FORM P-27 PRINTED IN U. S. A.

INTER-OFFICE CORRESPONDENCE SHEET

SUN OIL COMPANY

SUBJECT: Report - - Nevada Hot Springs Reconnaissance

DATE: November 27, 1963

FROM: R. C. Weart

OFFICE: Richardson

TO: Mr. R. R. Anderson
Philadelphia Office

Dear Sir:

Attached is a report "Nevada Hot Springs Reconnaissance" by Dr. G. W. Berry and based on information obtained during the period October 28 to November 5.

It is apparent, based on geological considerations, that more work needs to be accomplished before an optimum steam drilling site can be located with any degree of authority. Following the completion of Dr. Berry's field work near Point arena, California in early December, he will once again be available to pursue this subject.

Since it is desirable to obtain commercial minerals as by product from the steam providing the thermal energy, or vice versa as the case may be, particular attention should be devoted to delimiting areas where this possibility appears most probable. This is not an easy task unless surface manifestations are present. In the final analysis, exploratory drilling will be necessary. Success will be determinate on whether a sufficiently large water or steam reservoir, actually in contact with the mineral containing ore, can be tapped.

Analyses of the water samples to date do not indicate adequate concentration of minerals. Perhaps drilling below the present contributing aquifer, which supplies the surface flow, will encounter the necessary conditions, but their actual existence in a given area would be difficult to predicate by surface geology. Areas such as Steamboat Springs (mentioned in the report), where waters have actually deposited various minerals, would appear to be optimum areas to drill based on surface evidence.

Unless critical information is available from some other source, I do not believe we can justify drilling based on our knowledge to date.

Sincerely,

R. C. Weart

R. C. Weart

RCW/id

cc: Mr. P. E. Chaney

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he has digital scans of photos

NEVADA HOT SPRINGS RECONNAISANCE

G. W. Berry
November 15, 1963

During the period October 28 to November 5, 1963, I scouted in northwest Nevada, observing the general geology and examining and sampling hot springs, wells, and their deposits for potential sources of commercial thermal energy and minerals. I am certainly not an expert in these matters, and I emphasize that this is a preliminary report, only geologic "spade work." I can now ask more questions than I can answer. Much of the report is dull, so I hope the summary will save some reading. Seventeen color photographs may be more enlightening than the text. The discussion is under these headings:

1. Summary
2. Recommendations
3. Unnamed hot springs at Cordero claims
   - 3a. East spring
   - 3b. West spring
4. Beowawe Geysers
5. Bradys Hot Springs
6. Great Boiling Springs
7. Gerlach Geyser
8. Steamboat Springs
9. Other Nevada hot spring areas
10. Geological problems

11. Mackay School of Mines

12. Nevada Bureau of Mines

13. Nevada Mining Association

14. U. S. Geological Survey

15. Selected references

Maps in pocket:

1. Nevada road map, annotated
2. VYA Topographic map
3. Preliminary geologic map of Humboldt County
4. Hot springs, sinter deposits, and volcanic cinder cones in Nevada
5. Transmission and transportation facilities in Nevada

1. Summary. The area of Cordero mining claims at the unnamed hot springs in Humboldt County is 63 mi. airline northwest of Winnemucca, in the remote Black Rock Desert. Two springs are 1 1/4 mi. apart, issuing from alluvium overlying faults, at the sides of broad flat valleys. The waters are clear, odorless, and potable. The east spring has a temperature of 178°F. It has built a large tufa cone. The west spring has a temperature of 192°F. It has only a very small deposit. Prospecting has been done at both springs, and "shows" of cinnabar (HgS) have been found. For geothermal power development this location has drawbacks: remote from supplies for any activity, remote from power transmission lines, near a U. S. Gunnery Range, geologic and engineering problems of fault prospects, doubtful commercial values in minerals, questions of validity of mining claims for drilling wells for thermal energy, and questions of water control and ownership. While I certainly do not imply that this

area should be written off, I am not ready, and I have not found others ready, to recommend drilling here now.

There is considerable interest in geothermal energy. O'Neill Geothermal Inc. has drilled two hot brine wells (T.D. 4729 ft. and 5232 ft.) near the Salton Sea, in the Imperial Valley of southern California (White, Anderson, and Grubbs, 1963; Peret, 1963), and Shell and Pure now have interests in drilling operations there (Oil and Gas Journal, 1963, p. 100). I know personally geologists with Shell and Richfield who have recently been investigating metallic minerals and thermal energy in Nevada. The U. S. Department of Interior has proposed issuing steam-well leases on federal lands (Oil and Gas Journal, 1963, p. 100-101), which may help clarify presently muddled legal and jurisdictional matters.

Wells in the fumarole field of the Tuscany volcanic area, north of Rome, have produced steam for electric power generation for many years. In 1921 the first attempts were made to drill steam wells at The Geysers, 65 mi. north of San Francisco, and since 1959 Pacific Gas and Electric Co. has been generating electricity here commercially from the geothermal energy (Langton, 1961). Electric power has been generated from the Wairakei steam field, New Zealand, since 1958 (Smith, 1958). In his excellent "Preliminary Study of Steam Drilling Operations," Mr. J. W. Peret (1963, p. 2-3) concludes "***that if corporate economic opportunity in this field is obtainable it should not be by-passed in the belief that the drilling phase currently presents an insurmountable barrier." It is my opinion now that we can readily find some geologic prospects for steam wells. We should note, however, that the current interest in the Salton Sea area is inspired by thermal energy prospects <u>plus</u> substantial mineral values in the brines. The waters I have examined in Nevada are certainly not brines, and, although analyses of the water and rock samples are not complete, only minor metallic mineral content is expected. Considerably more preliminary work can be done at reasonable cost, but specific final location of optimum thermal-mineral areas will probably require a substantial effort. I am in favor of the research.

2. Recommendations. I have no categorical recommendations. I suggest that this scouting and study which I have started be continued by a team of me, or some other geologist, and an engineer qualified in drilling and power operations and economics, with the goal of locating specific, optimum geothermal-mineral prospects. The program should include a thorough wringing out of the literature, collecting of geological, operational, and economic data on the California, New Zealand, and Italian areas, and field examinations in California, Nevada, and perhaps elsewhere. It should exploit the extensive local knowledge of Cordero personnel and include sampling for them that they may suggest for assays and their Mercury Sniffer project. I would table detailed local mapping until we outline some optimum areas. Because of the lack of established government procedures, jurisdiction, contracts, etc., we should have some management and legal guidance as to what lands we should favor in exploration --- federal, state, fee, railroad, mining claims?

3. Unnamed hot springs at Cordero claims. Cordero Mining Company has recently located 9 mining claims, comprising 180 ac. aggregate, on and between two hot springs in Humboldt County, northwest Nevada, inspired by Sun and Cordero interest in recovering energy and minerals from natural hot water and steam.

The springs are located in partially surveyed T. 40 N., R. 28 E., 63 mi. airline northwest of Winnemucca, Nevada, in the Black Rock Desert. Winnemucca, population 4500, is the nearest town offering food, lodging, and minimum services. It is located on the Southern Pacific and Western Pacific railroads and U. S. Highway 40. Road distance from Winnemucca to the hot springs is 110 mi.: 31 mi. north on U. S. Highway 95, then 35 mi. northwest on Nevada Highway 8A, then 41 mi. generally southwest on gravel road via Leonard Creek ranch to 1 mi. south of Battle Creek ranch, thence 3 mi. southeast on ranch trail to the west spring.

Hague and Emmons (1877, p. 786) were apparently discussing these springs on the western edge of Black Rock Desert, in an irregular group of hills "called the Kamma Mountains." They state that the location was on Lander's cut-off wagon road, and that the springs were once "***walled in by General Lander, but the walls and adjoining stone house have largely fallen into ruin." Peale (1886, p. 198) lists 2 hot springs "Northwest of Sinks of Quinn River, Humboldt County." Stearns and others (1937, pl. 15, p. 155) also note these springs in the area of the Cordero Claims.

The springs (figs. 1-6) are 1 1/4 mi. apart, on the east and west sides of a low saddle in an isolated, east-dipping cuesta extending north-south 6 mi. Elevation of the springs is approximately 4200 ft. Elevation of the cuesta summit is 5000-5200 ft. The valley floors are nearly flat, bordered by gently sloping alluvial fans. They are an area of unconsolidated Tertiary fill and interior drainage. Vegetation consists mainly of sagebrush and other desert shrubs. There is no timber. Battle Creek ranch is now a cow camp only. The nearest permanent inhabitants are at Leonard Creek ranch, 12 mi. north of the hot springs.

At Leonard Creek ranch, annual precipitation is 8.11 in.; most comes in winter months. The average annual temperature is 53.4°F, average maximum monthly temperature is 76.5°F in August, and average minimum monthly temperature is 32.8°F in January.

Mr. Verne Haas of Cordero guided me to the springs on October 29, and Mr. E. H. Hager of Cordero accompanied me on October 31. On both occasions we reconnoitered the geography and geology. Although small scale, both the AMS topographic map (VYA) and the USGS geologic map (MF-236) appear to be accurate and regionally adequate. There is no large scale detailed mapping available. Generally the area is one of east-dipping (2°-15°) Tertiary basaltic and undifferentiated volcanic and sedimentary rocks (Tba) (fig. 5). A small patch of undifferentiated Mesozoic metamorphic rocks (JTru) is in fault contact with Tertiary volcanics. A granodiorite (B. J. Scull identification) stock (TKg) (fig. 1) appears to be intrusive in the Mesozoic rocks and to be older than the Tertiary volcanics. The small southern area shown as "TKg" on the USGS map is vesicular basalt, probably "Tba," not granodiorite. The hot springs issue from Quaternary alluvium overlying faults. From the surface traces on the topography, and the Basin and Range tectonics, these faults are presumed to be normal and high-angle. Whether the springs are also controlled structurally by the granodiorite stock is conjectural. The intrusion is too old to be of thermal influence now.

3a. East spring (figs. 2-4) issues from 2 vents in a tufa cone approximately 1500 ft. in diameter and 100 ft. high at the apex. About 1948 a prospector dug a trench to lower the water in the cone, and thus altered the surface and near-surface water flow. Estimated aggregate discharge is 80 GPM (by Haas, Hager, Berry). Maximum temperature recorded is 178°F (air temp. 60°F at 11:40 a. m.). Water and steam are clear, odorless, and tasteless, pH 7.5 (approx.). The water flows on to the valley floor, sinks in and evaporates. It improves the range over a few acres, and cattle favor the grassy area for forage and water. Sun water sample no. 11316. Cordero has assayed the spring deposits, and I brought samples to the Richardson Laboratory.

3b. West spring (fig. 6) issues from a single vent with only a very small deposit built up from the water. Estimated discharge is 50 GPM (by Haas, Hager, Berry). Maximum recorded temperature is 192°F (air temp. 64°F at 1:00 p. m.). Water and steam are clear, odorless, and tasteless, pH 7.5 (approx.). As with the east spring the water flows on to the desert floor providing an optimum area for cattle to graze and drink. Sun water sample no. 10966. Cordero has assayed spring deposits, and I brought samples to the Richardson Laboratory.

The Cordero claims include the two springs and the area between. It may be inferred that the springs are in the same hydraulic system on a transverse fault or fault zone, or on the side of the granodiorite intrusion, or both. However, I am of the tentative opinion that the springs are on different faults, as shown on the USGS map. In further support of this view, the west spring is hotter and has only a small deposit compared to the large cone of the east spring. If this interpretation is correct, then perhaps land control should be expanded along the strike of the two faults mapped by the USGS.

As stated above, I do not consider detailed geologic mapping indicated here now. If and when such a program is undertaken I estimate a

Figure 1. - View southeast across flat valley floor to area of Cordero claims. Granodiorite stock in center. Claims in topographic saddle south of stock. West spring at edge of valley, right center. Jackson Mountains on distant skyline.

Figure 2. - View northeast from granodiorite stock across Black Rock Desert to Jackson Mountains, 15 mi. distant. Light area in middle foreground is tufa cone at east spring. Cone is approximately 1500 ft. in diameter, 100 ft. high at apex.

Figure 3. - East spring. Mr. E. H. Hager at trench dug by prospector to lower water in tufa cone. View east across Black Rock Desert. Water and gas are odorless and tasteless. Water temperature is 178°F. Aggregate discharge of 2 vents at east spring is 80 GPM (est.).

Figure 4. - East spring. Mr. E. H. Hager at Natural vent of east spring area. View northeast across Black Rock Desert.

Figure 5. - View north from east spring tufa cone, showing east-dipping cuesta of Tertiary basalt flows and undifferentiated volcanics and sediments. Gently-dipping, light-tone, alluvium between tufa cone and base of cuesta.

Figure 6. - West spring. View west across west arm of Black Rock Desert. Valley floor is 3 mi. wide. Black Rock Range in distance. Mr. E. H. Hager standing at the single vent. Only very small deposit built up. Water temperature is 192°F. Discharge is 50 GPM (est.). Area of relatively lush range where flow sinks in and evaporates on valley floor.

two-man plane table party can accomplish it in 2 weeks. Light aircraft can land on the gravel road at Battle Creek ranch and probably on some areas of the valley floor. Probably, however, the most efficient operation would be from a camp at the west spring. Although it is possible in dry weather to drive a car to the springs, the area is so remote and rough that four-wheel-drive vehicles and at least two-man parties should be used for any work or travel. Mapping can be done at any time of year, without serious weather problems.

Township plats are available at the Bureau of Land Management office, Winnemucca. Plat of T. 40 N., R. 28 E. indicates quarter corners may have been set between secs. 16 and 17, between secs. 16 and 21, and between secs. 20 and 21. Brass caps are probably on the west township line. There are no bench marks in the area, but probably the county engineer can provide adequate local elevation control. Air photo index sheets may be examined at the Soil Conservation Service, Winnemucca, and certainly a mapping party should have the contact prints. Inquiry about them should be made to Soil Conservation Service, Ross Building, 209 S. W. Fifth Avenue, Portland, Oregon 97204; coverage at 1:20,000 by contact prints DTU 55L58-64, 35L158-165, 35L36-41, 35L230-234.

4. Beowawe Geysers. This has been one of Nevada's most spectacular natural thermal phenomena. Location is 8 mi. west of Beowawe, approximately 60 mi. southwest of Elko by road, on the Lander-Eureka County line (approx sec. 17, T. 31 N., R. 48 E., AMS map Winnemucca). I visited this area with Mr. E. H. Hager on October 30. There is a sinter terrace on a hillside (figs. 7, 8), extending about half a mile along a fault in Tertiary basalt. Nolan and Anderson (1934) described fumaroles and geysers here. Stearns and others (1937, p. 161) report "about 35 springs on tufa terrace***, 2 or 3 springs have true geyser action." There are now no natural geysers of appreciable size, but small natural fumaroles are numerous.

Magma Power Co. (631 South Witmer Street, Los Angeles 17, California), et al, have drilled 4 holes on the terrace, and 2 higher on the hillside. The latter appear to have failed to develop significant amounts of water or steam. Of the 4 wells on the terrace 3 were shut in on October 30, and one was open, blowing steam to an estimated distance of 50 ft. All wells have 20-in. conductor pipe and 13 3/8-in. casing, set in concrete, with 8-in. gate valves and flow lines (fig. 9). I have no data on well depths. There were no pressure guages. From stream about 200 yd. below

1 - 550
2 - 638

Figure 7. - Beowawe Geysers. View south showing steam from wells and fumaroles. Sinter terrace is approximately half a mile long, 100 ft. wide, and 200 ft. above valley fill. Outcrops above terraces are basalt. Steam well blowing at right.

Figure 8. - Beowawe Geysers. View northeast along sinter terrace showing one of shut-in Magma Power Co. steam wells. Whirlwind valley at left.

Figure 9. - Beowawe Geysers. Open Magma Power Co. Steam well. Mr. E. H. Hager at well head. Conductor pipe is 20-in., casing 13 3/8-in., with 8-in. gate valve and flow line. Steam jet is about 50 ft. long. Water temperature in natural mud pot is 198°F. Water and steam are odorless and tasteless.

the one active well (Sun water sample no. 11057), aggregate discharge of water and condensed steam was estimated at 150 GPM (by Hager, Berry). Sun water sample no. 11074 was taken from a small natural mud pot on the terrace; the sediment is a result of surface agitation. Water temperature is 198°F, pH 7 (approx.) (U. S. Geol. Survey lists temperature 204°F, pH 9.5). Water and steam are about odorless and tasteless. the water is potable. There is a detailed U. S. Geological Survey water analysis (White, Hem, and Waring, 1963, p. 40, table 17).

On October 30 there remained at location of the most recent well a stack of cable tools. This is an engineering matter, so I do not here discuss the advisability of drilling steam wells with cable tools.

5. <u>Bradys Hot Springs</u> (Springer's Hot Springs). This location is on U. S. Highway 40, 56 mi. northeast of Reno, in Churchill County (sec. 12, T. 22 N., R. 26 E., AMS map Reno). Stearns and others (1937, p. 160) remark that there were 6 springs, temperatures 158°-187°F, discharging 10 GPM. The AMS Reno map compiled in 1957 shows 2 springs. I examined the area briefly on November 1 and found 2 active wells (figs. 10, 11), no active springs.

Magma Power Co. has drilled 6 holes at Bradys Hot Springs since November 1959. On November 1, 1963, four wells were shut in, and apparently would not produce significantly when valves were open. The holes are about 100 ft. apart, staggered along a fault. Tertiary lava is at the surface in the well area. There are no conspicuous tufa deposits.

All holes have 20-in. conductor pipe, 13-3/8-in. casing, and 8-in. gate valves and flow lines. Casing is in concrete at the surface.

Figure 10. - Bradys Hot Springs. View northwest at most active of 6 Magma Power Co. steam wells. Twenty-in. conductor pipe and 13 3/8-in. casing are cemented to surface. Eight-in. valve and flow line. Steam jet is about 50 ft., with reported pressure 50 psi at well head. Aggregate water discharge is 25 GPM (est.). Catchment trough and pipe for local domestic heat and washing use.

Figure 11. - Bradys Hot Springs. View north at second active Magma Power Co. steam well. Completion and equipment same as well shown in fig. 10. Flow is by heads, aggregate water 15 GPM. Water temperature 204°F at well head.

Wells were reportedly drilled with both cable and rotary tools, to total depths of 341 to 700 ft., and completed barefoot. Plugging is a problem and the scale must be reamed "occasionally." On November 1 the most active well was blowing steam about 50 ft., with estimated (by Berry) steady discharge 10 GPM of water plus 15 GPM of water from condensing steam. Water at end of flow line is caught and piped about 300 yd. for domestic use, other than drinking. The second active well was flowing by heads an estimated (by Berry) 10 GPM of water plus 5 GPM of water from condensing steam. Sun water sample no. 11221 is from end of flow line on this well. Water temperature at flow line was 204°F. The water and steam are clear, odorless, pH 7.5 (approx), and, although apparently not desirable for drinking, it is potable. The steam temperature is locally reported to be 340°F. Steam pressure at the well head is reported to be 50 psi, but there were no operative pressure guages on November 1. Clarke and Chatard (1884, p. 24) give an analysis of this water from "Hot spring, at Hot Spring Station, Nevada, C.P.R.R."

This thermal activity is clearly related to a fault zone. The drilling changed the channels considerably, with apparently a net increase in water and steam discharge. The disturbance also caused extension of discharge along the fault to Highway 40, where the pavement "melted" and a new vent developed.

6. Great Boiling Springs (Gerlach Hot Springs, Ward's Hot Springs). John C. Fremont discovered and named these springs in 1844. The Gerlach-Empire Lions Club is now developing them as a park, with no great progress to date (fig. 12). Location is 1 mi. northwest of Gerlach, in Washoe County (approx. sec. 15, T. 32 N., R. 23 E., not shown on AMS map Lovelock). I reconnoitered here on November 2. There are now 3 active vents. Two southeast clear springs discharge an estimated aggregate 40 GPM (by Berry). A third spring 150 yd. northwest is boiling and flows about 4 GPM. There are no tufa build-ups. Temperature of the northwest spring is 204°F (air temp. 64°F at 1:00 p. m.). The water and steam are odorless, tasteless, and potable, with pH 7.5 (approx.). Sun water sample no. 11263 is from spring at "bath house." Clarke and Chatard (1884, p. 24) and Peale (1886, p. 202) list analyses of these waters.

Figure 12. - Great Boiling Springs. View northwest. Steam at bath house is from main southeast vent. Water temperature at northwest spring 204°F. Aggregate discharge of spring area is 44 GPM (est.).

7. Gerlach Geyser. This location is in remote desert, 21 mi. by road north of Gerlach, in Washoe County (T. 35 N., R. 23 E., not shown on AMS map Lovelock). I reconnoitered here on November 2. The spring activity is on the west side of a flat-floored valley tributary to the Black Rock Desert valley. A single "geyser" cone of sinter (fig. 13) is about 15 ft. high, from which water flows at about 3 GPM (by Berry). There are also, in an area of about 20 ac., 10 or 12 springs of warm, clear water, 10 to 100 ft. in diameter. Total discharge is probably several hundred GPM, part of which is caught in an artificial reservoir covering about 20 ac. The geyser cone is the only notable spring deposit.

Western Geothermal Inc. has a well (figs. 14, 15) which on November 2 was flowing an estimated 30 GPM from a 6-in. line. There was no pressure guage. I have no data as to depth of this well. Whether the casing was not cemented or whether the well has cratered around the casing is not clear, but there is no concrete in evidence now. Temperature of the water

Figure 13. - Gerlach Geyser. Sinter cone is about 15 ft. high. No geyser action apparent, only a fumarole, with small jet of steam. Total water discharge at cone is 3 GPM (est.).

Figure 14. - Gerlach Geyser area. Westtern Geothermal well. View east across Black Rock Desert. Water is odorless and tasteless. Flow is 30 GPM (est.), temperature 205°F. Cattle congregated at this oasis of water and good range.

Figure 15. - Gerlach Geyser area. Western Geothermal well, same as fig. 14. View north. Calico Mountains in distance. Gerlach Geyser cone (fig. 13) in middle distance. Note no cement at well head. Six-in. flow line. Blue and brown colors in water probably algal.

at the well head is 205°F (air temp. 64°F at 11:30 a. m.). Water is odorless and tasteless, pH 7.5 (approx.). Discharge is to valley floor, making about 40 ac. of relatively lush range and water for cattle. There are rough fish in the reservoir, and it is an oasis for large numbers of ducks.

8. Steamboat Springs (and Reno Hot Springs). This locality is 10-11 mi. south of Reno on U. S. Highway 395. It is geologically famous and has been the subject of intensive study and much literature since 1888 (Becker), mainly in connection with geochemistry and ore deposition. The waters are highly mineralized and are depositing considerable stibnite (Sb_2S_3) and arsenic, and some gold and silver (White, 1955, p. 110-113). I made a very cursory examination of this area on November 3. Reno Hot Springs (fig. 17) is 1 mi. north of Steamboat (fig. 16). They comprise one locality, but probably not a single, simple hydraulic system. The springs have built a terrace, or group of terraces, of silicious sinter "***ranging in texture from porous opal to dense calcedony and quartz." (Thompson, 1956, p. 60). Waters are used locally for mineral baths and heating. Wells have been drilled by Magma Power Co. for steam power, but without any visible success. I found 3 wells active, all for mineral bath use. These waters cannot be used for irrigation because of high mineralization, and plugging and corrosion are serious problems in wells. Water temperature is 89.2°C (193°F), pH 7.9 (U. S. Geol. Survey). Sun water sample no. 11188 is from west active well (fig. 17) at Reno Hot Springs at leak in the base of catchment tank. There are detailed U. S. Geological Survey water analyses (White, Hem, and Waring, 1963, table 17, table 21), and gas alalyses (White, Hem, and Waring, 1963, table 28).

Figure 16. - Steamboat Springs. Wells at spa for arthritics. Note heavy deposits on catchment and cooling tanks. Water temperature 193°F. This Steamboat-Reno spring area is geologically well known because waters are depositing gold and silver.

Figure 17. - Reno Hot Springs, 1 mi. north of Steamboat. Well and cooling towers for spa and swimming pool.

9. <u>Other Nevada hot spring areas</u>. There are more than 1000 thermal springs in the United States (Stearns and others, 1937), and 185 hot springs are listed in Nevada (Horton, 1963), not including those at the Cordero claims. Several areas that appear especially favorable, but I have not examined, are:

Dyke Hot Spring	T. 43 N., R. 35 E.	AMS Vya
Unnamed springs	T. 40 N., R. 24 E.	AMS Vya
Unnamed spring	T. 37 N., R. 26 E.	AMS Vya
Double Hot Springs	T. 36 N., R. 26 E.	AMS Vya
Unnamed spring	T. 36 N., R. 38 E.	AMS Winnemucca

Mr. Verne Haas has suggested examining an unnamed hot spring in eastern T. 46 N., R. 34 E., and Bog Hot Springs in western T. 46 N., R. 34 E. (AMS Vya). Mr. E. H. Hager has suggested that a spring a few miles south of Winnemucca may be of interest. He also has pointed out that hot springs at Dixie Meadows in T. 22 N., R. 35 E. (AMS Reno) are along a very recently active fault and that the Dixie Valley in T. 20 - 22 N., R. 34 - 35 E. is a notable topographic low which is perhaps analogous to the Imperial Valley where O'Neill has drilled hot brine wells. We should make special effort to examine these localities.

10. Geological problems. There is considerable literature that is helpful in studying the general geologic aspects of thermal energy, but almost none that treats making specific locations for commercial steam production. It appears that geologically the trick is to make the location for a bore to tap a reservoir of water or steam, or both, at the optimum depth for optimum pressure-volume-temperature for optimum production of steam and valuable minerals. A paragraph from Smith's report (1958, p. 355) on New Zealand geothermal development is worth special note:

> It is apparent that the best opportunity for exploitation by drilling is in a locality where the natural heat flow is large, but the amount which can be taken off by bores without overdrawal cannot be predetermined. The natural heat flow is an indication of the minimum amount available to shallow bores but not much guide to the maximum which can be withdrawn by deeper drilling. It would appear that only by drilling and producing from bores can the full potential of an area be ascertained.

All of the hot spring areas I examined in Nevada appear to be closely related to high-angle normal faults. Detailed surface mapping can provide some geometry that can be extrapolated, but until subsurface control is established by drilling there will be considerable uncertainty about a fault attitude and the width of the zone of breccia and gouge. Faults are never planes, and seldom simple fractures. Also, within a fault zone the fluid channels are certainly torturous.

Mr. J. W. Peret (1963, p. 6) points out that drill "***site characteristics must provide the following with good assurance:"

(A) Avoidance of adverse rig settlement.

(B) Avo'dance of steam percolation vertically through the soil surface exit in the area surround'ng the rig. He cited a case where roads were rerouted for this cause.

(C) Soil properties that will permit a good bond of cement to the hole walls is necessary (also pipe walls). Without this, severe trouble can result in blow-outs and loss of pipe fixity. Where pipe fixity is lost thermal expansion caused by as much as 715°F temperature would extend the well head many feet vertically causing trouble, possible breakage, and allowing a blow-out external to the pipe.

(D) Good surface drainage is necessary 'n order to accommodate run-off of large volumes of water that would be produced in event of a "kick" while drilling, completing or testing a well.

In the Beowawe and Bradys areas of Nevada steam wells have been drilled in the immediate area of the natural vents, about on the surface traces of the faults. The bores have, 'n effect, gone down the fault zone and provided more efficient outlets for the fluid. At Beowawe the wells are on a sinter terrace which overl'es basalt. At Bradys there is no large deposit built up, and the well heads are cemented in basalt.

Generally, an area of hot springs is dangerous to explore at the surface, not to mention drill a well. Tufa crust may be thin, dormant vents and mud pots may be crusted over, breccia and gouge 'n the fault zone are probably unconsolidated, vents shift along the fault zone, discharges vary seasonally, and natural hydraulic systems are commonly disturbed by local fault movements, major earthquakes, and drilling of wells.

At the Cordero claims, for a typical example, the west spring issues from alluvium and the east spring from a tufa cone overlying alluvium. Such sites present serious mechanical problems, and geological problems of unknown thickness of alluvium and no local control on the underlying fault. An example of a poor site was at The Geysers in California (Langton, 1961, p. 45-46) where a steam well blew out on the side of a slope, a relief well blew out and was finally controlled after 2 years, and shortly thereafter a portion of the ground used in the relief project fell 90 ft. into an underground cavern.

To avoid some of the operational drawbacks of a location on a fault, and to get a "better angle" and control for intersecting the fault zone, I would now be inclined to drilling a directional hole, concerning which Mr. J. W. Peret (1963, p. 6) states:

> Where the soil characteristics are extremely adverse but of a localized area the possibility of a directional hole can be considered providing the lateral distance required is not excessive.

Drilling in the immediate area of hot springs is an attempt to tap a reservoir that is already leaking naturally. I feel we should seriously search also for geothermal fields without holes in them.

In searching for, and perhaps roughly delineating, "hot areas" I am struck with the idea that infrared air photography may be worth serious investigation. Its primary sensitivity is to thermal emissions and reflections.

One of the first questions is about the volume of fluid available. Generally, the valleys of the Basin and Range country are areas of alluvium, several thousand feet in maximum thickness, and areas of interior drainage. Published reports indicate high water tables, and thus large volumes of water in these basins. Certainly the mountain areas have less porosity and permeability, with water tables generally much deeper below the surface. Subsurface data are very sparse, but we can scout out some well information and the U. S. Geological Survey Ground Water Branch can probably be of considerable help. I believe there is a large quantity of water in the Great Basin now, but, like the Phoenix area of Arizona, large withdrawals for any purposes will not be readily replaced.

I am of the opinion that we can locate some geologically attractive prospects for thermal energy without great effort. However, it appears the most desirable prospect includes recoverable mineral values, a combined geothermal-mineral operation as in the Imperial Valley. Location and development of such operations will probably be a major project, involving geology, hydrology, geochemistry, geophysics (heat flow), and engineering.

11. Mackay School of Mines is located on the campus of the University of Nevada at Reno. I visited on November 4 with Prof. E. R. Larson, Chairman, Department of Geology & Geography. He showed no special knowledge of, or interest in, thermal springs and referred me to Mr. Robert C. Horton of the Nevada Bureau of Mines and to the outstanding authority on mineral springs, Dr. Donald E. White of the U. S. Geological Survey, Menlo Park, California.

12. Nevada Bureau of Mines is at the Mackay School of Mines. Mr. Robert C. Horton was very cordial to me on November 4, but he made clear that neither the Nevada Bureau of Mines nor any other state agency had made detailed studies of Nevada's thermal waters. Mr. Horton handed me a copy of his list and map showing hot springs, sinter deposits, and volcanic cinder cones in Nevada, which I have reproduced for this report. He indicated that interest in Nevada's geothermal energy prospects was

increasing. A permit from the state (Department of Conservation and Natural Resources, Carson City) is necessary for drilling any well in Nevada, other than for household use. There has been no state program of collecting and filing well cuttings. Drillers' logs are filed at the office of the state engineer, Carson City, but Mr. Horton was not encouraging about the completeness or quality of these files. There has been no state program of production testing, sampling, or analyzing well and spring waters. The Nevada Bureau of Mines does not have information on drilling, depths, completion, or potential of wells drilled for steam in Nevada, and suggests only the operators for such data.

13. Nevada Mining Association. Mr. E. H. Hager suggested conferring with Mr. Louis Gordon at this office (206 N. Virginia, Reno), but I did not have time to make the call.

14. U. S. Geological Survey. The Ground Water Branch has an office at 809 North Plaza Street, Carson City, and probably can be helpful, but I have not yet contacted them. Dr. C. W. Merriam of the U. S. Geological Survey at Menlo Park is an authority on Nevada geology and an old friend of mine. I plan to call on him and Dr. Donald E. White in 2 or 3 weeks when I go through Menlo Park to or from the Point Arena area.

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