the survey area.

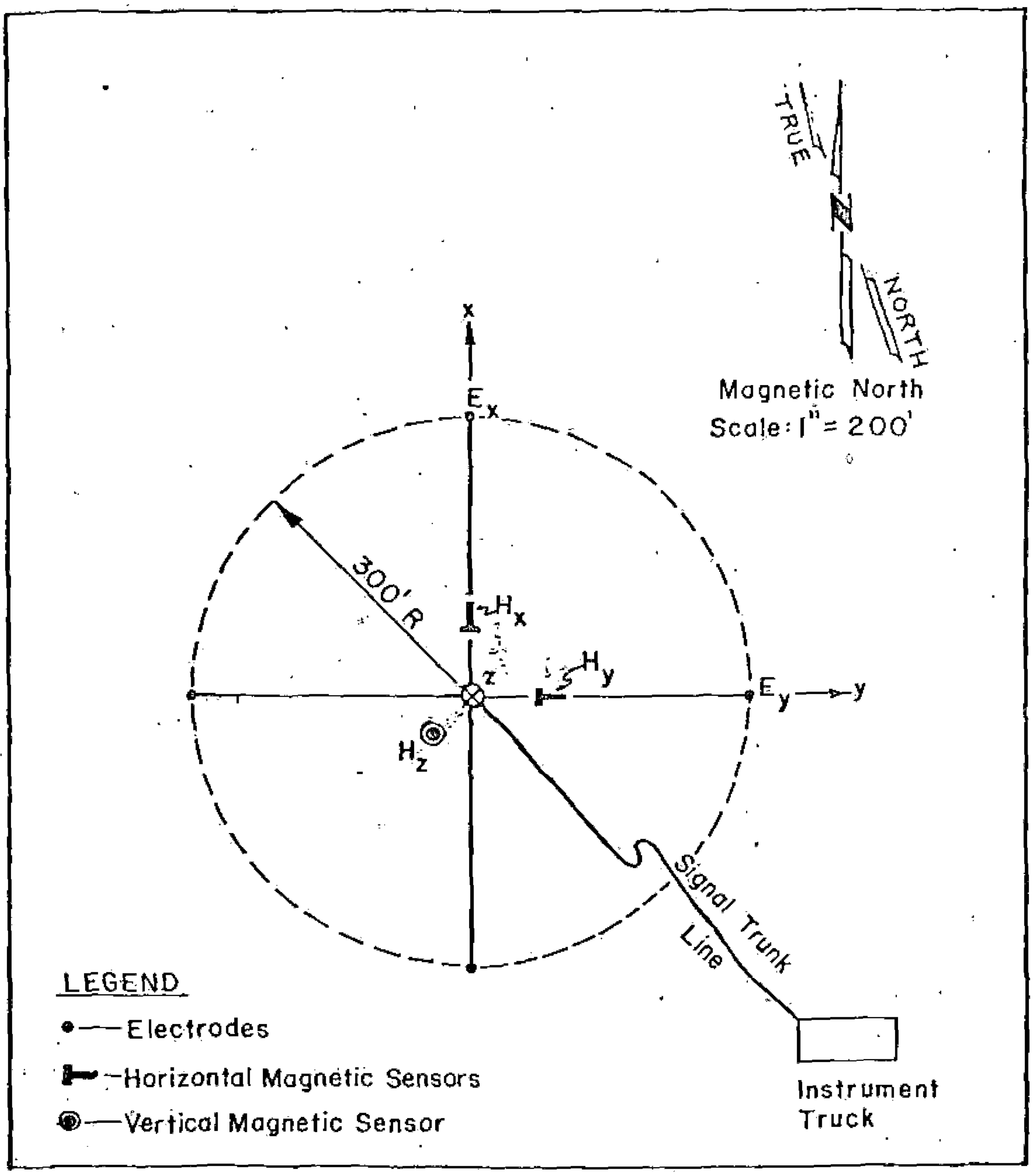

FIGURE #1. Magneto-Telluric Field Sensor Layout.

Appendix B - Data Processing Procedure

Computer processing is done on the Control Data Corporation Cybernet System. The Houston based CDC 6600 is used and accessed through the CDC-Austin 200 series user terminal. Field tapes are sent to Houston and stored in the CDC tape library in read-only mode for the duration of the survey and analysis.

The initial processing is done by program MAGTAN2, which performs a tensor MT analysis. A brief description of the program functions and output results is given in Appendix C. The frequency domain results used in the interpretation of this survey are:

(1) Rotated apparent resistivity and phase functions (RTE and RTM and related phase functions) for E-parallel to strike and E-perpendicular to strike respectively.

(2) Rotation angle (A(YZ)) for the apparent "dip-axis" direction determined from H_z, the vertical magnetic field, and is the direction of maximum gradient.

(3) Rotation angle (A(Z)) for maximum or minimum impedance.

(4) Three-dimensionality indices (ALPHA and BETA) which are the "skew" and "ellipticity" of the impedance tensor. Zero value for both of these quantities constitutes the necessary and sifficient condition for two-dimensionality.

The frequency bands used in the analysis are given in Table B-1, which includes the sampling parameters and the frequency range of results used for each band. The upper limit on the frequency range used is near the alias filter cut-off frequency, which is set to approximately half the Nyquist frequency. The lower three frequency points of the analysis results are omitted to avoid truncation aliasing error that is apt to be present. The analysis frequency bands overlap for redundancy.

Strip chart records and field logs are checked to select the best data recording runs for analysis. Initially, one run of each band for each site is processed and the results checked for several acceptance criteria. Additional runs are processed where needed to produce the best definition of the computed functions. Finally, all runs of the frequency domain results to be used are plotted for use in the subsequent interpretation. Averaged and smoothed functions are produced from the raw results for use in modeling and other interpretation. All data is corrected for local magnetic declination so that all subsequent results can be presented in geographic coordinates.

One-dimensional models are produced from the RTE and phase functions at each site using program INVERT, which analytically produces a continuous smoothed function of intrinsic resistivity vs. depth. These 1D models are correlated or contoured to produce laterally and vertically smoothed versions of the vertical cross-sections along the survey traverses.

The 1D models are considered as estimates of the resistivity-depth, vertical profile under a given site. The 1D inversion of the RTE function produces the best estimate of the 1D vertical profile, but it must be kept in mind, when interpreting the model, that any neighboring lateral variations in the conductivity structure have some degree of influence on the profile, depending upon the distance to and magnitude of the anomaly. Normally, the influence produces a lateral smoothing effect on the cross section. Consequently, it must be considered that a change in any direction in the structure may, in reality, be more abrupt than reflected in the interpreted cross section. When a low degree of two- and three-dimensionality is indicated in the MT results the lateral structural variations (electrical parameters) are usually gradual enough to yield a reasonably faithful interpreted cross section.

Finally, a study is made to correlate the two- and three-dimensional properties of some of the computed MT results with the interpreted geoelectric cross sections. This includes the apparent anisotropy evidenced in the RTE and RTM functions, the rotation angles, A(YZ), and the 3D indicators ALPHA and BETA.

It is convenient to define an anisotropy factor as

$$AF(f) = RTM/RTE \qquad (B\text{-}1)$$

where f is frequency. Let $AF'(f)$ be the first derivative of AF with respect to f. For one-dimensional results $AF(f) = 1$ and $AF'(f) = 0$ for all f. For frequencies where a lateral anomaly (or apparent anisotropy) is sensed, the RTE and RTM functions separate and $AF(f) \neq 1$ and $AF'(f) \neq 0$. It can be shown that the conductive or resistive nature of the anomaly is indicated by the polarity of $AF'(f)$ as follows:

for $AF'(f) < 0$, anomaly is conductive;
$AF'(f) > 0$, anomaly is resistive.

The 3D indicators (ALPHA and BETA) serve to indicate the presence of three-dimensionality in the impedance tensor at a given frequency, and they also serve to help classify the anomaly type. The condition

$$\text{ALPHA} = 0$$
$$\underline{\text{and}} \quad \text{BETA} = 0 \qquad (B\text{-}2)$$

is a necessary and sufficient condition for two-dimensionality (or one-dimensionality). Nonzero value for either index necessarily indicates three-dimensionality is present. The anomalies causing the three-dimensionality can be effectively classified in terms of two or more two-dimensional anomalies that are either (1) coupled - meaning that the presence of one anomaly modifies the effects of another; or (2) uncoupled - meaning that the effects of the two or more anomalies are seen independently in linear superposition. The condition ALPHA $\neq$ 0 indicates coupled effects, suggesting, for example, that a shallow anomaly is distorting the effects of a deeper anomaly having different principal axes. The conditions ALPHA = 0, BETA $\neq$ 0, indicates uncoupled effects, suggesting anomalies that might be displaced laterally in different directions from the measuring site.

Table B-1 - Recording Frequency Bands

Band	Post Filter (Hz)	Sampling Rate (Hz)	Number Samples	Frequency Range Used (Hz)	No. Runs Recorded (Nominal)
B6	10-256	1000	4096	2.08-256	2-4
B5	1-25	100	4096	0.208-25.6	4
B4	.1-5	20	4096	0.0415-5.12	4
B3	.01-.5	2	4096	0.00415-0.512	2
B2	.002-.125	.5	2048	0.00208-0.128	1

Appendix C - Computer Programs

I. MAGTAN2 - produces the tensor impedance analysis results in the frequency domain for use in the subsequent modeling and interpretation. The binary field tape is unpacked. Site parameters and system parameters are taken from header information on selected tape files and the corresponding data is processed to produce the rotated impedance tensor results and related quantities, including data quality indices. One or more of a number of optional outputs is produced on selected output media, including line printer and magnetic tape.

The program accepts as measured input data the total E and H field time domain signals in 5 components in a right-hand, rectangular coordinate system, with the + Z-axis vertically downward.

The basic relationships computed are:

A. Impedance, defined by

$$[E] = [Z][H],$$

which relates the horizontal E and H fields.

B. Vertical H relations, defined by

$$\text{a) } [H_z] = [Y_z][E]$$

and

$$\text{b) } [H_z] = [K_z][H]$$

which relate H_z to the horizontal fields, where the positive z-axis is vertically downward.

C. Rotation angles, defined for a given tensor as the angle to the principal axes of the tensor. The angle computed in each case is the azimuth angle of the +x-axis. The rotation criteria in each case leave the x-axis directed along the tensor axis that is nearest the normal to the strike, termed herein as the "dip-axis". The computed rotation angles are:

a) A(Z): [Z] rotation for Z-max or Z-min.

b) A(YZ): $[Y_z]$ rotation to maximize Y_{zy}.

c) A(KZ): $[K_z]$ rotation to maximize K_{zx}.

D. 3D index parameters, skew (ALPHA) and ellipticity (BETA).

Reference 5 (Word, et al, 1970) should be consulted for a more detailed explanation of the analysis techniques and terminology.

The computed quantities are all in the frequency domain. The Z-max and Z-min elements of [Z] are converted to apparent resistivities RTM (E-perpendicular to strike) and RTE (E-parallel to strike) and output together with the corresponding impedance element phase functions.

II. INVERT - produces a one-dimensional (1D) inversion of an impedance function. The program inputs apparent resistivity and phase vs frequency and outputs the approximated intrinsic resistivity vs depth as a continuous function. The program employs two variations in the inversion algorithm to produce two alternate models referred to as AMPLITUDE INVERT (AI) and PHASE INVERT (PI). Both model functions represent smoothed versions of the actual 1D resistivity profile. The PI model is inherently more smoothed than the AI model. The AI model tends to show more fine structure and is more responsive to fine structure in the input function; consequently the AI function must be used with discretion as to whether the fine structure is meaningful information or noise. For both models the smoothing effect is essentially a depth proportional smoothing of the conductivity (inverse resistivity) function. Both models are more sensitive to conductive zones and will tend to underestimate the resistivity for electrically thin resistive zones.

III. OPTMOD - produces a one-dimensional N-layered model by least squares fitting the complex impedance functions for the model and the measured data, with respect to all model parameters, for up to N = 10 layers.

IV. LAYERPXY - produces the forward MT solution for a one-dimensional layered model and plots the model apparent resistivity and phase with the like measured functions for comparison. Results for permutations of a number of values for one or two model parameters can be produced to examine the effect of a parameter change.

Appendix D

MT Analysis Results -- Defining Equations and Glossary of Computed Quantities

I. MT Model and basic relationships

The total electric and magnetic fields [E] and [H] in the frequency (F) domain at point -0- on the earth surface are related by

$$[E] = [Z]\,[H] \qquad \text{(I-1)}$$

$$[H] = [Y]\,[H] \qquad \text{(I-2)}$$

(excluding F=0), where [E] and [H] are column vectors and [Z] and [Y] are dyadic tensors representing the surface impedance and admittance respectively. [Z] and [Y] are functions of frequency, the field source and the earth parameters.

Coordinate System - (see Fig. I-1)

Standard right hand rectangular coordinate system (X, Y, Z - axes) with +Z - down (vertical axis) with the origin at point -0-. The X-axis is rotated clockwise (looking in +Z direction) by an angle -A- from the reference axes XR and YR (normally north and east, respectively). In the rotated coordinate system, all fields and computed tensor quantities are functions of the rotation angle -A-.

Model ---

$Z \geq 0$ - semi-infinite conductive half space (solid earth) with generally 3-D in distribution of properties.

$Z < 0$ - free space

Field source ---

EM plane wave propagating in +Z-direction (down) and incident on Z = 0 surface. Any polarization is allowable except at least some degree of random polarization is required by the computation process. [Z] and [Y] are independent of plane wave source conditions.

Field Relations in Rectangular Coordinate System ---

For the (X, Y, Z - axes) Equation (I-1) and (I-2) become

$$EX(A) = ZXX(A)\,HX(A) + ZXY(A)\,HY(A) \qquad (I\text{-}3)$$

$$EY(A) = ZYX(A)\,HX(A) + ZYY(A)\,HY(A) \qquad (I\text{-}4)$$

$$HX(A) = YXX(A)\,EX(A) + YXY(A)\,EY(A) \qquad (I\text{-}5)$$

$$HY(A) = YYX(A)\,EX(A) + YYY(A)\,EY(A) \qquad (I\text{-}6)$$

$$HZ(A) = YZX(A)\,EX(A) + YZY(A)\,EY(A) \qquad (I\text{-}7)$$

Another relationship used is obtained by substituting (I-3) and (I-4) into (I-7) to get

$$HZ(A) = KZX(A)\,HX(A) + KZY(A)\,HY(A) \qquad \text{(I-8)}$$

Units used - (MKS)

[E] - mv/km

[H] - gamma

F - Hz

A - degrees

II. Rotated Quantities

Define:

$$Z1 = ZXY - ZYX \qquad \text{(II-1)}$$

$$Z2 = ZXX + ZYY \qquad \text{(II-2)}$$

$$Z3 = ZXY + ZYX \qquad \text{(II-3)}$$

$$Z4 = ZXX - ZYY \qquad \text{(II-4)}$$

A. Special values of the rotation angle -A- for the principal axes of the tensor functions defined in Section I

$$A(ZMX): \left|Z3(A(ZMX))\right| = \left|Z3(A)\right|_{mx} \qquad \text{(II-5)}$$

$$A(KZ): \left|KZX(A(KZ))\right| = \left|KZX(A)\right|_{mx} \qquad \text{(II-6)}$$

$$A(YZ): \left|YZY(A(YZ))\right| = \left|YZY(A)\right|_{mx} \qquad \text{(II-7)}$$

$$A(Z) = \begin{cases} A(ZMX), & (A(YZ)-45^{\circ}) \leq A(ZMX) \leq (A(YZ)+45^{\circ}) \\ A(ZMX) \pm 90^{\circ}, & \text{otherwise} \end{cases} \qquad \text{(II-8)}$$

B. Rotated tensor components for principal axes.

$ZTE = ZYX(A(Z)) = |ZTE| \underline{/PTE}$ (II-9)

$ZTM = ZXY(A(Z)) = |ZTM| \underline{/PTM}$ (II-10)

$RTE = (0.2/F) \; |ZTE|^2$ (ohm-meters) (II-11)

$RTM = (0.2/F) \; |ZTM|^2$ (ohm-meters) (II-12)

$KZTE = KZX(A(KZ))$, $(HZ/\ H \perp \text{strike})$ (II-13)

C. 3-D indices (skew and ellipticity)

$ALPHA = |Z2(A(ZMX))/Z1(A(ZMX))|$ (II-14)

$BETA = |Z4(A(ZMX))/Z3(A(ZMX))|$ (II-15)

III. Notes and Glossary of Terms

A. Notes

1) Principal values of the rotation angle -A- for a given tensor function are indicated by a parenthetical suffix on A.

2) A "TE" or "TM" suffix is used on some variable names to indicate transverse electric (E parallel to strike) or transverse magnetic (H parallel to strike) components.

3) Refer to sections I and II for mathematical definitions of the terms described herein.

4) The variable names and symbols used in sections I, II, & III correspond to the notation used in the MAGTAN2 analysis program output.

B. Glossary

1) Dip axis - a straight line in the Z=0 plane, passing through the measuring point and <u>normal</u> to the apparent strike direction.

2) A(ZMX) - principal rotation angle for the [Z] tensor, placing the X-axis in the maximum impedance direction.

3) A(KZ) - principal rotation angle for the [KZ] tensor, such that HZ is most coherent with HX. X-axis is an estimate of the dip-axis.

4) A(YZ) - principal rotation angle for the [YZ] tensor, such that HZ is most coherent with EY. X-axis is an estimate of the dip-axis.

5) A(Z) - principal rotation angle for the [Z] tensor, but adjusted by $\pm 90^{o}$ such that the X-axis angle is nearer A(YZ), the dip-axis angle. Either X-axis or Y-axis is in max impedance direction.

6) ZTE - principal component of rotated [Z] tensor for E parallel to strike and H perpendicular to strike.

7) ZTM - principal component of rotated [Z] tensor for E perpendicular to strike and H parallel to strike.

8) RTE - apparent resistivity for ZTE.

9) RTM - apparent resistivity for ZTM.

10) PTE - phase of ZTE.

11) PTM - phase of ZTM.

12) KZTE - principal component of rotated [KZ] tensor for x-axis aligned with dip-axis (equal to HZ/H⊥ strike).

13) ALPHA - skew of [Z] tensor. Ratio of magnitudes of phasor positions of the centers of the elliptical loci with rotation angle -A- for ZXX (numerator) and ZXY (denom.)

14) BETA - ellipticity of [Z] tensor. Ratio of minor to major axes of rotation angle loci ellipse.

Cost of study covered

Geothermal resource program lauded

By DEBORAH FRAZIER
News Staff

GLENWOOD SPRINGS — A Department of Energy program to evaluate the nation's geothermal resources has found enough potential in each state studied thus far to more than pay for the investment in the study, the program manager said Tuesday.

Margaret Widmayer, geothermal section manager for the State Coupled Resource Assessment Program, said reports made by state teams here this week indicate the West is richer in geothermal energy than anticipated, and that research also has found unexpected potential in Kansas and Nebraska.

"It is a highly successful program in that each of the states we have gone into has enough of a resource to warrant the amount of money we put in," said Widmayer. "We have not found a state yet that didn't have a good resource."

Since the assessment program began in 1977, the DOE has spent between $150,000 and $250,000 annually in each participating state and, in addition, each state has provided 15 percent or more of the program's total budget, she said.

Widmayer warned, however, that this could be the last year for the program, depending on the Reagan administration's budget priorities for the DOE. But she noted the program was designed to provide resource assessment and to leave the application to industry, which is a philosophy Reagan has espoused.

She said eliminating the program in Colorado and some other Western states, where the research is nearly completed, would have less impact than in the East where assessments are just getting started.

Richard Pearl of the Colorado Geological Survey, which has contracted with the DOE to assess the state's geothermal resources, said 58 geothermals have been identified and that about two-thirds have commercial potential. Data accumulated since 1975 indicate there are enough geothermals in Colorado to heat about 16,000 homes or about 27 communities, Pearl said.

For example, he said, geothermal energy could provide heat for most of Glenwood Springs. The city was selected for this week's gathering of state assessment teams because of its hot springs, a surface manifestation of a geothermal which provides the city with a year-round tourist attraction.

But most geothermals in the West are not that easily detected, and the assessment teams must use geochemical, geophysical and geological data in their search, Widmayer said. Assessment teams in states with oil and gas development have been able to use temperature information obtained from the energy companies' research and from on-site monitoring of existing wells, she said.

A geothermal is naturally heated underground water resulting from volcanic activity or natural decay of radioactive material. Geothermals are more accessible in the West because the earth's crust is thinner here and less drilling is required, Widmayer said. ?

Under the DOE assessment program, Widmayer's office contracts with individual states for the research. Thirty states have assessment contracts, and her office is negotiating with the remaining states, she said.

Widmayer added that the goals of the DOE program are to assess the resources and to attract private investment to develop geothermals. The program is farthest along in Colorado, Wyoming, New Mexico, Montana, Idaho, Utah and Nevada and some practical applications have already resulted, she said.

As examples of buildings that will be heated with geothermals, she cited the state prison in Utah, a hospital in Truth or Consequences, N.M., and municipal buildings in Pagosa Springs.

Widmayer said another goal of the project is to develop geothermal expertise in each state that would be available to assist with commercial applications of the technology.

She said most geothermals found in the West lack sufficient water volume or temperature to generate power, but that most are suitable for supplemental uses. A plant in South Dakota has tapped a geothermal to dry grain, and several fish farms in Idaho are using geothermal water to grow seafood, she said.

Results of the assessment may help companies locate sites for gasohol and waste-conversion plants near geothermals, which could provide a less expensive energy source than fossil fuel, Widmayer said.

Two products of the research program will be maps showing the geothermal resources in each state and technical reports providing the data compiled by each state assessment team, she said.

POST

G.R.I.P.S. COMMISSION

2628 MENDOCINO AVENUE, SANTA ROSA, CALIFORNIA 95401 (707) 527-2025

September 2, 1981

This letter is to inform you that as of October 30, 1981, the G.R.I.P.S. Commission office will be closed and staff will be terminated. Two staff members have already moved on and we anticipate that others will do so prior to October 30, 1981. If you try to reach us by telephone during the next two months and do not receive an answer, please try again.

We will be spending these last two months completing responsibilities under our current contracts with the Department of Energy and the State Energy Commission. We will also be negotiating arrangements for the placement of our Geothermal Environmental Data Base developed for us by the Sonoma State University Library, our Direct Use Geothermal Map System and other files and materials. As soon as arrangements have been made on these placements, we will put out another letter indicating where you can arrange to make use of those resources.

We have enjoyed the opportunity of working with those many people and organizations to whom this letter is addressed. We will look forward to continuing many of those relationships as we move on.

Bob

ROBERT F. VAN HORN
Executive Director

Paula

PAULA E. BLAYDES
Research Analyst

Geothermal Research, Information and Planning Services / A California Joint Powers Agency

Lake County
Mendocino County

Napa County
Sonoma County

LAST WORD

By David E. H. Jones

Here is an excellent example of how not *to say something in an important journal.*

Scientific knowledge depends crucially on clear, effective communication. Here is "Fifty Centuries of Right-handedness: The Historical Record," a research report written in a normal scientific manner by Stanley Coren and Clare Porac, published in *Science*, 198, 631 (1977), and—in italic type—a translation into clear, effective English by David E. H. Jones.

Original: It is common knowledge that contemporary man prefers to use his right hand when performing unimanual tasks; however, little evidence exists as to whether this has always been so.
Translation: Most people nowadays are right-handed.
To embark on such an investigation is theoretically important because it could possibly elucidate the adequacy of competing explanations of the etiology of hand preference.
If we knew whether this has always been so, it would help us to understand why.
Basically, there are two types of theories that attempt to explain the development of handedness in man. The first maintains that there are physiological predispositions, probably heritable in nature, which lead to the favoring of one hand over the other.
One theory is that handedness is innate and probably inherited;
This position is supported by reports of familial similarities in handedness patterns.
this is supported by its tendency to run in families.
The second type of theory suggests that social or environmental pressures (or both) lead to the high incidence of dextrality in man. This position is supported by human and animal work that has attempted to alter limb preferences through behavioral manipulations.
Another theory, supported by experiments in which people and animals have been coerced into changing their handedness, is that it arises from social or environmental pressures.
The social pressure position is summarized by Wile, who stated: "There arose not so much a decline in the hereditary presence of left-handedness but rather a suppression of it under the demand for adaptation to changing principles of social organization, preservation and advancement."
Wile supposes that inherited left-handedness was suppressed by the forces of social conformity.
Given these different viewpoints, one might be led to different predictions about the distribution of handedness if it were measured at different points along the historical continuum. The social pressure theory would predict an increase in the percentage of human dextrality with the development of more formalized societies with more complex patterns of tool use.
If handedness is socially determined, one might expect right-handedness to have increased over the centuries with the standardization of manual techniques.
In contrast, the physiological theory, which views handedness as being independent of these influences, should presume a relatively constant distribution of manual preference regardless of historical period measured.
But if it is innate and inherited, the proportions of right- and left-handers should have been constant throughout history.
Unfortunately, these predictions are difficult to test since written references to the distribution of lateral preferences are rare.
Unhappily, written historical references to handedness are rare.
Perhaps the earliest quantitative account of handedness appears in the Bible, Judges 20: 15-16, where 700 left-handed or ambidextrous men were counted against 26,000 right-handed individuals. Thus, this biblical population was 97 percent dextral.
The earliest account seems to be in the Bible (Judges 20: 15-16) where 700 left-handed or ambidextrous men were found among 26,000 right-handers. Thus, this biblical population was 97 percent right-handed.
However, unhappily, such written reports are too rare to be useful in systematic investigations of the history of handedness.
Such direct reports are too rare to provide much useful evidence.
There are, however, other archival sources which can be used to assess historical trends in the distribution of manual preference. Nearly all cultures have art forms that depict human beings engaged in various activities.
More common are works of art showing people using their hands.
To the extent that such artistic efforts are an attempt to describe reality, one might expect that such drawings and paintings would mimic the distribution of hand use which the artist actually observed. If so, then manifestations of lateral preference in works of art could serve as a record of the handedness within the culture which produced them.
If the artists were trying to be realistic, their works should reveal to us the pattern of handedness in their society.
Although this has been suggested before, no systematic studies of handedness over the broad range of eras and cultures using this data base have as yet been attempted.
This idea has been suggested before but has not hitherto been used to study handedness over many eras and cultures.

(Dr. Jones is available to undertake further translations of this type, but does not guarantee the compression ratio of 2.2:1 obtained in this excerpt.)

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Phillips Executive Sees Fast Geothermal Gain

By Peter Gillins
United Press International

Geothermal energy still isn't as cheap as Utah coal for producing electricity, but it is far less expensive than oil, says a scientist for Phillips Petroleum Co.

Phillips is developing naturally occurring steam energy at Roosevelt Hot Springs near Milford for commercial electricity production. The company is also exploring other possible geothermal sites in Nevada.

But the initial cost of developing steam energy has slowed negotiations with power companies that might build a generating plant at Milford, said Dr. William Berge, a geologist who heads Phillips' geothermal branch based in Salt Lake City.

"At this point we are trying to sell our steam," he said. "We are negotiating with Utah Power and Light Co. and four or five municipal power companies."

"For the first 120 megawatts, it's not going to be cheaper than UP&L's coal costs for power generation," said Berge. "But it is a lot cheaper than West Coast costs for oil and gas to generate electricity."

California may prove to be the best market for geothermal power, he said. Another possible market would be the Air Force, which is going to need considerable power for the proposed MX missile system, if it is deployed across Utah and Nevada.

Phillips has talked to the Air Force about the use of steam energy, but prefers to have a utility company develop the plant, Berge said.

In a few years, Berge added, the cost of geothermal power should be cheaper than coal. The price of coal will continue to go up as the cost of labor and transportation increases. But the cost of steam from the natural wells should remain nearly constant.

"With geothermal power, there are no underground mines to operate, no large labor force to be paid," he said. "It's also environmentally better than coal."

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Up & Down the Street

Utah Roses Goes Geothermal

By Robert H. Woody
Tribune Business Editor

If you think your gas bill is high, consider Utah Roses Inc., a firm that grows roses year-round in greenhouses at Sandy.


Mr. Woody

Their natural gas heating bill topped $100,000 during three months last winter, says C. Richard Wright, president.

But much of the problem may have been solved over the weekend when drillers hit hot water on a site 15 miles south.

The well flowed 190-degree water at the rate of 200 gallons a minutes, says Mr. Wright. And plans are under way to build a greenhouse at the site, close to the Utah State Prison.

Plan Sandy Test

At the same time, drillers were moving in equipment to drill another geothermal test hole at the Sandy greenhouses under a $450,000 grant from the U.S. Department of Energy.

The issue is simple, says Mr. Wright. A lot of greenhouses are going out of business if energy costs keep climbing.

Expectations are that drillers will have to go to 4,000 feet at the Sandy site. However, they reached the hot water at only 400 feet at Bluffdale, a few hundred yards from a well drilled earlier at the prison.

Owned by Brother

The Bluffdale site is owned by Ralph Wright, chairman of Utah Roses, and elder brother of C. Richard. Ralph will lease the site to Utah Roses.

Utah Roses will build a greenhouse of about 70,000-square-feet, for starters, says C. Richard, based upon initial estimates of well flow.

Ralph Wright, said that if all goes well, the firm will eventually build a million square feet of greenhouses at Bluffdale.

That compares with 250,000-square-feet at the Sandy facility, where 40 are employed in the growing and marketing of near $1 million worth of roses yearly.

As far as is known, this will be the first major application of geothermal energy in the state.

According to C. Richard, growers try to maintain a high (60 to 65) humidity environment with daytime temperatures of 75 to 80 degrees and nighttime temperatures of 60 to 65 degrees.

Passive Solar Aid

During winter, greenhouses get passive solar heating on clear days.

If the company had not developed geothermal sources, it would have to consider such alternatives as inflatable plastic envelopes over the roof areas or internal blankets drawn over the eves during the cold night hours.

Because of the ravages of weather the roof envelopes would have to be replaced yearly, he said.

Abandoning geothermal an option

By R. BEHNKE
The New Mexican Staff

An option to abandon plans for a 50 megawatt demonstration geothermal plant in the Jemez Mountains will be included in the final Environmental Impact Statement (EIS), a Department of Energy spokesman said Monday.

Bennie DiBona, the director of the Division of Geothermal Energy in the DOE, said the option not to build any geothermal-hydrothermal power plant in the Jemez Mountains would be submitted to the Assistant Secretaries for Energy Technology and the Environment.

Those officials will decide whether to continue with plans to build a 50 megawatt demonstration geothermal, electric producing plant in the Jemez Mountains.

The DOE has already awarded a $50 million contract to Union Oil Co. and Public Service Co. of New Mexico to build a 50 megawatt plant on the Baca location.

However, residents in the area, including several Pueblo Indian tribes, recently expressed concern over the environmental impact of producing more than the 50 megawatts of power.

Four-hundred megawatts, Union Oil spokesmen claim, is the potential of the area.

While residents admitted that a 50 megawatt plant might be within most environmental limits, they were concerned with the impact of a 400 megawatt operation.

Residents made the concern known three weeks ago during a hearing on the EIS in Albuquerque.

DiBona, a speaker at the opening of a conference at the Santa Fe Hilton Inn on geothermal energy, said until DOE stationed a man on the scene in New Mexico, there had been no discussion with local residents about their concerns on the subject of geothermal power.

Once an office was opened in Albuquerque, "we realized a serious concern," he said.

The two most pressing concerns, DiBona said, were Indian concerns over areas of religious significance and concerns over both the fresh and hot water table.

DiBona said the problem of Indian concern "is a tough one."

Other potential problems with subsidence and seismicity, the

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vibration of the earth, were cited by DiBona.

DiBona said if the Indians were only concerned about specific sites (of religious significance) "something could be done about it." However, if the Indian concern is a general one for the entire area then the problem would be much more difficult.

"We could guarantee protection for specific sites," he said.

He said meetings with the various pueblos would be conducted to determine if development of the geothermal potential of only specific areas or the entire area of the Jemez Mountains was a cause for concern among the Indians.

Several residents testified at the draft EIS hearing that increasing production of electricity from geothermal power from 50 to 400 megawatts would substantially increase the environmental impact.

They argued, apparently successfully, that the EIS should address the 400 megawatt potential because, if the 50 megawatt demonstration plant was a success the 400 megawatt potential would probably be developed.

DiBona said the criticism was accepted and the total impact of 400 megawatts, and associated production facilities, would be addressed in the final report.

During the draft EIS hearing in Albuquerque, residents of the area said road traffic, housing and other factors would be impacted much more if a decision was made to go ahead with developing a 400 megawatt power source than if the project was limited to the 50 megawatt demonstration plant.