GL00899

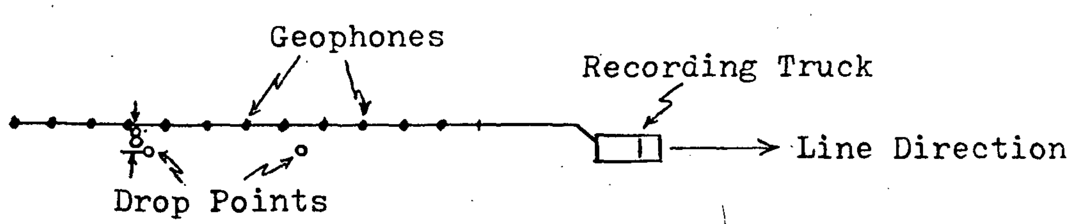
SODA LAKE AREA SEISMIC SURVEY

CHURCHILL COUNTY, NEVADA

<u>Introduction</u>: During April and early May, 1975, a shallow reflection seismic survey was carried out in the Soda Lake area, near Fallon, Nevada for the Minerals Staff of the Chevron Oil Company. The purpose of the survey was to provide structural geological information as an aid in exploration for geothermal steam resources. Faulting and folding systems were regarded as of importance in geothermal exploration in the area.

The survey consisted of seven lines (three east-west and four north-south) totalling about 24 miles in length. Station spacing along the lines was 330 feet (100 meters) measured by use of a measuring rope of that length. As many survey monuments such as section corners as possible were used in locating the lines accurately on a U.S.G.S. topographic map. Elevations for elevation corrections were taken from the topographic map, supplemented by field observations. The data were corrected to a reference datum plane at 4000 feet above sea level using a correction velocity of 5000 feet per second, which was selected on the basis of short refraction measurements.

The seismic energy source used consisted of a 300 lb. steel weight dropped free-fall 3.5 feet. The average number of drops summed at each station was slightly greater than three, for a total average energy of about 3300 ft/lbs per station. The recording instruments included a Seaman Nuclear Corp. single-channel engineering-type seismograph, with digital summing memory, modified to incorporate frequency filters, programmed gain expansion, a paper strip chart recorder and a magnetic cassette recorder. The reciever array consisted of 12 Mark Products 21L, 10Hz geophones spaced 12 feet apart inline for a theoretical group length of 144 feet. The weight was usually dropped one or more times at each of two positions 48 feet apart symetrically placed forward and back ofthe group center and offset about 8 feet from the geophone line (see sketch below) to achieve constant normal moveout. One-half second from time zero was recorded at each station.



faults observed on the seismic data appear to be normal faults or vertical in attitude, but a few suggest high-angle reverse faults. None of the possible high-angle reverse faults, however, appear to have large displacement.

Another point of note with regard to the faults in the area is that few seem to generate well-developed diffraction systems. This may be interpreted to suggest that considerable crushing of nearby rock may be associated with the faulting here.

Respectfully submitted,

Charles B. Reynolds

Charles B. Reynolds
Registered Geophysicist (Calif.)
Certified Professional Geologist

Enclosures:

7 VAR record sections
7 migrated depth sections
1 structure contour map
1 table

SODA LAKE HR

April 4, 1979

MEMORANDUM

TO: H. P. Ross

FROM: W. Frangos

SUBJECT: Initial Review of Soda Lake-Stillwater KGRA Magnetotelluric, Resistivity, and Gravity Data

First-pass examination of magnetotelluric and other geophysical data from the Soda Lake KGRA yields some insight into the structure and configuration of the area. I have also considered the relevance of the various geophysical techniques to the sorts of questions being posed concerning the case study. The magnetotelluric results, in particular, require interpretation beyond that presented by the contractor and by the USGS, since neither adequately recognizes the influence of three-dimensional resistivity configurations on MT data.

The data examined includes:

1) 10 tensor MT sites surveyed by Geotronics Corp. in 1975 for Chevron.

2) 4 tensor MT sites surveyed by Geotronics Corp. in 1977 for Chevron.

3) 60 line-miles of dipole-dipole resistivity (A=2000 ft.) surveyed by McPhar in 1973 for Chevron.

4) a simple-Bouguer gravity map and interpretation by R.R. Wahl dated 1965.

5) 25 tensor MT sites surveyed by Geotronics Corp. for the USGS.

A evaluation of various physical influences upon electrical resistivity with special reference to the Soda Lake-Stillwater environment is included in the Discussion section.

Gravity

Gravity data throughout the Carson Sink and immediate surroundings were gathered, reduced, and interpreted by R.R. Wahl as a student research project at Stanford University. The lack of terrain corrections (for the complete Bouguer reduction) is not of major significance to interpreting the data. Wahl carefully considered rock densities in his two dimensional interpretations, using laboratory determinations on samples as well as known depths to bedrock.

Significant aspects of his interpretation include the discovery of a buried bedrock ridge plunging southwestward from Lone Rock, its highest point, toward Fallon. This feature is apparently a small Basin and Range horst which has been inudated by alluvium from the nearby higher ranges. Alluvium and poorly consolidated sediments on each side of the horst are estimated to obtain thicknesses to 10,000 feet. Wahl interprets a basin floor dipping southward away from Fallon at about 4 degrees; a similar aspect to the west is likely, supporting the general concept of an acurate system of structures roughly concentric with Soda Lake tilting the basin floor down to the southwest.

Galvanic Resistivity

The 2,000-foot dipole-dipole data generally show a resistive over conductive geoelectric structure, the underlying resistivity often being about 2-3 ohm-m. Thickness and intrinsic resistivity of the upper layer are very poorly defined by these results. Several places where the upper layer appears to be missing may only be thinning zones (i.e., "absent" may only mean less than, say, 300 feet thick). No shorter spacing information was gathered to clarify this issue. At no point is there any indication of underlying resistive material.

At one point the contractor's report interprets upper layer resistivity to be about 80 ohm-m. The data appear to me to be poorly suited to such inference, and the MT results generally contradict this conclusion.

Electromagnetic coupling effects for the dipole-dipole array on a two-layered earth can be severe when the upper layer is more resistive than the lower. Using results computed previously (Frangos and Stodt, 1977) I estimate that the apparent resistivities presented by McPhar may be low by as much as a factor of two at the longer separations.

Geologic significance of the thinning of the upper layer is possibly the upwelling of hot, saline waters from a deep reservoir. Figure 1 (reproduced from Olmstead, et al, 1975, Figure 13) presents a hypothetical cross section illustrating a plausible temperature distribution around a fluid flow system postulated for the Stillwater thermal area. Hot, low-viscosity water above the vertical "fault conduit" may cause the shallow regions to be more conductive than otherwise.

Figure 2

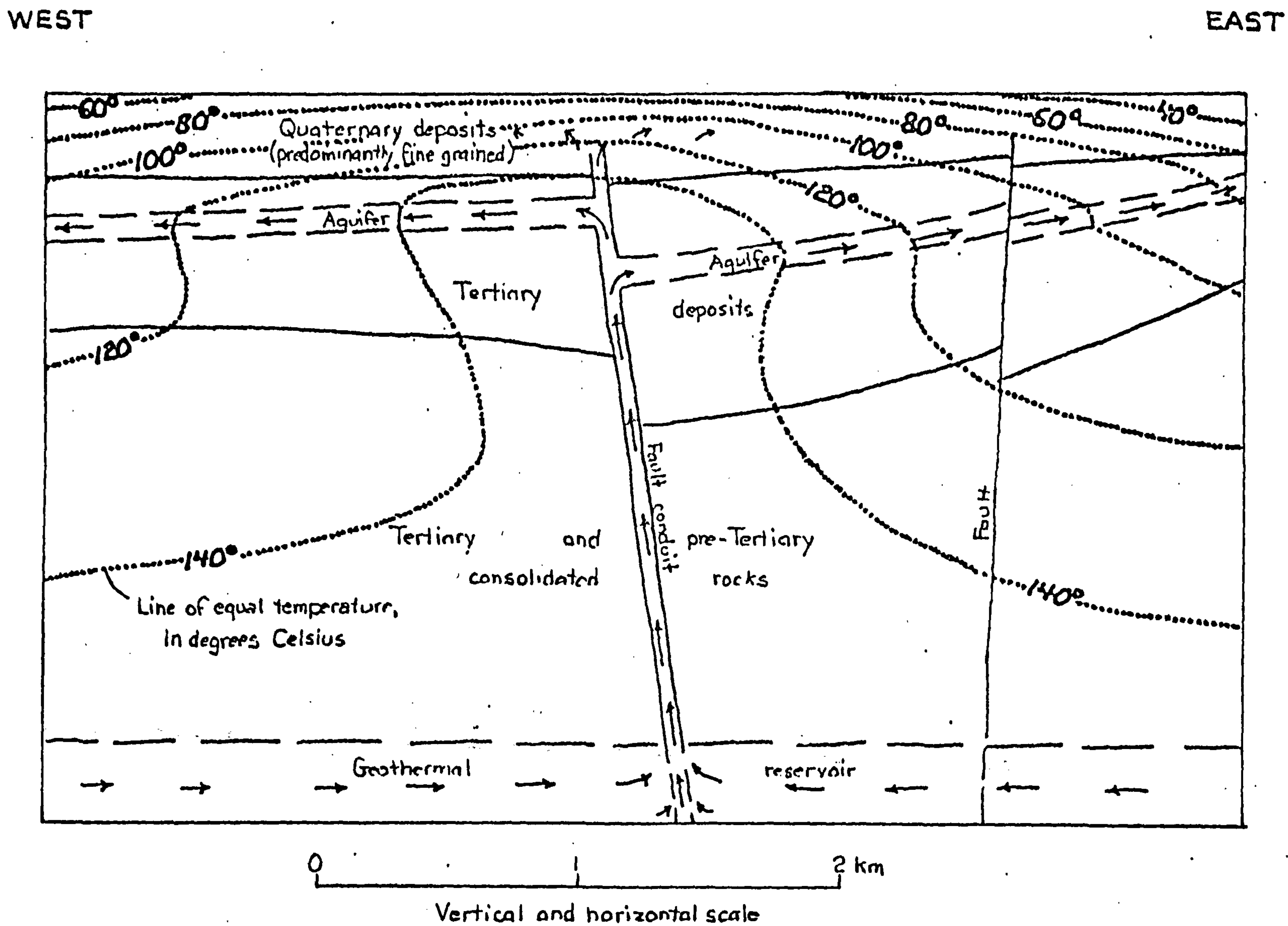


Figure 13 — Idealized cross section of central part of Stillwater thermal anomaly.

A NE-SW alignment of shallow conductive zones is noted by McPhar roughly paralleling the projection of the buried ridge interpreted by Wahl (1965). Thus the Basin and Range structures may be the conduits controlling thermal water flow in this area. An alternative geologic explanation is that the alluvium may have a higher clay content in the depositional centre of the basin than nearer the margins. Such a configuration would cause a lower resistivity upper layer (due to intergranular surface conduction) incidental to geothermal activity.

Magneto-telluric Surveys

Thirty-nine tensor MT soundings have been taken in the Soda Lake - Stillwater KGRA by Geotronics in four different surveys. Data packages and interpretations vary greatly between these surveys, but similar gathering and processing methods are helpful. Three of the four data set have been inverted into discrete layered earth (i.e., one-dimensional) models, one (the 1975 Chevron data) using a parameter estimation technique and the two USGS surveys using a generalized linear inverse method. The only inversion results explicitly available are Chevron's; the USGS presents only grouped, interpreted cross sections. Both the 1975 and 1977 Chevron surveys have been inverted to a continuous resistivity vs. depth function via Bostick's "little inverter."

All of the one-dimensional interpretations have been assembled into pseudo-two dimensional cross sections by simply connecting common points between stations arranged as a profile. As a first-pass procedure, this technique yields plausible and probably useful information. Neither the inferred structures nor the interpreted depths have particular credibility, however, since three-dimensional structures have been shown (Hohmann and Ting, 1978) to cause major deviations from one-dimensional interpretations. Perhaps surprizingly, the scale of lateral inhomogeneities giving rise to unwanted three-dimensional effects is quite large, such that the Soda Lake Region is not adequately one-dimensional below frequencies of about 0.3 Hz.

A remarkably similar geo-electric section is observed on each MT sounding, with only minor deviations. The resistivity sequence from the surface down is moderate, low, moderately high, and very low; typical values determined by discrete-layer one-dimensional inversion methods are 20, 3, 50, and 0.5 ohm-meters, respectively (see Figure 2). Stanley et al (1976, e.g., Fig. 6) tentatively assign the following geologic significances to these inferred layers:

first layer	=	Aeolian sediments & ashes
second layer	=	Quaternary playa sediments
third layer	=	Tertiary volcanic rocks
basement	=	Tertiary and pre-Tertiary sediments

The apparent basement is then interpreted to be a high-temperature, very saline geothermal reservoir. The first Geotronics interpretative report to Chevron concludes that the deep conductive region is a magma chamber, reasoning that "molten rock is the only material that deep (i.e., 8-10 km) in the earth likely to have such a high conductivity." Both these interpretations are dubious. The shallow regions are generally poorly resolved in these data. Although the instrumental passband permitted analysis up to frequencies of 256 Hz., few data sets yield acceptible coherencies

Inversion Resistivity Range, Ω-m	Inversion Thickness, km Range	Typical
5-20	0-2	1/3
1-5	0-2	~1
20-50	2-4	3
<1	infinite	

Figure 2: Summary of Inversion Results

(i.e., > 0.8) above 70 or 80 Hz and many go no higher than 40 to 50 Hz. Accordingly, the high frequency asymptotes are often poorly defined, requiring arbitrary fixings of parameters in the inverse solutions. Generally, the data meeting the coherency acceptance criterion are numerous but poorly grouped; a great measure of subjectivity is involved in hand-smoothed curves fit by the inversion routines. A notable exception occurs in the 1977 Chevron survey, where acceptible points in the spectral region 0.1 Hz to 10 Hz are extremely rare. The interpretation of resistivities in this region (corresponding to the interval from about a few 100 metres to a kilometre) is very subjective, often without substantial support in the data. Apparently the smoothing procedure is performed assumming that all errors are random since no systematic errors are mentioned and the curves seem to be drawn for best fit without bias. Figure 3 presents a typical suite of Fourier component resistivities passing the coherency criterion and the smoothed sounding curve derived from it. This example is drawn from the 1975 Chevron survey.

The possibility must be raised that the modes have been identified incorrectly on some of the soundings. This may readily be a consequence of three-dimensional resistivity environment wherein the usual terms TE and TM tend to lose their meaning. The TE mode is generally the more conductive and yet a number of soundings show a lower TM resistivity.

After discussion with Phil Wannamaker (University of Utah Geology and Geophysics Department), it seems unlikely that the omnipresent deep conductive zone is either a geothermal reservoir or a magma chamber. Instead, because near-surface three-dimensional inhomogenities tend to cause an upward bias of

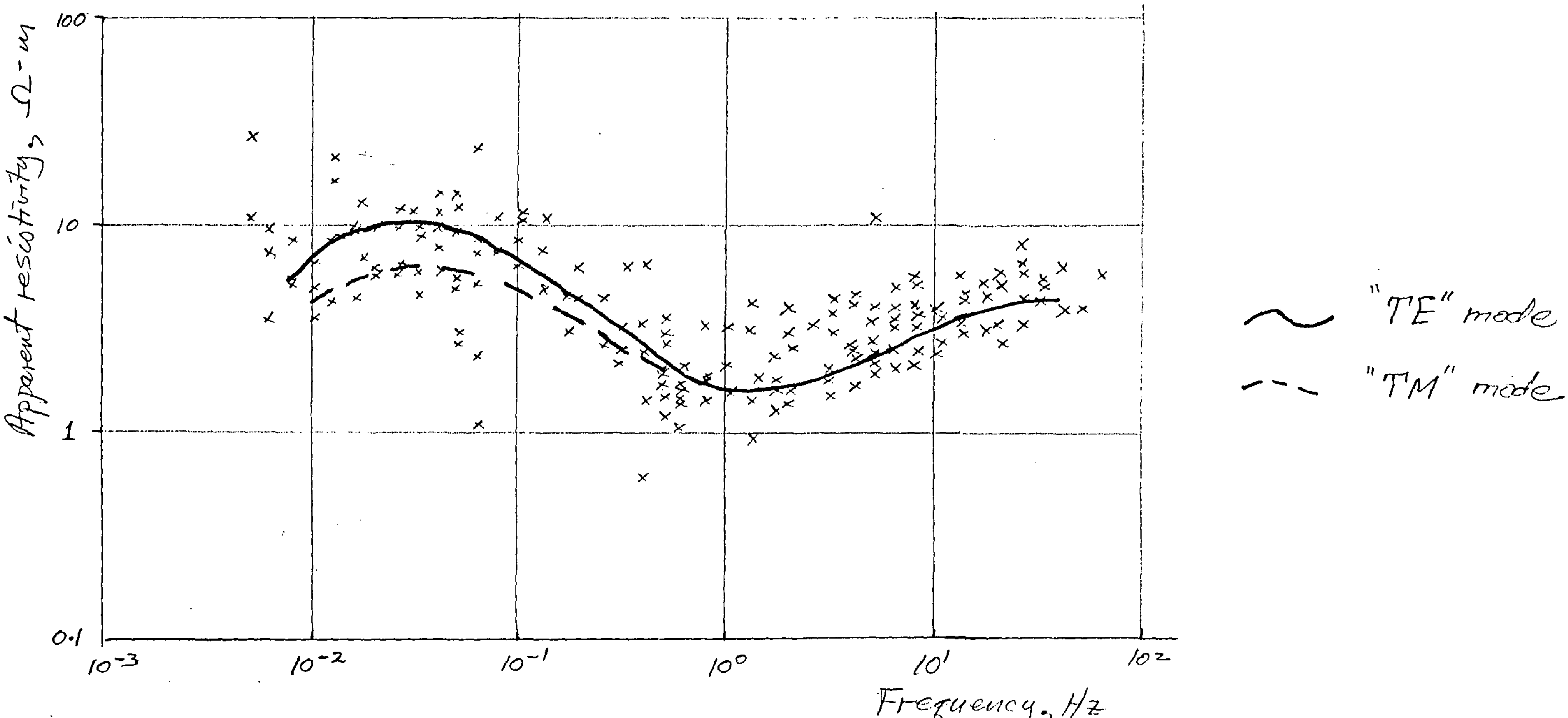


Figure 3 :

Typical MT sounding data, showing hand-smoothed curve through coherent apparent resistivity values interpreted depth, it seems more probable that the very conductive material is the upper mantle. Wannamaker (verbal communication) says that depths estimated by one-dimension fits are frequently shallow by a factor of 2-3 in three-dimensional models he has computed. Such error in these data would be approximately correct for the thickness of the crust in western Nevada (roughly 15-20 km).

One possible indication of a deep heat source might be a conductive portion of the resistive layer. The data were examined for such a feature and no clear evidence for one was found. The problem may be that, since this layer is not thick enough to reach its asymptotic resistivity, we are always dealing with a conductivity-thickness product. MT cannot differentiate between thin portions and conductive portions of resistive layers without asymptotic values.

Discussion

In evaluating electrical surveys of geothermal areas, it is worthwhile to consider the phenomena which effect electrical properties changes in order to understand the significance of any interpretation. In general, electrical methods are employed on the premise that four phenomena associated with geothermal systems all tend to produce anomalously conductive rock in or near the system. These effects are i) heating of pore fluids, ii) increased salinity of pore fluids, iii) increased porosity (or rather, permeability) due to wall-rock alteration, and iv) increased clay content due to wall-rock alteration products. With reference to the Soda Lake-Stillwater KGRA, it appears that pore-fluid heating may be the only significant effect, the latter three being outweighed by other variations within the system. Each effect is briefly examined below with special reference to its applicability in the Soda Lake-Stillwater system.

Saline solutions become more conductive as they are heated largely due to a decrease of viscosity which leads to increased mobilities of the charge-carrying ions. At higher temperatures the effect is reversed since the number of ions available decreases due to ion association. Figure 4, generalized from Quist and Marshall (1969), summarizes this phenomenon for water with a salinity of roughly 700 milligrams/litre. It is readily apparent that a resistivity decrease by a factor between 4 and 10 may be expected due to heating effects alone in the Soda Lake-Stillwater system. Fluid temperature ranges based on drillhole measurements and geochemical inferences might be 20^{o}C to 100^{o}C on the low end or 0^{o}C to 150^{o}C on the high. The shallow conductivity variations mapped by the dipole-dipole survey may thus be due to temperature differences of near-surface groundwater.

Note that for hydrostatic head, i.e., unconfined water such as probably exists here, fluid pressure increases at roughly 100 bars/km, and temperatures of 300-400^{o}C at depths of 2-3 km would result in relatively <u>resistive</u> material. Stanley et al (1976) hint at such temperatures and a linear extrapolation of temperature and gradient observed at the bottoms of holes 1-29 and 44-5 comes near to 300^{o}C at depths of 3 km. This speculative mechanism would provide an explanation for several aspects of the remarkably uniform geoelectric section observed in the MT data over this demonstrably heterogeneous and structurally complex area, in addition to misinterpretation

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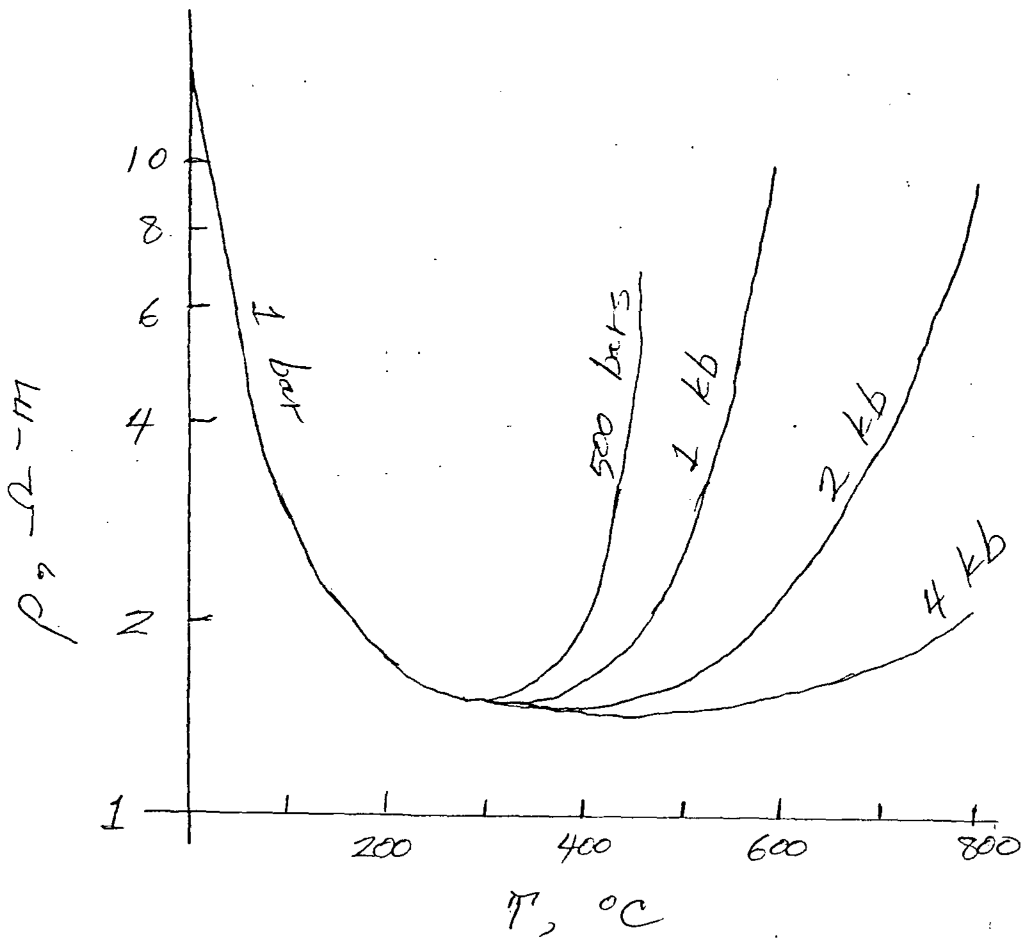

Figure 4

Resistivity of 0.01 M NaCl solution as a function of temperature. After Quist & Marshall, 1969.

due to three-dimensional effects.

Salinity of the pore fluids has a direct influence on their conductivity, since

$$\sigma_{\text{fluid}} = \alpha \sum_i n_i z_i$$

where

N_i = number of ions of ith species present

Z_i = valance of ith species

α = proportionality constant incorporating various physical constants and water properties
the summation is taken over all species present

In many geothermal systems, the hydrothermal fluids are considerably more saline than other nearby fluids. At Soda Lake-Stillwater such may not be the case however. This is the basin for a large region of internal drainage and the remnant of a Pleistocene lake and the groundwaters are naturally quite saline. Soda Lake, for example, has salinites to 61,000 milligrams/litre and well waters are reported in the range 600 to 6,000 mg/l (Olmstead, et al, 1975).

Fresh water influx from surface sources and outflow to the even more saline Carson Sink complicate the situation, making groundwater salinites variable independently of the geothermal waters.

Increased porosity greatly enhances conductivity as expressed in the familiar Archie's Law

$$\sigma_{rock} = \sigma_{water} \phi^{m}$$

where

σ = conductivity

ϕ = porosity

m = an empirical parameter dependent upon petrofabric, usually in the range $1 \leq m \leq 2$

In systems of uniform natural porosity, hydrothermal dissolution of rock matrix can produce anomalous conductivity increases through porosity effects alone. Soda Lake-Stillwater rock porosities are innately highly variable. The Tertiary and Quaternary sediments are terrestrial deltaic and lacustrine deposits with a large range of porosities on all geometric scales. Dikes, sills, and intercollated volcanics further complicate the situation. The basement rocks, being largely volcanics, are also predictably inhomogeneous. Thus porosity variations are anticipated to serve poorly as a guide to hydrothermal sources and reservoirs at Soda Lake-Stillwater KGRA.

Clay content is also anticipated to have a poor spatial correlation with hydrothermal activity for reasons similar to those cited for porosity. Clay distribution is predominantly due to sedimentary processes, not hydrothermal ones. Clays increase rock conductivities by allowing surface conduction between ion exchange sites within their lattices. Waxman and Smits (1968) give the following formula for the influence of clays on rock conductivity.

$$\sigma_{rock} = \phi^m(\sigma_{water} + BQv)$$

where, in "practical units", $B = 3.83 \left\{1-0.83e^{-1/2\,\sigma_{water}}\right\}$

where

σ, ϕ, & m are as in Archie's Law

and

Q_v = ion exchange capacity of a rock in equivalents per litre of pore volume, dependent upon types of clays present and to the amount of each type

In regions of highly conductive pore waters, the clay content may dominate rock conductivity. Assuming a plausible 1 ohm-m for fluid resistivity at Soda Lake-Stillwater, variations in the second term in the above formula will be twice as important as variations of the first. Waxman and Smits (1968) report Q_v values ranging over a factor of 200 (i.e., from 0.01 to 2.0), which is of the same order as the range of water conductivities. Thus rock resistivities may be expected to be as strongly influenced by irregular sedimentary variations as by thermal effects at the Soda Lake-Stillwater KGRA.

W. Frangos

W. Frangos

WF/smk

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GEOLOGY

The Soda Lake-Upsal Hogback area is located on the west side of the Carson Desert which is a large Quaternary basin in west central Nevada. The basin is oval in form, extending about sixty miles northwest with a width of twenty-five miles. The bedrock in the mountain ranges bounding the basin is mostly Tertiary volcanic rock with Mesozoic sediments and igneous rock around the north part of the basin. The structural setting is basin and range with north-northwest trending normal faults dominant.

The basin sediments consist of fluvial, lacustrine, deltaic and eolian deposits. Alluvial fans constitute most of the sediments two to three miles out from the mountain front and may have extended further during long inter-lake periods. These sediments have been reworked to some extent into various beach deposits. Morrison (1964) gives a detailed description of these deposits.

Most of the sediments in the interior part of the basin, including the Soda Lake area, have been supplied by the Carson River. The Quaternary stratigraphy in the basin is the result of the character and mode of deposition of these sediments.

Morrison (1964) has subdivided the Lake Lahontan sediments into several formations. Most of these formations are best exposed as beach deposits and their deep lake or mid-basin equivalents are poorly exposed. The Wyemaha formation (Morrison, 1964, p. 34) consisting mostly of fine sand with minor silt and clay, is exposed widely around the Upsal Hogback.

Within a mile or two of the Upsal Hogback, basaltic sand is a major component of the unit.

On Upsal Hogback and around Soda Lake the Sehoo formation forms the present surface. The Sehoo formation is deep lake sand, silt and clay. The surface of both the Sehoo and Wyemaha is currently being reworked and covered by sand dunes.

Subsurface information in the Soda Lake area comes from four holes: Carson Sink 1 (Horton, 1978) and Soda Lake 44-5, 1-29 and 36-78 drilled by Chevron Resources (Chevron Data Package, 1978). The most abundant sediment type is poorly sorted lithic sand and tuffaceous sand and mudstone with silt, gravel and clay fractions. The coarse sediments are probably deltaic, channel and alluvial fan deposits of the Carson River. Silt, mudstone and clay units are lacustrine and playa sediments. The tuff fraction is probably waterlain with some possible airfall into a lake. The contacts appear gradational, at least as seen in ten to thirty foot sample intervals. The gravel beds found in Soda Lake 44-5 and Carson Sink 1 are probably channel deposits. Gravel beds were not found in Soda Lake 1-29, two miles north of Soda Lake, but cuttings are not available for the upper 1,000 feet and there may be gravel zones in this interval. The few clean sand zones may be beach deposits.

STRATIGRAPHY

Because of the nature of the sediments and laterial facies changes, correlation between holes is very difficult but several conclusions can be made. The Quaternary sediments are 4,600 feet thick under the west of

Soda Lake and overlay Pliestocene Bunejug basalt flows. Two miles north of Soda Lake the basement rock is gabbro and six hundred fifty feet higher.

The following stratigraphy is drawn from the Carson Sink 1 and Soda Lake 44-5 cuttings. Tuffs and tuffaceous sand and mudstone are predominant in the lower half of the Quaternary sequence. The basal eight hundred feet is poorly sorted mudstone, sand, silt and tuff. This is overlain by two hundred feet of organic rich, laminated mudstone which may represent the first lake event or a deltaic swamp. A channel gravel has replaced most of the mudstone unit in Soda Lake 44-5. Above the organic rich mudstone is two hundred feet of sand and mudstone which may also be lacustrine. Above these units is 2,400 feet of poorly sorted sand, mudstone and siltstone with a few beach and channel deposits. Individual units do not correlate between holes. The material is probably both delta and alluvial fan deposits. Above this is one hundred forty to two hundred forty feet of clay and mudstone with its base at a depth of about one thousand feet. This unit probably represents a major lake event and is overlain by two hundred feet of delta gravels and sand. The lake sediments are thicker to the northeast and the delta sediments thicker to the southwest. The delta gravels are overlain by forty to ninety feet of beach and fluvial sand. The upper five hundred feet are deltaic and fluvial deposits. Lake Lahontan sediments are within the upper three hundred feet but could not be distinguished.

The sediments in Soda Lake 36-78, a two thousand foot hole two miles northeast of Soda Lake, are similar to those just described, but gravel less abundant. The sediments in Soda Lake 1-29, just half a mile northwest of 36-78, are generally finer than the two holes to the south. Most of the hole is silty and sandy mudstone formed from tuffaceous material. The conclusion here is Soda Lake 1-29 is in the lake or playa facies of deposition. The fine tuff material which was removed from or carried beyond the delta-fan area was deposited in the lake or basin while coarser deltaic and beach sediments accumulated to the south.

IGNEOUS ACTIVITY

Another unique feature of 1-29 is two basalt dikes between 1,300 feet and 1,650 feet deep. The fault contacts, alteration of ajoining sediments and lack of vesicles suggest they are dikes rather than flows.

Upsal Hogback, seven miles northeast of Soda Lake, is composed of overlapping basaltic tuff cones. Morrison (1964, p. 38) thought the cones were of Wyemaha age which would be 30,000 to 45,000 years old. The basaltic tuff is olivine-rich, mostly sand to pebble-size and was deposited subaerialy (Morrison, 1964, p. 38).

Soda and Little Soda Lakes occupy craters formed by multiple phreatic explosions and volcanic eruptions. The crater rim consists of volcanic sand, lapilli and lacustrine deposits (Morrison, 1964, p. 71). The last eruption was subaerial and post dated the last lake rise to that level.

The basaltic dikes in Soda Lake 1-29 may be related to the Upsal Hogback and Soda Lake volcanic activity. The dikes consist of non-porphyritic pyroxene basalt however, while the Upsal Hogback lapilli contain abundant olivine phenocryst.

FAULTING

Morrison (1964) mapped three faults on the south edge of Soda Lake, striking northeast with the west side down. Two north-south faults extending two miles south from Upsal Hogback were also mapped. The Sagouspe fault, which trends N25^{o} W, is a few miles east of the Soda Lake-Upsal Hogback area. The fault has up to ten feet of vertical displacement down to the east and a nine mile trace.

ALTERATION AND SINTER DEPOSITS

Hot springs deposits and alteration are very limited in the Soda Lake area. At the old steam well, two miles north of Soda Lake, the soil has been altered to kaolinite and iron oxides or hydroxides (Olmsted and others, 1975, p. 103). The present investigator found the alteration to extend about two hundred feet to the section-line road west of the steam well (Plate 1) and less than a hundred feet to the east where a sand dune covers the alteration. Over most of the area the iron oxide coloration is subdued and nearly covered by eolian sand. In the low area around the steam well, shallow hand dug pits have exposed brightly colored alteration a few inches below the surface. Vapor was escaping from a caved hole which is probably the old steam well.

Several small areas of sinter cemented sand form low knolls to the west of the steam well, in the SE 1/4 of section 29 and the NE 1/4 of section 32. The sand is clean, moderately sorted, coarse to very fine lithic arkose or lithic orthoquartzite and is cemented with opal. Silica replaced grass stems are abundant in some samples and silicified brush stems are also present. A thin rind of chalcedonic sinter is present on some of the outcrops; and sinter filled fractures were found at one location. The extent of erosion of the outcrops suggest sinter deposition ceased hundreds or thousands of years ago. Sand dunes have partly covered some outcrops. Alteration produced coloration was not evident in the sinter cemented sands.

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February 21, 1979

MEMORANDUM

TO: Dennis Nielson & Howard Ross

FROM: Bruce Sibbett

SUBJECT: Report on Trip to Soda Lake, Nevada

While at the Nevada Bureau of Mines and Geology, I learned that a second open file report on the Carson Sink #1 hole (NURE Project) was available. A copy of this report was obtained and the cuttings on file were compared with the lithologic descriptions. This log was found to be satisfactory. The report also includes thin section descriptions. A slice of the core from the bottom of the hole (8502') was obtained. The lithologic descriptions for the U.S.G.S. O.F. Rep. GJBX - 53(78) were done by Ed Bingler, formerly with the Nevada Bureau of Mines, now with the Montana Bureau of Mines. Ed Bingler has logged the cuttings from many holes in the Carson Desert, including Chevron's. He will be publishing a report on correlations within the sink, but the date for publication has not been set.

I talked with Dick Benoit and Bob Forest of Phillips at their office in Reno. Dick Benoit has been in charge of Phillip's work at Brady (Desert Peak) KGRA. He will publish a case study based on Phillips information next fall as a Nevada Bureau of Mines & Geology publication. Included with this publication will be the mapping which John Heiner did for his thesis. Heiner will have his thesis defense in a couple of months, after which it should be public information. Heiner is working for Phillips and was out of town when I was there. John Heiner will be giving a talk on Desert Peak at the Reno GRC next September.

I discussed geophysical methods in geothermal exploration with Dick Benoit and his boss (district geologist?) Bob Forest. They have looked at Chevron's data for Soda Lake. They made the comment that Seismic work was of "no value" in the Basin and Range Province. Benoit said that Phillip's vibroseis survey at Roosevelt Hot Springs failed to even find the range front fault. They also felt that MT was not useful. Dick Benoit said that he "hadn't seen a MT survey in the Basin and Range that didn't show a magma chamber at depth", implying that the method or its interpretation indicated magmas which did not actually exist. In reference to resistivity they thought that there were too many near surface factors such as salinity variation, surface thermal springs, etc. for the method to indicate the thermal reservoir. Rush (1972, Hydro. recon. Soda Lakes) reported that 900,000 tons of salts have been lost from Soda Lake in the last 70 years. This salt has probably moved into aquifers to the north.

I would strongly recommend that you call Mr. Forest and Benoit (702-386-2273) and discuss their feelings about seismic and other methods in geothermal exploration.

The most interesting thing that I found in the field was several small areas of silica cemented sand north of Soda Lake, near the Soda Lake 1-29 hole. Some opal or chalcedonic material is present as well as silica replaced wood and grass. These outcrops and the small area of hematite stained alteration around the old steam well were mapped.

Bruce Sibbett
Bruce Sibbett

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Re e-m coupling effects in McPhar DIDI survey at Soda Lake.

$a = 2000$ ft, $f = 1/8$ Hz throughout.

Using theoretical coupling curves for a few typical cases, we find that resistivities are <u>under</u>estimated according to following factors

Case: n	Homog. Earth, $\rho = 2\frac{1}{2}\ \Omega$-m ($a^2 f/\rho = 2\times10^5$)	Thin, resis upper layer $\rho_1 = 12\frac{1}{2}, \rho_2 \cong 1\frac{1}{2}, D_1 = A/8$	Thick, resis upper layer $\rho_1 = 12\frac{1}{2}, \rho_2 \cong 1\frac{1}{2}, D = A/2$
1	.98	.95	1.01
2	.93	.86	.91
3	.87	.74	.78
4	.79	.63	.67
5	.71	.54	.60
6	.63	.48	.55

And, for lesser contrasts, it's not so bad, viz:

n	Thick resis upper layer, $\rho_1 = 10$, $\rho_2 = 5$, $D = A/2$ ($A^2 f/\rho = 2\times10^4$)	Thin resis upper layer = $\rho_1 = 10, \rho_2 = 5$, $D = A/8$ ($A^2 f/\rho_1 = 2\times10^4$)
1	1.0	1.0
2	.99	.99
3	.99	↓
4	.96	↓
5	.94	↓
6	.92	.92