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INTERIM GEOLOGIC REPORT

ON THE

GEOTHERMAL STEAM PROJECT

AT

MILFORD, UTAH

INTERIM REPORT ON MILFORD STEAM WELL PROJECT

by

William G. Kane, Consulting Geologist

The discovery of the new geothermic steam well on March 2, 1968 several miles North of Milford, Utah was one of the most significant developments that has taken place in this new field of scientific enterprise in the Rocky Mountain Region during the past year. Since the sensational results of drilling for this new energy source in the Salton Sea area of Southern California were so widely publicized during 1957 a broad new interest has come to this new earth science development. Many of the western states have made geologic studies and appraisals of the geothermal potentials within their borders, printed pamphlets and maps on the locations of prospective areas for exploration and revamped their regulations for giving drilling permits and exploitation concessions on their lands.

The Federal Government, through the Department of the Interior began to distribute circulars and maps to enlighten the public regarding these new important potential values in large segments of our public lands domain. The U.S. Geological Survey made an inventory of all the lands of the 13 western states and designated 1,051,000 acres of Federal lands in the five states of California, Nevada, Montana, Idaho and New Mexico as having "current potential values for geothermal resources" and on the basis of this report all of this land has been withdrawn from entry or sale, pending legislation by Congress for the development of geothermal energy. The U.S.G.S. inventory also noted that another 86.3 million acres in Arizona, Arkansas, California, Colorado, Idaho, Montana, New Mexico, Oregon, South Dakota, Washington and Utah should be classified as "prospectively valuable" for geothermal energy.

As of March 29, 1967 these "prospectively valuable" areas were not placed on a withdrawn status but they were said to be subject to continuing review by the U.S.G.S. specialists and some of these might be reclassified and be subject to withdrawal for sale or entry by order of the Bureau of Land Management. In January 1967 President Johnson requested Congress for legislation on this matter. The Congress had already passed a bill on it during 1966 but the President had vetoed it on the grounds "it did not contain adequate safeguards."

The new legislation requested by the President contains the following provisions:

1) Delete the clause which would have favored holders of existing oil or gas leases, mining claims or permits for future leasing.
2) Maximum lease to any one person of 10,240 acres in any one state
3) Royalty on steam "reasonably susceptible for sale or use" by lessee rather than on steam actually sold or utilized.
4) Provide specific authority for Secretary of Interior to renegotiate or readjust terms of lease at intervals prescribed by regulations.
5) A 60 year lease rather than a perpetual term.
6) If steam produced in commercial quantities, developer must begin production within 10 years rather than 15 or 20 years.
7) All leases would be offered on a competitive basis.
8) Lands administered by the Department of Interior or Department of Agriculture would be limited to only 2560 acres and be subject to special regulations.
9) All royalties would be not less than 10% of value of steam plus not less than 5% of all by-product values.

Copies of the State of Utah and Federal Government maps of Potential Geothermic Steam Areas are included herewith.

From the above indicated state and federal government proposals with respect to land acquisition, it will be seen that the amount of presently owned acreage is one of the critical aspects of any projected development in this field. So far as we know the only acreage that this project can regard as secure is the State lease on School Section 16, T27S R 9 W which is located one mile east of State Highway #257 about two miles North of Milford in Beaver County, Utah.

We are advised by Mr. Austin Smith of Salt Lake City that the application for this State lease in the names of Austin Smith, Louis Cooper and Dr. Eugene Davie has been approved subject to the presentation of a survey showing the location of a number of wells that are to be drilled on this tract. When we last visited the area Dr. Davie had a surveyor out there making these locations.

Dr. Davie reports that 8 or 10 mining claim denouncements have been made on federal lands located to the North and South of Section 16 but as will be noted from the above new federal land proposals, these will not be acceptable for geothermic steam rights. Although the lands having "prospective values" for such rights apparently have not yet been withdrawn from entry for this use, it is doubtful that under the present circumstances one could hope to make much progress in securing such federal claims until the Congress has passed some legislation setting forth the guidelines and specifications for such claims.

Apart from the probability that concessions cannot now be obtained on such federal lands, the proposed terms on which such concessions would be granted are most unrealistic and would put the prospective investor in such a project in a very unattractive situation to protect himself against competitors who might obtain claims on the adjoining lands to a new discovery.

In spite of all of these unfavorable factors, it is thought that the recent discovery near Milford is a very valuable asset because it is located along the eastern edge of the Western Desert Area described in Special Studies 14 of the Utah Geological & Mineralogical Survey of January 1966.

The broad Milford valley along which the Union Pacific Railroad runs West of the high snow-capped Tushar Mountain Range and the Pavant Range that extend up through the center of the State of Utah to Provo, Salt Lake and Ogden, is characterized by a number of areas where there are or have been significant hot springs occurrences. The Western Desert Area extending from Thermo through Minersville up the West flank of the Mineral Mountain East of Milford on up to the area of extinct volcanoes between Kanosh and Black Rock, appears to be one of the more important of these thermal zones since in most cases the steam coming from these is of volcanic or magmatic origin rather than tectonic, and may therefore be expected to be more dry and free from excessive salt content.

The springs near the Black Rock Mountain have precipitated a considerable amount of sulphur and siliceous material but they are not characterized by travertine deposits or other salts. The same is true of the Bailey Springs near the edge of the Mineral Mountain about 8 miles North of Milford. While it was not possible at this locality to find the exact outcrop of the springs in relation to the granite or porphyry of the mountain, it appeared probable that the hot springs had issued from the contact of the igneous rock of the mountain with some sedimentary rocks in the valley under the overburden or had come up through a fault along the mountain's edge in the igneous rock itself. The whole area at and around these springs for several hundreds of feet was covered by a reddish small pebble conglomerate that was composed mainly of disintegrated granite, prophyry and even some pieces of obsidian, or volcanic glass, that had been washed down from the higher places in the mountain. The North end of this valley between Bailey Springs and Black Rock Mountain has many lava flows right up against the West flank of the mountain.

The soil all over the discovery well area is an eroded surface of the same reddish pebble conglomerate as described above and over near the East side of Section 16 large boulders of monzonite prophyry were found. Along the East line of this section we found the quarter-corner and 150' North of here a tongue of igneous rock prophyry and gneiss extended about 1/4 mile West into its SE¼. From the close proximity of the edge of the mountains and the extension of igneous rock into Section 16 it is apparent that its East half will not have very much valley fill other than the detrital material from the disintegrated prophyry, granite and gneiss. This reddish conglomerate material is cemented by a siliceous matrix such as that described above in the Bailey Spring locality.

In the first well drilled on the top of the opalite ridge decomposed greenish granite cuttings were fround from 86' to 116' depth and this well is believed to have drilled 4' into the solid prophyry before it was lost. The fourth well drilled, the discovery well, had chloritic decomposed green granite cutting from 80' to 90' and other decomposed granite with hard opalitic beds in between down to 230'. While it is difficult to distinguish the cuttings of the conglomeratic granite detrital material from the solid granite it does seem likely that any well drilled between the opalite ridge and the mountain will find the solid granite or prophyry within several hundred feet depth and it may therefore be hard to get a well down here to 1000'. The shallow depths at which steam will be found in this area may preclude the higher temperatures and rock-pressures that might be found at greater depths. On the other hand when it is considered that the discovery well was 158° F at 240' depth whereas the normal pressure gradient is only 1.2° F per 100', this indicates unusually high heat. In the next 25' depth at 265' (T.D.) the temperature moved up from 150° to 178° at the well head.

In view of the fact that insufficient preparations had been made to handle the steam found in this well, a considerable amount of steam started seeping out at the surface about 70 feet South of the well when it was shut in. In order to protect the field from such steam seepage in the shallow beds, it was deemed necessary to have Halliburton come in and do a complete cement job on the well plugging all the formations from top to bottom. The picture included in this report is the only evidence remaining of this exciting and unexpected discovery.

It is believed that the next well that is drilled should have a rig that is capable of drilling several thousand feet and be prepared for high pressure. It is this writer's opinion that the next well should be located within a few hundred feet and East of the opalite ridge and that an effort be made to drill 1000' straight down and then attempt to whipstock the hole westward in an effort to get under the long lateral vent through which the great masses of opalite had exuded to form this ridge.

It is thought that this long outcrop of vertically standing opalite beds that formed in this vent is an unusual situation and a striking picture of it is included in this report. If indeed the steam that brought up this almost pure silicification phenomenon has plugged itself off beneath this ridge there could be a sizeable cavity down there holding a considerable reserve volume of superheated magmatic fluid or gaseous material that might flash into high pressure and high temperature steam when its pressure has been tapped and released. For this reason it is thought that the deeper we might get the new well before we get over under the opalite ridge, the better chance there would be of getting a big well.

Naturally the cost of drilling a deep well that would provide proper protection for the production that would be hoped for, would be expensive. We might conceivably duplicate the shallow well like the #4 well to 260' and provide it with better surface protection for $10,000 or less, but to drill a well that could go to two or three thousand feet with full protection for a big well with high temperature and pressure might cost $150,000.

The only example of an actually operating steam power generating project in U.S.A. is at the Geysers, located in Sonoma County, California about 100 miles North of San Francisco. Between 1955 and 1960 eleven wells were completed here producing over 1,000,000 lbs. of dry steam per hour at a pressure of 60 psi and temperature of 350° F. Pacific Gas and Electric opened its first power generating plant there in 1960, put in their second unit in 1963 for a combined output of 26,000 kwh, and were expected to have their third and fourth units on stream this year for a total of 81,000 kwh.

It is calculated that it takes about 20 lbs. per hour of dry steam to produce 1 kwh and the wells at Geyser will average about 5,000 lbs./hr. The cost of developing steam at Geyser ranges from $60 to $90 per foot of completed steam well including drilling, geology, roads, testing, well-head equipment, casing and administration, although the drilling itself could be contracted for up there for $10 to $14 per foot. Their cost of steam delivered to the power plant is 2.5 mills/kwh of electric energy delivered to the transmission line, but the overall cost including power generation has not been published.

It is reported that the cost of installing the generating plant at Lardarello, Italy was $113 per kwh and that the first plant (rebuilt) at Geysers cost $152 per kwh but, had a new generator been installed, it would have cost $192 per kwh. From a perusal of a considerable amount of data on the subject of costs of plants and cost of kwh generated from them, the following figures seem to be indicated for the various types of generating plants:

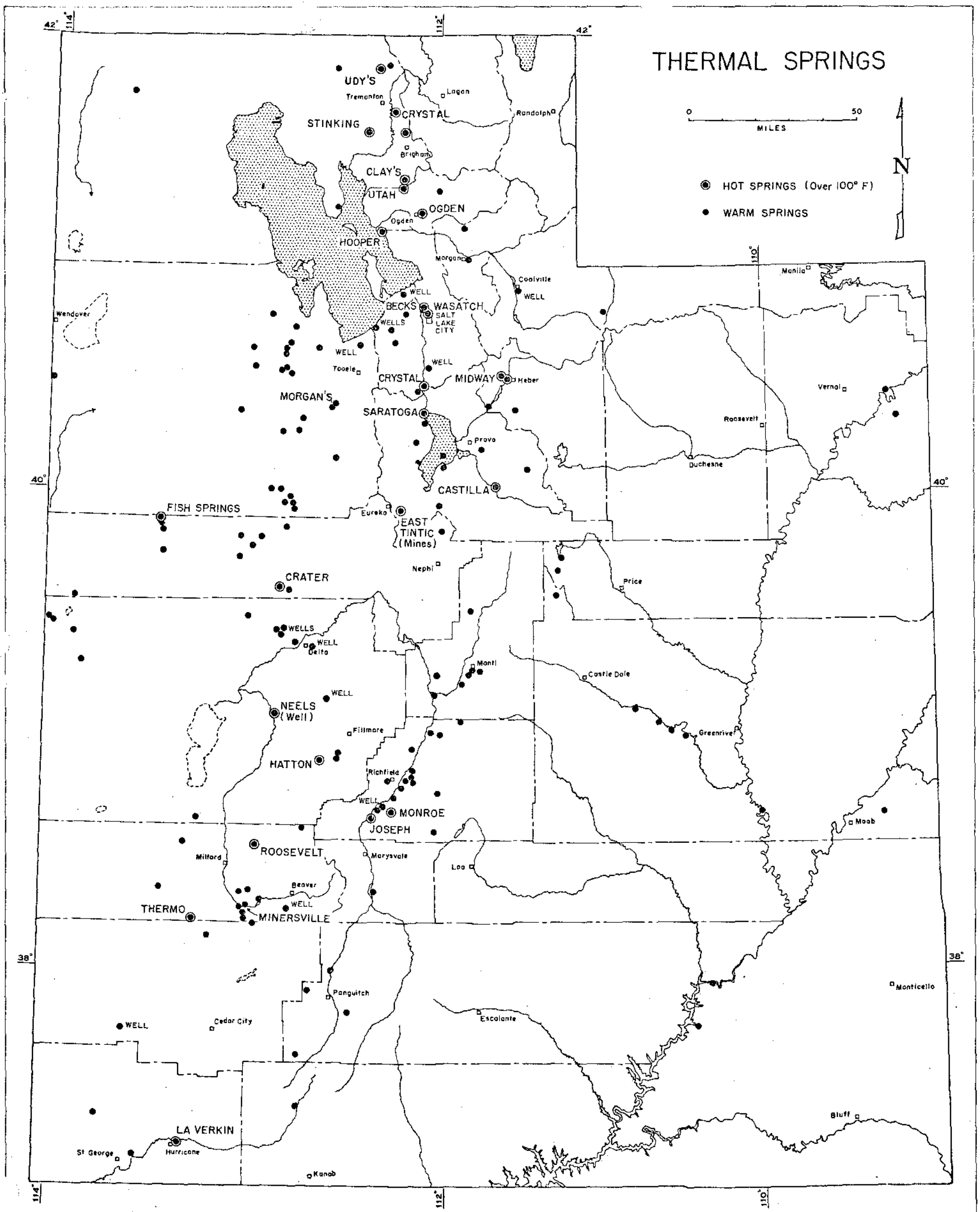
Types of Plant	Cost of Plant per KWH	Cost of power mills/Kwh
Geothermal Energy	\$63 - \$143	2-3
Thermoelectric	\$110 - \$125	4.6 - 7.74
Nuclear Energy		5.42 - 11.56
Hydroelectric		5 - 11.36

In view of the very unfavorable land factors in this situation at this time and taking into consideration the extreme difficulty that will be encountered in drilling through the opalite beds at the surface as well as the porphyry or gneiss that may be found at shallow depth, it is apparent that whoever undertakes to drill the exploratory well here must be well provided with a substantial amount of risk capital, some well experienced operating personnel and probably some capable administrative talent to be able to make the most of the government leasing arrangement that will be made available.

It does appear to this writer that the geologic relations here are quite different, much more challenging to deal with but perhaps excitingly more attractive than the localities that have been drilled in many other places where the indications were limited to hot-springs or mud-pots. The evidence here of some kind of a vent a half mile long that had exuded highly siliceous gases or solutions during a long time before it closed itself off with its own opalitic residue suggest the possibility, if not the probability of a really tremendous heat source beneath the surface in this particular area. It is most certainly a prospect that warrants drilling and if the right people, tools and financing can be assembled to do it it should be a most attractive speculative venture.

William G. Kane

May 15, 1968 — William G. Kane



THERMAL SPRINGS
0
50
MILES
N
HOT SPRINGS (Over 100° F)
WARM SPRINGS
42°
114°
112°
110°
40°
38°
UDY'S
Tremonton
CRYSTAL
Logan
Randolph
STINKING
Brigham
CLAY'S
UTAH
OGDEN
Ogden
HOOPER
Morgan
Coalville
WELL
Manila
Wendover
BECKS
WASATCH
SALT LAKE CITY
WELLS
WELL
Tooele
CRYSTAL
MIDWAY
Heber
MORGAN'S
SARATOGA
Vernal
Roosevelt
Provo
Duchesne
CASTILLA
FISH SPRINGS
Eureka
EAST TINTIC (Mines)
Nephi
CRATER
Price
WELLS
WELL
Delta
Manti
Castle Dale
NEELS (Well)
Fillmore
Greenriver
HATTON
Richfield
MONROE
JOSEPH
Moab
Milford
ROOSEVELT
Marysvale
Loa
Beaver
THERMO
MINERSVILLE
Panguitch
Monticello
Cedar City
Escalante
LA VERKIN
St George
Hurricane
Kanab
Bluff

Figure 2.

The Wasatch and western desert areas are perhaps the most significant, although geothermal prospects may exist in other areas as well.

The principal thermal areas considered here are coincident with zones of major faulting and crustal collapse near the eastern periphery of the Great Basin. This extensive collapsing occurred during the Late Tertiary and Quaternary, apparently as a result of the evacuation of large amounts of magma from within the crust. The magma was extruded in the form of fiery volcanic outbursts, including lava flows and nuées ardentes. It is presumed that the slow cooling of the volcanic material, both near the surface and at depth, coupled with continued volcanic activity up to recent time, accounts for the heat source supplying the thermal springs in many parts of Utah.

Wasatch Area

The Wasatch area includes the Wasatch Range and flanking valleys to east and west, extending from Idaho south to the Tintic mining district and Nephi. Thermal springs rise from concealed faults at a number of localities, mostly along the west side of the Wasatch Range. Warm and hot springs[1] occur in Ogden, Morgan, Heber, and Round Valleys on the backslope (east side) of the Wasatch Range; of these, Hot Pots at Midway, in Heber Valley, are the most interesting (Wheeler, 1875).

Some of the more important hot springs which occur in the fault zones along the west side of the Wasatch Range are, from north to south, Crystal Springs near Honeyville (north of Brigham City), Utah Hot Springs north of Ogden, and Beck's and Wasatch Springs near Salt Lake City. (See fig. 2.) These springs rise along the Wasatch fault zone, commonly near the apex of spurs or salients projecting westward from the main mountain range. For the most part, waters of springs issuing from fault zones along the west side of the Wasatch Range have relatively high chloride content and are rather remote from Tertiary or Quaternary volcanic rocks. The closest rocks, in many instances, are Paleozoic sedimentary units on the upthrown side of the faults. In all probability, waters rising in thermal springs along the west side of the Wasatch Range and in the adjoining valleys consist largely of recirculated meteoric water. High chloride content of waters in some springs suggests invasion by highly saliniferous waters associated with Great Salt Lake. The heat source for springs along the west side of the Wasatch Range is probably of tectonic origin, and it is doubtful that this source could provide a very great store of geothermal energy.

Waters at the Hot Pots near Midway, in Heber Valley, contain considerably less chloride than those on the west side of the Wasatch Range. (See analysis,

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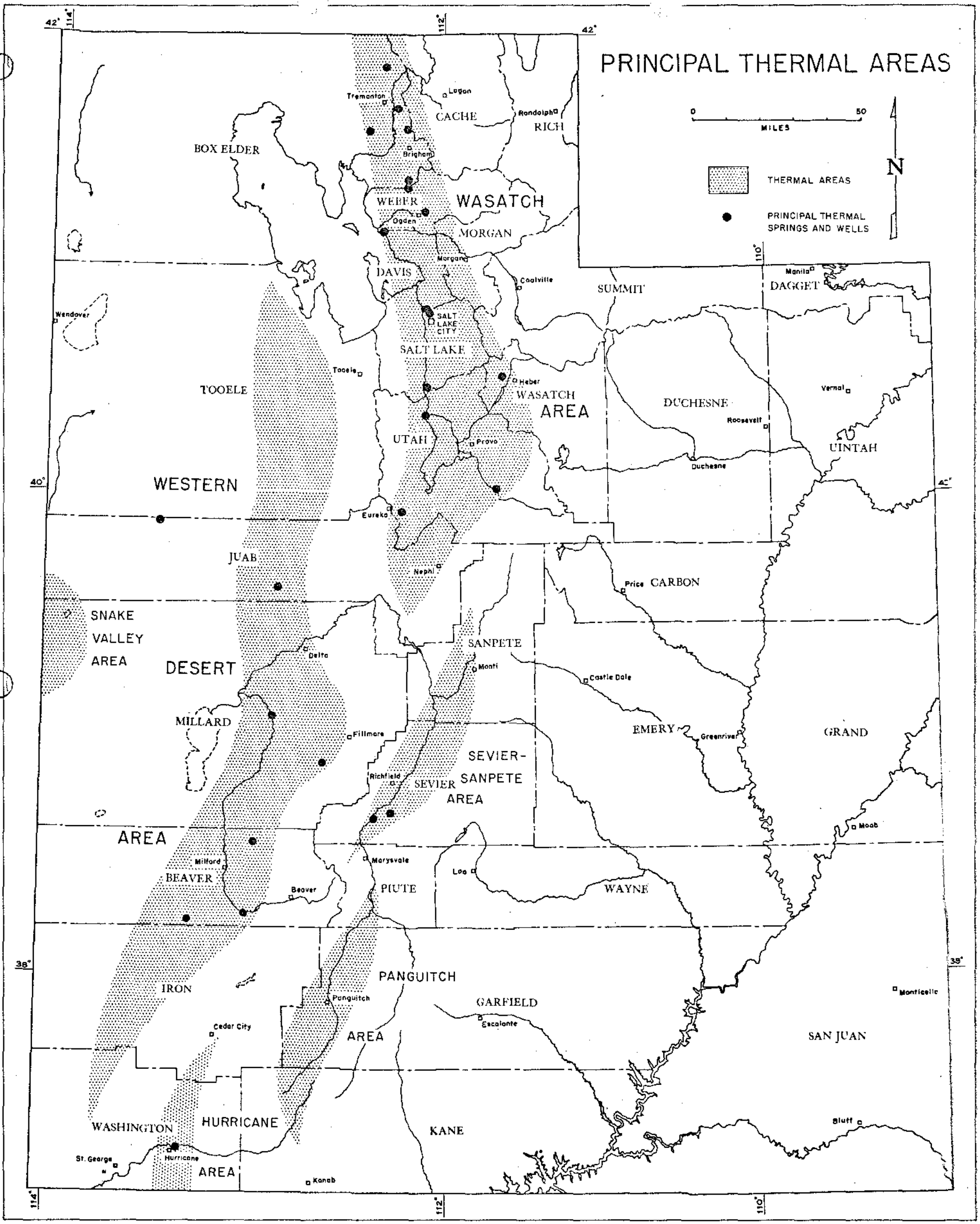
1. The principal localities of warm and hot springs are described in detail on pages 15 - 19. Chemical analyses of some springs are listed on pages 21 - 25.



PRINCIPAL THERMAL AREAS
0
50
MILES
N
THERMAL AREAS
PRINCIPAL THERMAL SPRINGS AND WELLS
42°
114°
112°
110°
40°
38°
39°
WESTERN
DESERT
AREA
WASATCH
AREA
SNAKE
VALLEY
AREA
SEVIER-
SANPETE
AREA
PANGUITCH
AREA
HURRICANE
AREA
BOX ELDER
CACHE
RICH
WEBER
MORGAN
DAVIS
SUMMIT
DAGGET
SALT LAKE
TOOELE
WASATCH
DUCHESNE
UINTAH
UTAH
JUAB
CARBON
SANPETE
MILLARD
EMERY
GRAND
SEVIER
BEAVER
PIUTE
WAYNE
IRON
GARFIELD
SAN JUAN
WASHINGTON
KANE
Tremonton
Logan
Randolph
Brigham
Ogden
Morgan
Coalville
Manila
Wendover
SALT LAKE CITY
Tooele
Heber
Vernal
Roosevelt
Provo
Duchesne
Eureka
Nephi
Price
Delta
Manti
Castle Dale
Fillmore
Greenriver
Richfield
Moab
Marysvale
Loa
Milford
Beaver
Panguitch
Monticello
Escalante
Cedar City
St. George
Hurricane
Kanab
Bluff

Figure 1.

"Volcanic" springs are generally considered to be more favorable than "tectonic" springs for geothermal power development. Heat generated by tectonic stresses rather than from magmatic sources could be expected to contain much less geothermal energy. Wilson (1964) states that true volcanic springs have a calcium to magnesium ratio very close to 4:1, whereas tectonic springs are much more variable, being either higher or lower. Methane gas is characteristic of tectonic springs, whereas the gas of volcanic springs is nearly pure carbon dioxide (CO_2). The deuterium content and the ratios of silica (SiO_2) to solids, bromine to chlorine, potassium to sodium, and lithium to sodium indicate whether or not the waters have received magmatic contributions. For further discussion the reader is referred to White (1957).

Areas where the chemical analyses of thermal waters vary markedly from place to place are not favorable for power development. Uniformity of chemical analyses over a considerable area suggests a sizeable reservoir source. If there are several centers of activity in a given thermal area, the center with the lowest sodium to potassium (Na/K) ratio would be fed most directly from the underground supply (Wilson, 1964).

No reliable methods have been established for calculation of steam reserves at a given field. A great variety of factors must be considered in estimating the reserves. Methods used to calculate the reserves of oil and gas fields are not applicable to steam fields.

LEASING PROCEDURE

Although there is no way that wells can be drilled for steam on federal lands due to conflicts with other interests, a bill is pending[1] before Congress to permit the leasing of federal lands for geothermal power. State and private lands may be drilled for steam by obtaining a well-drilling permit from the State Engineer's Office, and, in the case of state land, filing appropriate lease forms with the State Land Board.

THERMAL AREAS IN UTAH

Broadly speaking, thermal springs in Utah can be grouped into six areas which are roughly parallel or en echelon in nature and trend in general north-south or northeast-southwest directions. (See fig. 1.) The areas or belts of thermal springs have been arbitrarily named as follows:

1. Wasatch area
2. Western desert area
3. Sevier-Sanpete area
4. Panguitch area
5. Hurricane area
6. Snake Valley area

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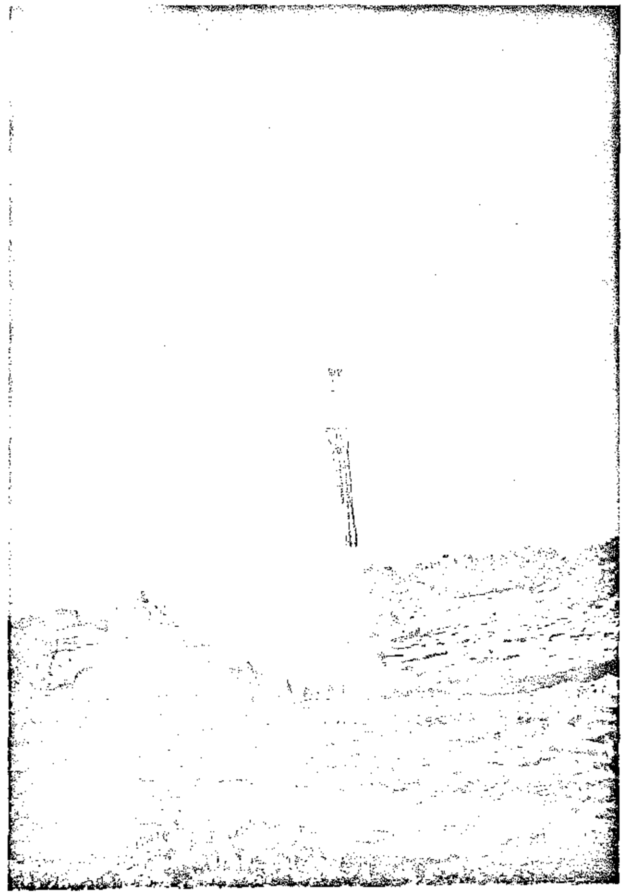
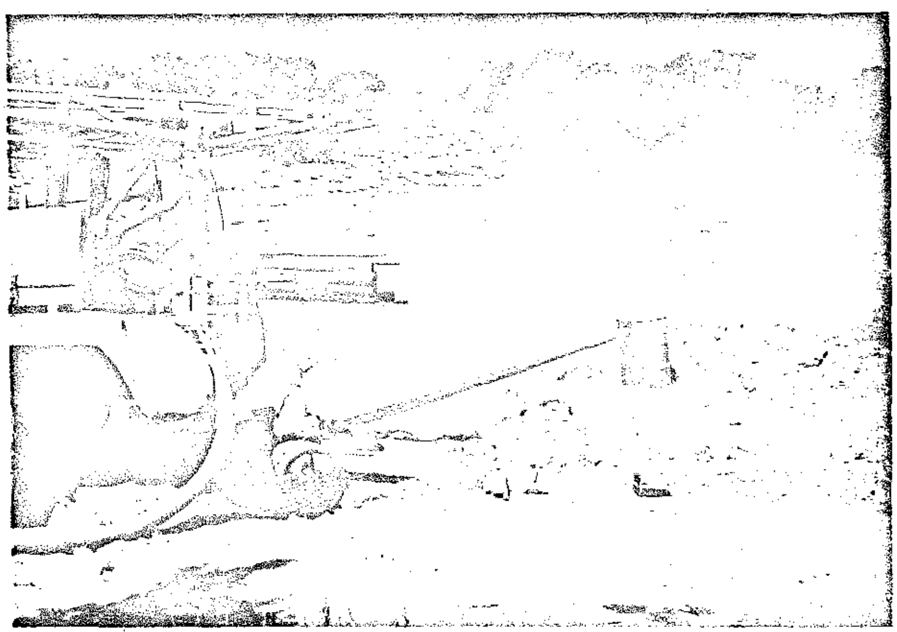
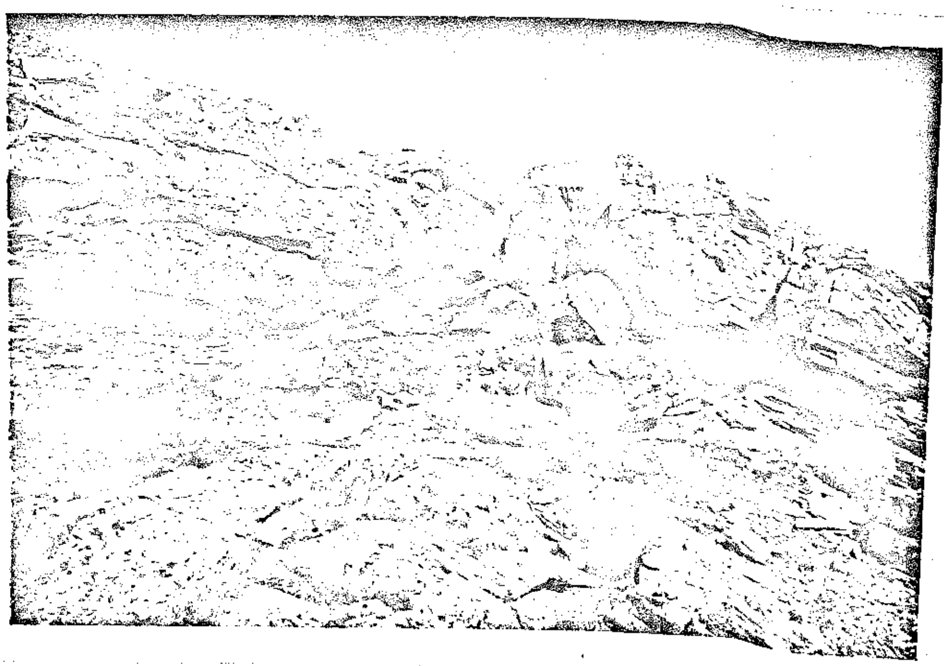
1. At the time of this writing - October, 1965.



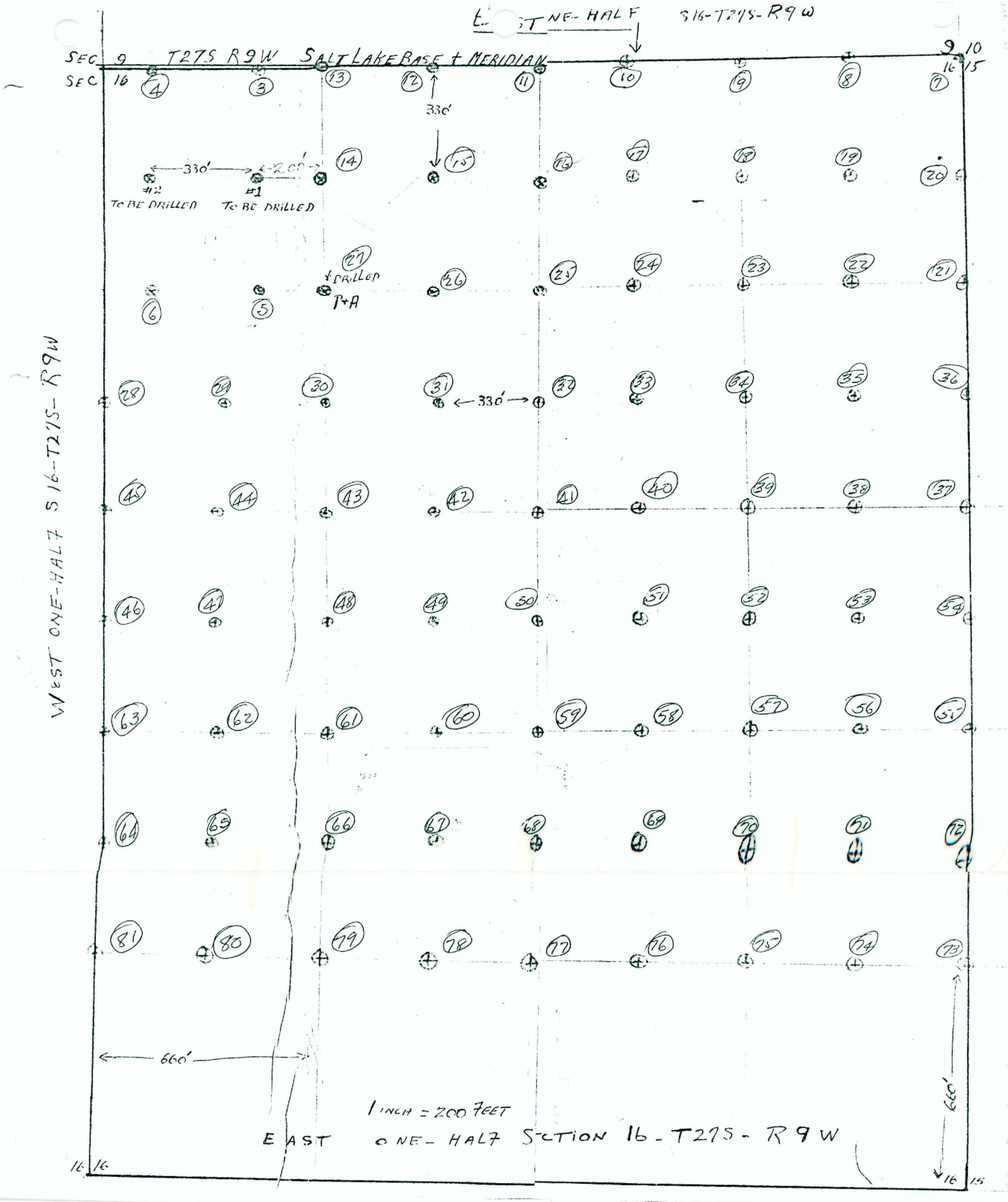
Discovery Well #4 - 266' Deep



Vertical dipping opalite along 1/2 mile axis to the south with east and west dipping opalite flows on flanks



Vertical dipping opalite along axis to north in center and east dipping opalite flows to right.


NE-HALF
S16-T27S-R9W
SEC 9 T27S R9W SALT LAKE BASE + MERIDIAN
SEC 16
330'
330'
200'
#2 TO BE DRILLED
#1 TO BE DRILLED
DRILLED
P+A
330'
WEST ONE-HALF S16-T27S-R9W
660'
1 INCH = 200 FEET
EAST ONE-HALF SECTION 16-T27S-R9W
660'