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18 February 1973

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RECONNAISSANCE GEOLOGIC INVESTIGATION OF THE GEOTHERMAL POWER POTENTIAL OF LONG VALLEY, LASSEN COUNTY, CALIFORNIA

Purpose and Scope of Investigation

The most extensive and one of the more highly prospective geothermal resource sections of the United States is comprised of northeastern California, northwestern Nevada and adjacent portions of Oregon (Figure 1). As a result of recent studies of Sierra Valley by the writer for R. K. Summy, Inc., attention was focused on Long Valley which lies immediately to the east. Initial interest was enhanced by the knowledge of two widely separated, but little known hot springs situated in the valley.

This report is a geologic appraisal of the geothermal potential of that portion of Long Valley which lies north of Hallelujah Junction, section 11, T. 22 N., R. 17 E., Lassen County, California, as requested by R. K. Summy, Inc. of Long Beach, California.

A considerable research effort was undertaken by the writer in government, academic and private sectors. Where ever possible hydrogeologic, geophysical, geochemical and seismological data have been integrated into the report. Data retrieval trips were taken to Sacramento, Red Bluff and San Francisco, California and Carson City, Nevada. In addition two days were spent in the field taking water samples for analysis at the Desert Research Institute (Reno), questioning Long Valley inhabitants and undertaking a general geological reconnaissance.

Summary and Recommendations

Precisely on trend with the most promising geothermal prospects (KGRA's and others), situated along the extensive eastern flank of the Sierra Nevada, lies the Long Valley geothermal prospect. Here also, where the California-Nevada-Oregon prospective area broadens, long recognized thermal anomalies persist both to the east and west as well. Generally characterized by early Tertiary through Pleistocene volcanic activity, Long Valley straddles, and is intimately influenced by several structural features of regional importance. Numerous Pliocene and Pleistocene volcanic vents may be observed in the area, and evidence of continuing shallow magmatic activity and crustal disturbance is well-documented by frequent recording of seismic events.

The northerly trending and narrow valley is structurally and geomorphically controlled by pronounced Cenozoic Basin and Range faulting and uplift. The faulted main mass of the granitic Sierra Nevada batholith forms a formidable and relatively stable western flank to the valley. Although within the Basin and Range province, Long Valley lies directly within a major shear zone, which has developed by the stresses paralleling the Sierra massif. An intense shear zone of up to three miles in width is present through much of the valley, due to a directional diverstion of these stresses around the periphery of a separate granitic block or batholith on the southeast flank of the basin.

On two separate faults within this zone, and on the western flank of one of three recognized sub-basins within the valley, are two extensive thermal spring areas. The Seralegui Hot Springs and pools extend over a linear distance of 480 feet, with undeveloped and naturally flowing water of up to 130°F. Structurally on trend five miles to the north, a mild flow from fractured granodiorite and numerous alluvium seeps covering several acres, tests temperatures of up to 104°F at Fu Fu Hot Springs. Anomalous traces of arsenic, boron and fluorine in these springs point to a deep-seated magmatic source for these thermal waters.

Mapping by others provides a strong basis for expectation of multiple reservoirs. Below an estimated 4500 feet of Cenozoic rocks, the fractured and brecciated granitic basement, within the broad Long Valley shear zone, should be considered an excellent objective. The overlying Tertiary volcanics of 700 feet plus, and especially the younger Tertiary fluvio-lacustrine section of an estimated 3500 feet, provides a substantial potential reservoir with a cap rock of at least 500 feet of impervious diatomite and related fine-grained clastics.

A very conservative estimate of the most prospective area is considered to be not less than twenty to twenty-five square miles. All the primary regional and local aspects important to a geothermal producing area, including source of heat, structure, hydrology and presence of a reservoir and cap rock must be considered as being very favorable.

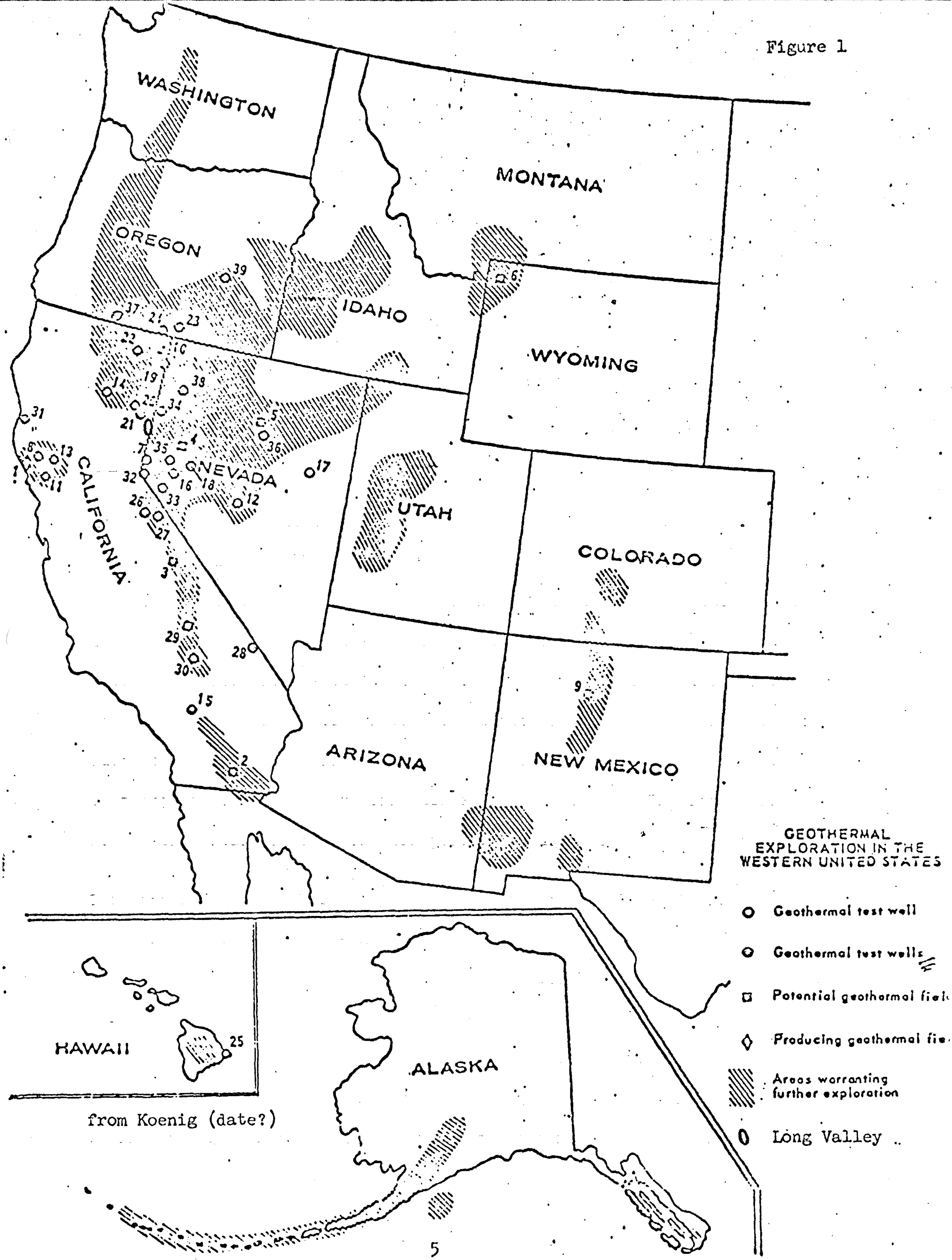
It is strongly recommended that the next natural step, prior to a drill test, be surface mapping supported by better structural definition through geophysical surveys in the primary target area as outlined. Field reconnaissance northward to the edge of Honey Lake Valley (Constantia-Doyle sub-basin) is definitely encouraged.

Introduction

Index maps of the western United States (Figure 1) and California (Figure 2) illustrate the location of the more promising geothermal prospective areas and some of the better known geothermal test wells, fields and springs. It is obvious that Long Valley is very favorably situated along the strong north-south trend which runs between Lower California and Washington. This belt retains its linear identity on the northeastern flank of the Sierra Nevada Mountains where it passes through a much broader prospective area in northern California and Nevada. The Long Valley hot springs fall directly on this geothermal lineation.

That portion of Long Valley considered in the study (Plate I) lies within the Chilcoot and Doyle 15-minute topographic quadrangles, along the Nevada state line. Over a distance of twenty-six miles, from Hallelujah Junction (elev. 5000 feet) on the south and Honey Lake Valley (elev. 4200 feet) on the north, the valley floor, as defined by a thick Tertiary-Quaternary section, varies from five miles to a few hundred yards in width. Vegetation, composed largely of sagebrush, grasses and scattered junipers,

Figure 1



from Koenig (date?)

covers a rolling to flat topography. A mean average annual rainfall of thirty-two inches on the higher slopes, is double the precipitation for the semi-arid valley which is bisected by the permanently flowing Long Valley Creek.

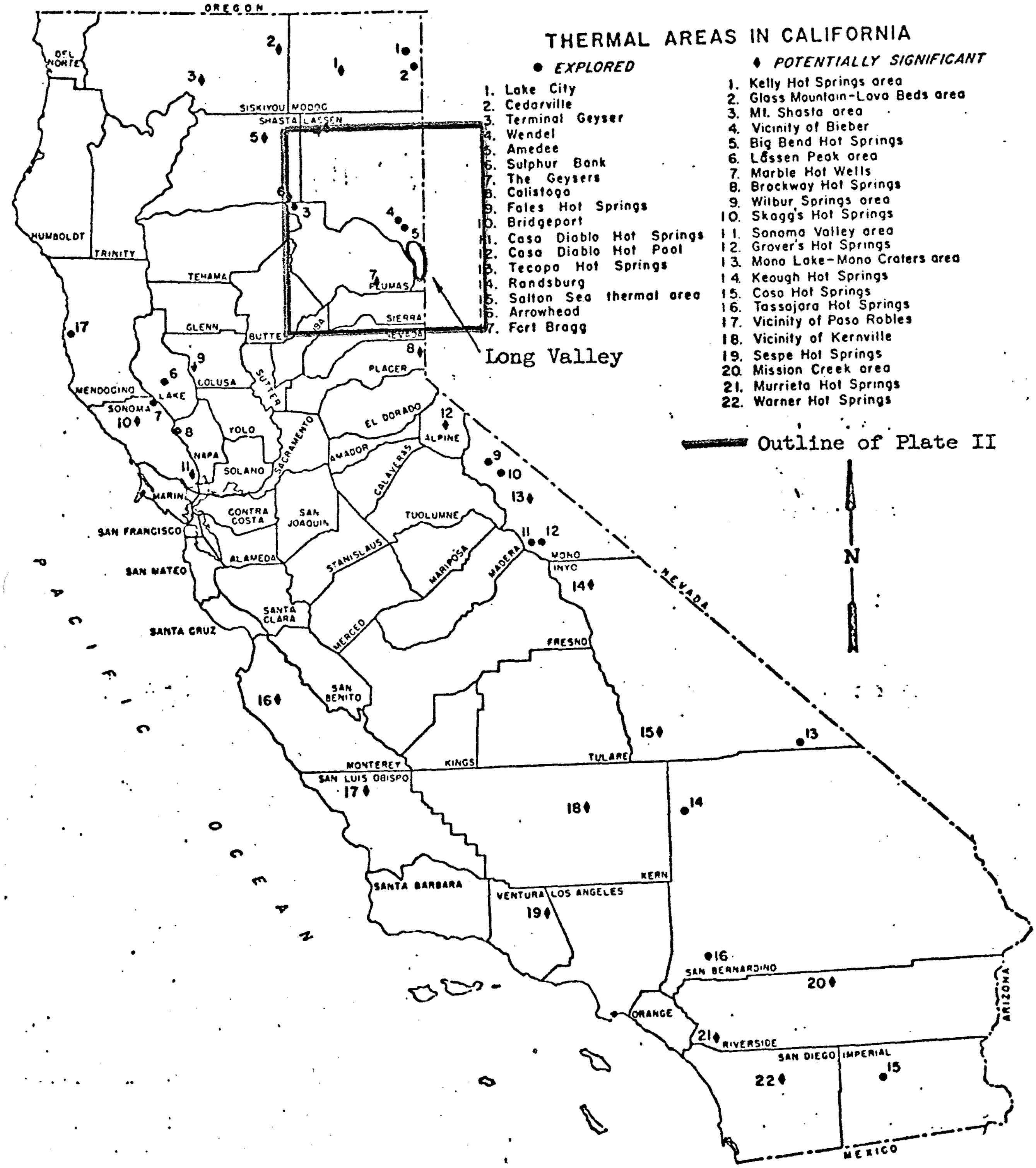
The sparce population is concentrated on a few ranches and isolated settlements along the Western Pacific Railroad and U. S. Highway 395. Cattle and sheep ranching, together with services to travelers, are the main sources of income for the residents of the valley.

Unlike many areas of California and Nevada, the subject region has seen no serious exploration for oil, and only minor sporatic minerals exploration and development. Being relatively unsettled and undeveloped, compared to a number of neighboring valleys, the density of water wells for subsurface geological and hydrologic data is minimal. Approximately two dozen wells were cited in government records and publications (Appendix A), and only half of these provided scanty data which was of value to this reconnaissance survey. Unfortunately the generally comprehensive Northeastern Counties Ground Water Investigation of the California Department of Water Resources, only touched on this basin.

Regional Structural Setting and Geologic History

The composite geologic map (Plate II; outlined on index map, Figure 2) includes the northeastern end of the granitic mass of the Sierra Nevada and Basin and Range structural province of Nevada. There is no true fine

Figure 2


THERMAL AREAS IN CALIFORNIA
● EXPLORED
1. Lake City
2. Cedarville
3. Terminal Geyser
4. Wendel
5. Amedee
6. Sulphur Bank
7. The Geysers
8. Calistoga
9. Fales Hot Springs
10. Bridgeport
11. Casa Diablo Hot Springs
12. Casa Diablo Hot Pool
13. Tecopa Hot Springs
14. Randsburg
15. Salton Sea thermal area
16. Arrowhead
17. Fort Bragg
♦ POTENTIALLY SIGNIFICANT
1. Kelly Hot Springs area
2. Glass Mountain-Lava Beds area
3. Mt. Shasta area
4. Vicinity of Bieber
5. Big Bend Hot Springs
6. Lassen Peak area
7. Marble Hot Wells
8. Brockway Hot Springs
9. Wilbur Springs area
10. Skagg's Hot Springs
11. Sonoma Valley area
12. Grover's Hot Springs
13. Mono Lake-Mono Craters area
14. Keough Hot Springs
15. Coso Hot Springs
16. Tassajara Hot Springs
17. Vicinity of Paso Robles
18. Vicinity of Kernville
19. Sespe Hot Springs
20. Mission Creek area
21. Murrieta Hot Springs
22. Warner Hot Springs
Long Valley
Outline of Plate II
N
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
DEL NORTE
SISKIYOU
MODOC
SHASTA
LASSEN
HUMBOLDT
TRINITY
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
MENDOCINO
LAKE
COLUSA
SUTTER
PLACER
SONOMA
YOLO
NAPA
SOLANO
SACRAMENTO
EL DORADO
ALPINE
AMADOR
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
SAN FRANCISCO
TUOLUMNE
ALAMEDA
STANISLAUS
MARIPOSA
MADERA
MONO
INYO
SAN MATEO
SANTA CLARA
SANTA CRUZ
MERCED
FRESNO
SAN BENITO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL

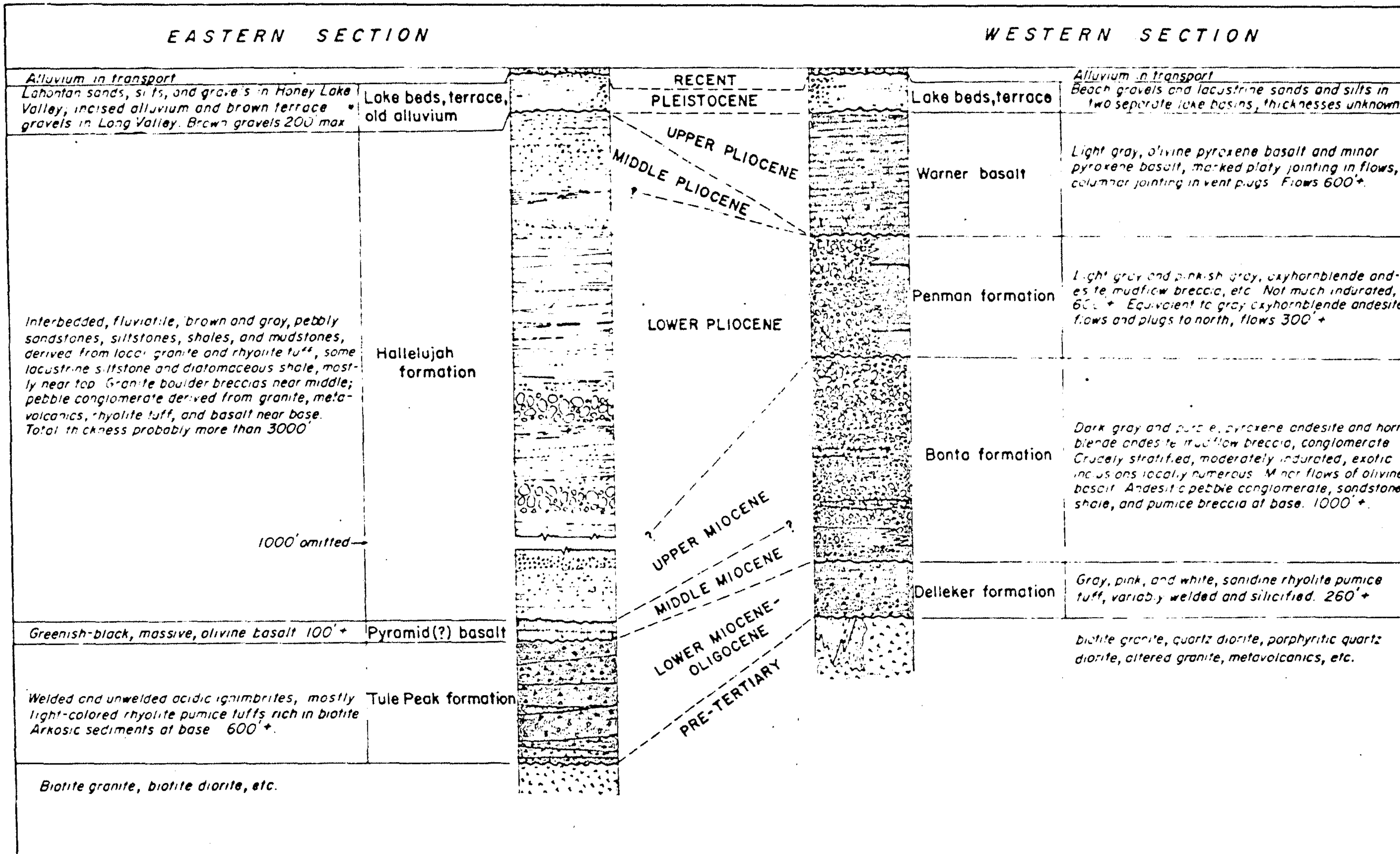
line which neatly separates the two provinces. Rather, the monolithic granitic batholith in the southwest quadrant of the map, becomes severely block-faulted over a twenty to thirty mile wide zone (outlined on two sides by black tape), as one moves in a northeasterly direction. The strongly developed northwesterly trending fracture pattern is the westernmost development of the deep-seated, high angle normal faulting of the Basin and Range province. The eastern boundary of this transition zone is coincident to the Pacific drainage divide.

The Great Basin interior drainage, so typical of Nevada, lies to the east (northeast half of Plate II). Here the elongate, northerly trending mountain ranges are often volcanic-capped, granitic segments of the Sierra Nevada massif (or genetically related, but smaller batholiths or stocks). Where the larger, more equidimensional blocks or batholith masses exist, they appear to have invariably acted as islands of interference to the shearing stresses which parallel the main Sierra Nevada mountain massif. The wide blue tape on Plate II shows where extensive fault displacement was observed following the formidable Sage Mountain earthquake of December 1950.

It is at this structural juncture where the northwest trending Honey Lake fault zone meets a northerly to northeasterly trending fault zone (Plate I). Both fracture sets have been observed to offset the other. Just ten miles to the southeast of the Sage Mountain dislocations lies a regional feature having a circular form, approximately six miles in diameter (Plates II and III, ERTS satellite photo). Originally recognized on satellite photos, and subsequently publicized in Life magazine, there was conjecture that this land form was due to meteor impact. On the contrary, this circular feature is undoubtedly a faulted, and essentially autonomous granitic unit (referred to below as the Washoe batholith), which has been parrying shearing movements, tangential to the Sierra Nevada batholith since at least early to middle Tertiary time. A shear zone (of up to three miles in width in Long Valley) has developed on the periphery of the Washoe batholith during this same time interval. The resultant regional, grossly arcuate displacements on a larger scale, and the accompanying finer scale massive crushing, which immeasurably hastens erosion within the zone, have together produced the circular structural feature.

A record of some of these deep-seated stresses in the form of earthquake epicenters, is shown on Plate II. The pattern of historical and more recent earthquakes from Sage Mountain southward, shows very well the subcrustal disturbances (including probable shallow magmatic activity) leading to and around the periphery of the Washoe batholith.

It is due to the complex structural history from at least the Jurassic period to the present, and the masking effect of the Tertiary volcanics, that little is known of the Paleozoic and early Mesozoic age rocks. The orogenesis which accompanied the emplacement of the Sierra Nevada pluton during later Mesozoic to earliest Tertiary, has left the pre-Laramide volcanic and sedimentary sequence as metamorphosed, faulted pendants and septa within the more granitic basement (Plates IV and V). These plates illustrate the more detailed mapping of Van Couvering (1962) and his



CENOZOIC STRATIGRAPHY AND CORRELATION, CHILCOOT QUADRANGLE, CALIFORNIA

PLATE II

John A. Van Couvering November 1960

recognition of separate Eastern and Western stratigraphic sequences within the Chilcoot quadrangle.

Until Middle Miocene time the Eastern section (i.e. the Long Valley section) had much the same history as Sierra Valley just to the west. Intensive erosion of the ancestral Sierras continued until probable Oligocene-lower Miocene when successive layers of the Delleker volcanics and the Tule Peak ignimbrites blanketed the area, from the west and east respectively. Subsequent uplift and tilting to the west of the main and lesser granitic blocks of the Sierra Nevada batholith, caused or intensified the formation of Long Valley and its final separation from the main depositional record west of the Pacific drainage divide. From mid-Tertiary on, the Western section received thousands of feet of tuffs, mudflow breccias and minor basalt flows of the Bonta and Penman formations and the Warner basalt. These rock units, though not continuous with, have volcanic equivalents in much of nearby Nevada.

Long Valley Structure and Stratigraphy

On the east flank of Long Valley, beginning with the Tule Peak formation, the distribution and thickness of these outpourings varies greatly due to the faulting, tilting, uplift and minor folding which accompanied deposition. For example, McJannet (1957) identified not less than twenty rhyolite tuffs in the Tule Peak formation, which in Long Valley is present on the east slope but not on the west slope, which is occupied by the Delleker formation of equivalent age, but of a wholly different source.

The overlying Pyramid(?) basalt has been found as forty-foot thick outcrops, also on the eastern side of the valley, and up to 100 feet thick just above on Peterson Ridge. There is no direct evidence to tell the thickness of this and older volcanics beneath the valley floor of overlapping basal sandstones of the Lower Pliocene Hallelujah formation and younger sediments.

The Hallelujah formation of Van Couvering (1962) is similar to many of the fluvio-lacustrine deposits of the Great Basin (Table 1). He states that:

> Most of the...formation is fluvatile debris from the granite and rhyolite tuff exposures in the Long Valley area, that was deposited in interlayered, lensing bodies of arkosic pebbly sand, gray silty sand, mica-rick sandy silt, and silty mud and clay. The lower part of the formation is marked by beds of sandy pebble and cobble conglomerate, and in northern Long Valley two horizons of granite boulder breccia are about midway in the section. Lacustrine, diatomaceous sediments occur mostly at the top of the section...exposures in the southern part of the valley are poor, and marker beds such as the granite boulder breccia are either missing or obscured.
>
> The Hallelujah formation rests with an angular unconformity of from 15° to about 45° on the Tule Peak rhyolite tuffs on the east side of Long Valley, and on Peterson Ridge it overlaps onto the granodiorite basement. South of the quadrangle boundary, the formation overlies Miocene Pyramid(?) basalt at the southern end of Peterson Ridge. The older Tertiary rocks dip steeply basinwards under the Hallelujah, and they probably underlie it in considerable thickness in the central part of the valley.

While diatomaceous interbeds are exposed at several horizons in the formation, Van Couvering has found impermeable, massive-bedded diatomite beds principally on the east side of Long Valley Creek, about six miles north of Hallelujah Junction, where they are capped by Quaternary terrace gravel:

...the lacustrine deposits at this place are interpreted to form a major unit at the top of the Hallelujah section (Table 1) because they occur in what appears to be the present structural axis of the basin, and because they apparently do not correlate with the much thinner diatomaceous beds near the base of the formation.

Table 1.* Stratigraphy of the Hallelujah formation in northern Long Valley

Description	Thickness (feet)
(UNCONFORMITY)	
White and yellow diatomaceous shale diatomite, minor sand	500 plus
Interbedded arkosic sandstone, shale, siltstone, and mudstone	500-600
Granite boulder breccia	100
Interbedded arkosic sandstone, shale, siltstone, and mudstone	500-600
Granite boulder breccia	100
Interbedded arkosic sandstone, shale, siltstone, and mudstone	1000
Pebble-cobble conglomerate	50
Interbedded arkosic sandstone, siltstone, diatomaceous shale, and pebble conglomerate	500
(UNCONFORMITY)	
	Total 3450 plus

* from Van Couvering (1962)

The boulder beds (Plate I and IV) have been interpreted as being the product of rapid uplift and erosion of the west side of the valley - probably from Honey Lake Valley south to just a few miles north of the junction.

Further southward the absence of the boulder breccia and the prevalence of conglomerates indicates this part of the depositional basin is shallower and therefore less tectonically active.

As outlined above the structure and resulting depositional history of Long Valley is complex, but Van Couvering (1962) was able to make some generalizations:

> With very few exceptions, the fault planes appear to dip steeply, from about 80° to vertical. The total slip, or cumulative movement, on most of the faults is probably greater than the net slip, since repeated reversal of movement has been common on the faults which cut Tertiary formations (see section C-C', Plate IV). Pleistocene movement on some of the faults in the escarpments may have been as much as 1,000 feet, but few of the faults in Tertiary strata appear to have displacements in excess of 200 or 300 feet, and most have much less. No strike-slip displacement on any fault was observed; the mapped fault pattern appears likely to have developed as a result of nearly vertical movements.

Sub-Basins in Long Valley

Three rather well-defined segments of the twenty-six mile long structural basin can be defined:

1. Constantia-Doyle Sub-Basin. From the structural/topographic basin constriction about two miles south of Constantia, north to Honey Lake Valley, the valley floor is flat, undissected, and essentially Quaternary covered. Coupled with the Bouger Gravity Anomally Map of Honey Lake Valley (Overlay I to Plate I), it is safe to assume that this sub-basin is deep and has not been subjected to the post-middle Pliocene westward tilting that the Red Rock and Hallelujah sub-basins have been. A thick section of Hallelujah formation can be expected beneath the Quaternary

veneer.

2. Red Rock Sub-Basin. From the granite pass just north of Red Rock, south to the termination of the granite boulder breccia outcrops (Plate I), the Red Rock segment has a 3450-foot measured section of Hallelujah formation. Tilting of the sequence is impressive, with the bedding regionally striking parallel to the north-northeast to northeast trending faulting which forms a band up to three miles wide across the sub-basin. These numerous (as mapped by Van Couvering) dislocations are post-middle Pliocene, at least in part, and constitute the later movements within the aforementioned deep-seated fault zone found on the periphery of the Washoe batholith. As stated above the two boulder breccia beds, each approximately 100 feet thick, indicate very active tectonism that is probably obscured in the Constantia-Doyle sub-basin and is absent in the Hallelujah Junction sub-basin.

The two geothermal areas, Seralegui Hot Springs and Fu Fu Hot Springs, issue from or near the granitic/sedimentary contacts along this trend (Plate I).

3. Hallelujah Sub-Basin. Contiguous with and having no striking separation from the Red Rock sub-basin on the north, the Hallelujah segment is characterized by probable finer-grained clastics and a thinner Hallelujah section. Topographic and structural relief is less intense than that in the two northern sub-basins.

Seralegui and Fu Fu Hot Springs

Seralegui Hot Springs. About five feet above and eighty feet west of Long Valley Creek, in section 10, T. 23 N., R. 17 E., a good flow of 130°F water flows from highly fractured, unaltered granodiorite. Four hundred and eighty feet to the north there is a second spring of 126.5°F, also flowing from highly fractured granodiorite. Both springs are controlled by a single regional fault. At the spring site the western, upthrown block is a steep-sloped granodiorite hill, while the downthrown side is alluvial covered and holds the hot water ponds between the fault and Long Valley Creek.

Mr. Ray Hintz of Doyle, a relatively new valley resident, and owner of Fu Fu Hot Springs, recalls that Mr. Pete Zamboni, also of Doyle, used to scald hogs in 158°F water at these springs prior to the filling of Frenchman's Dam (seven air miles to the northwest, Plate I).

Fu Fu Hot Springs. Beneath the Western Pacific Railroad trestle in section 24, T. 24 N., R. 17 E., warm water of 104°F seeps from at least three orifices of largely alluvium-covered granodiorite. In an easterly direction down slope, there are several more warm water seeps in the boggy ground. These spring too, ran warmer up until a few years ago according to Mr. Hintz.

Water Quality Analyses

Appendix A shows the results of the gross and trace water analyses run on bulk spring water samples collected by the writer, and analysed within a few days by the Desert Research Institute, University of Nevada, Reno. The results show that there is a close similarity to the geothermal springs of Sierra and Honey Lake Valleys and other geothermal areas.

Background reference water quality samples are not available, but the tests on several of the water wells provide a negative or very low contrast in fluoride, arsenic and boron. The single exception is the well located in the SW$\frac{1}{4}$SW$\frac{1}{4}$ of section 21, T. 25 N., R. 17 E., in the Constantia-Doyle sub-basin, which tested 3.8 ppm fluoride on a normal temperature of 57°F.

Reservoir and Cap Rock

The primary area of interest must be considered to be within the Red Rock sub-basin, on strike with and around the Seralegui - Fu Fu Hot Springs geothermal trend. This linear trend is very favorable in that it lies entirely within the fault zone bordering the Washoe batholith. Within this zone, as previous mentioned, shearing has caused extensive fracturing of the basement, and to a progressively lesser extent, the younger Tertiary section above it.

Under the abnormally hot conditions which probably exist in the pre-Tertiary basement, dissolution of silica by the circulating hot fluids through the highly fractured rock, could be expected to further increase the porosity and permeability over a wide area (see prospective area outlined in red tape, Plate I).

The 700-foot plus section (Plate V) lying unconformably on the basement rocks is a volcanic sequence of welded tuffs, unwelded tuffs and basalts, which should provide an impermeable cap rock to a basement reservoir. It should be noted also that studies of tuffs over much of Nevada have found them to be capable of acting as good reservoirs as well (Eagle Springs oil field, Nye County, Nevada).

The Mio-Pliocene Hallelujah clastics, as mapped and described by Van Couvering (1962) provide an ideal reservoir relationship over better than 3450 feet. The dominance of coarser-grained clastics with some minor finer-grained interbeds in the lower 3000 feet of the section presents a very favorable geothermal reservoir target. Diatomaceous shale, diatomite and minor sand of greater than 500 feet in thickness would provide an ideal cap rock.

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APPENDIX A

Laboratory Report
Gross Water Samples

Sample F.....Fu Fu Hot Springs
Center, Sec. 24, T. 24 N., R. 17 E.
Sample S.....Seralegui Hot Springs
$SW\frac{1}{4}$, Sec. 10, T. 23 N., R. 17 E.

Water Analysis Laboratory
Center for Water Resources Research
Desert Research Institute

Date: Mid-October, 1972

Sample Designation	Sample F		Sample S		Sample F		Sample S			
pH	9.18		9.21							
TDS (Summation)	231.09		340.13							
Conductivity (μmhos/cm @25°C)	299.8		510.7							
	epm	mg/l	epm	mg/l	epm	mg/l	epm	mg/l	epm	m
HCO_3^-	0.311	18.98	OH^- 0.033	OH^- 0.56	Arsenic	0.015	Arsenic	0.079		
$CO_3^=$	0.912	27.38	1.078	3237	Boron	0.56	Boron	1.34		
Cl^-	0.414	14.7	0.917	32.5	Iron	0.01	Iron	0.045		
$SO_4^=$	1.176	56.51	2.630	126.3	Lithium	0.06	Lithium	0.20		
F^-	0.061	1.15	0.189	3.6						
NO_3^-	0.010	0.62	0.002	0.11						
$PO_4^=$	0.005	0.15	0.005	0.17						
Total Anions	2.889		4.854							
Na^+	2.799	64.33	4.673	107.5						
K^+	0.030	0.50	0.047	1.82						
Ca^{++}	0.112	2.25	0.125	2.5						
Mg^{++}	0.002	0.02	–	<0.01						
Total Cations	2.916		4.845							
SiO_2		44.5		32.7						
Anions/Cations	0.991		1.002							

TABLE 7

ANALYSES OF GROUND WATER
HONEY LAKE VALLEY AREA

Mineral constituents in parts per million / equivalents per million

Well number	Date sampled	Water-bearing formation[a]	Depth in feet	Water class	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Silica (SiO_2)	Other constituents[b]	Total dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks[c]
26N/16E-21J2	6/10/58	Qps	53	1	59	400	7.7	52 / 2.59	19 / 1.56	22 / 0.96	2.8 / 0.07	0 / 0.00	255 / 4.25	7.9 / 0.16	13 / 0.37	0.4 / 0.02	36 / 0.58	0.00	63	Fe 0.00	341	19	210	0	D
-35P1	6/10/58	Qal		1	57	260	7.6	38 / 1.90	7.3 / 0.60	22 / 0.96	1.8 / 0.05	0 / 0.00	192 / 3.15	1.3 / 0.03	7.5 / 0.21	0.4 / 0.02	5.7 / 0.09	0.00	42	Fe 0.06	221	27	124	0	D, Spring
27N/14E-6C1	7/15/58	Qf	30*	1	55	218	7.7	26 / 1.30	5.6 / 0.46	9.4 / 0.41	3.0 / 0.08	0 / 0.00	122 / 2.00	2.1 / 0.04	2.4 / 0.07	0.2 / 0.01	6.7 / 0.11	0.00	42	Fe 0.01	157	18	88	0	D, I
-16F1	7/9/58	Qps	32	1	58	194	7.8	22 / 1.10	3.9 / 0.32	11 / 0.48	0.8 / 0.02	0 / 0.00	88 / 1.44	4.8 / 0.10	4.0 / 0.11	0.2 / 0.01	15 / 0.24	0.01	40	Fe 0.02	145	25	71	0	D
-21A1	7/15/58	Qps		1	66	108	7.0	9.1 / 0.45	1.8 / 0.15	11 / 0.48	0.9 / 0.02	0 / 0.00	60 / 0.98	2.0 / 0.04	1.4 / 0.04	0.1 / 0.01	0.7 / 0.01	0.00	36	Fe 0.07	93	44	30	0	D, I, Spring
-23J1	8/22/57	Qal, Qps, Qpl	457	2	62	280	6.6	15 / 0.75	4.5 / 0.37	41 / 1.78	1.9 / 0.05	0 / 0.00	145 / 2.38	13 / 0.27	4.4 / 0.12	0.5 / 0.03	1.9 / 0.03	0.11	43		196	60	56	0	I
-24A1	7/18/58	Qf	21	1	53	325	8.2	39 / 1.95	5.0 / 0.41	20 / 0.87	2.7 / 0.07	0 / 0.00	147 / 2.41	15 / 0.31	8.8 / 0.25	0.5 / 0.03	18 / 0.29	0.06	37	Fe 0.02	218	26	118	0	D
-26E1	7/18/58	Qf, Gr	202	1	60	198	7.2	20 / 1.00	1.0 / 0.05	17 / 0.74	2.5 / 0.06	0 / 0.00	75 / 1.23	13 / 0.27	5.4 / 0.15	0.2 / 0.01	12 / 0.19	0.00	49	Fe 0.01	157	39	54	0	D, C
	9/8/59			1	--	193	7.6	19 / 0.95	2.1 / 0.17	16 / 0.70	1.7 / 0.04	0 / 0.00	72 / 1.18	15 / 0.31	6.2 / 0.17	0.0 / 0.00	12 / 0.09	0.00	51	Al 0.04: Cu 0.06: Zn 0.12	158	38	55	0	
27N/15E-30B1	8/23/57	Qal, Qpl	250	1	--	296	7.6	9.1 / 0.45	9.6 / 0.79	41 / 1.78	3.8 / 0.10	0 / 0.00	168 / 2.75	8.7 / 0.18	1.9 / 0.05	0.2 / 0.01	0.1 / 0.00	0.11	39		197	57	62	0	S
-32G1	6/11/58	Qf	100	1	54	180	7.0	24 / 1.20	4.6 / 0.38	8 / 0.35	2.4 / 0.06	0 / 0.00	89 / 1.46	14 / 0.29	3.0 / 0.08	0.2 / 0.01	7.3 / 0.12	0.00	40	Fe 0.04	147	18	79	6	D
27N/16E-11E1	6/11/58	Qpl, Tl	550	3	60	1880	7.6	126 / 6.29	18 / 1.51	206 / 8.96	17 / 0.43	0 / 0.00	142 / 2.33	81 / 1.69	470 / 13.25	0.2 / 0.01	11 / 0.18	0.30	55	Fe 1.2: Al 0.06: Mn 0.26: Cu 0.02	1030	52	390	274	D
	9/8/59			3	59	1920	8.3	133 / 6.64	18 / 1.46	264 / 11.48	19 / 0.49	2 / 0.07	136 / 2.23	184 / 3.83	462 / 13.03	0.4 / 0.02	9.1 / 0.15	0.30	52	Al 0.17: Mn 0.35: Zn 0.02	1210	57	405	290	
27N/16E-29D1	6/11/58	Tl		3	58	550	8.0	5.6 / 0.28	1.1 / 0.09	154 / 6.70	8.0 / 0.20	0 / 0.00	302 / 4.95	51 / 1.06	39 / 1.10	0.6 / 0.03	1.0 / 0.02	0.18	56	Fe 0.00	464	92	154	0	S, Spring
-35Q1	7/17/58	Qpl	540	1	63	540	8.3	29 / 1.45	12 / 0.99	60 / 2.61	8.8 / 0.22	4 / 0.13	182 / 2.98	76 / 1.58	18 / 0.51	0.6 / 0.03	2.5 / 0.04	0.23	54	Fe 0.18	354	50	122	0	M
-36Q1	6/11/58	Qpl	590	2	63	800	7.4	84 / 4.19	30 / 2.47	116 / 5.05	6.6 / 0.17	0 / 0.00	187 / 3.06	360 / 7.51	46 / 1.30	0.6 / 0.03	0.5 / 0.01	0.22	40	Fe 0.16	775	42	332	183	M
-36Q2	7/17/58	Qpl	430	1	63	931	8.3	66 / 3.29	24 / 1.94	97 / 4.22	6.0 / 0.15	2 / 0.07	185 / 3.03	255 / 5.31	44 / 1.24	0.6 / 0.03	0.4 / 0.01	0.28	45	Fe 0.48	633	44	259	103	M
	9/8/59			1	--	905	8.0	70 / 3.49	21 / 1.71	97 / 4.22	7.5 / 0.19	0 / 0.00	198 / 3.25	237 / 4.93	58 / 1.64	0.5 / 0.03	0.0 / 0.00	0.40	51	Al 0.07	649	44	260	98	

TABLE 7
ANALYSES OF GROUND WATER
HONEY LAKE VALLEY AREA

Well number	Date sampled	Water-bearing formation[a]	Depth in feet	Water class	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Silica (SiO_2)	Other constituents[b]	Total dissolved solids in ppm	Per cent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks[c]
								Mineral constituents in parts per million / equivalents per million																	
24N/17E-3M1	8/27/57	Qal	415	1	--	270	8.2	34 / 1.70	6.6 / 0.54	13 / 0.57	4.7 / 0.12	0 / 0.00	174 / 2.85	0.0 / 0.00	3.9 / 0.11	0.3 / 0.02	0.9 / 0.01	0.00	45		194	19	112	0	I
25N/17E-7R1	6/10/58	Qf	79	1	56	200	7.2	27 / 1.35	7.4 / 0.61	14 / 0.61	2.8 / 0.07	0 / 0.00	141 / 2.31	4.0 / 0.08	5.0 / 0.14	0.1 / 0.01	6.7 / 0.11	0.00	33	Fe 0.00	169	23	95	0	D, S
-17A1	6/10/58	Qf, Qb	90	1	61	345	7.6	29 / 1.45	11 / 0.90	35 / 1.52	9.0 / 0.23	0 / 0.00	200 / 3.28	15 / 0.31	20 / 0.56	0.6 / 0.03	1.8 / 0.03	0.14	60	Fe 0.26	279	37	119	0	D, I
-21N1	8/28/57	Qal, Qf	120	1	57	177	8.0	19 / 0.95	4.0 / 0.33	15 / 0.65	1.9 / 0.05	0 / 0.00	102 / 1.67	1.8 / 0.04	3.9 / 0.11	0.1 / 0.01	6.4 / 0.10	0.05	41		143	33	64	0	I
-21N3	8/28/57	Qal, Qpl	450	3	61	291	8.1	3.7 / 0.18	0.5 / 0.04	60 / 2.61	0.9 / 0.02	0 / 0.00	84 / 1.38	39 / 0.81	14 / 0.39	3.8 / 0.20	0.9 / 0.01	0.78	28		193	92	11	0	D
	9/8/59			3	--	288	7.5	3.6 / 0.18	0.6 / 0.05	54 / 2.35	0.3 / 0.01	0 / 0.00	84 / 1.38	43 / 0.90	4.2 / 0.12	3.2 / 0.17	0.4 / 0.01	1.0	27	Fe 0.18; Al 0.21; Cu 0.01	178	91	12	0	
-34L1	6/10/58	Qb, Qal	250	1	59	190	7.5	20 / 1.00	6.7 / 0.55	18 / 0.78	3.0 / 0.08	0 / 0.00	149 / 2.44	0.0 / 0.00	1.5 / 0.04	0.3 / 0.01	0.2 / 0.00	0.00	48	Fe 0.62	170	32	76	0	S
26N/15E-3F1	8/23/57	Qf, Qps, Qpl	505	1	62	198	7.4	16 / 0.80	3.4 / 0.28	19 / 0.83	3.3 / 0.08	0 / 0.00	100 / 1.64	13 / 0.27	1.3 / 0.04	0.1 / 0.01	0.5 / 0.01	0.05	33		139	42	54	0	I
	9/8/59			1	65	205	7.9	17 / 0.85	4.1 / 0.34	19 / 0.83	3.1 / 0.08	0 / 0.00	108 / 1.77	12 / 0.25	3.2 / 0.09	0.0 / 0.00	0.7 / 0.01	0.1	34	Fe 0.01; Al 0.04; Cu 0.01	146	40	60	0	
-11B6	9/15/58	Qal, Qpl	80	2	60	216	7.9	7.0 / 0.35	1.6 / 0.13	36 / 1.57	5.3 / 0.14	0 / 0.00	119 / 1.95	4.9 / 0.10	4.0 / 0.11	0.3 / 0.02	1.0 / 0.02	0.07	51	Fe 0.05	169	72	24	0	D
-11H1	6/10/58	Qal, Qpl	91	1	58	200	7.5	21 / 1.04	7.5 / 0.62	18 / 0.78	4.6 / 0.12	0 / 0.00	141 / 2.31	3.3 / 0.07	3.0 / 0.08	0.4 / 0.02	1.7 / 0.03	0.00	50	Fe 0.06	178	30	83	0	C
	6/10/58	Qpl	108	1	62	375	7.8	28 / 1.40	7.8 / 0.64	58 / 2.52	7.0 / 0.18	0 / 0.00	206 / 3.38	35 / 0.75	14 / 0.39	0.3 / 0.02	3.7 / 0.06	0.10	47	Fe 0.03	303	53	102	0	D
-4E1	6/10/58	Qpl	65	1	60	420	8.1	31 / 1.55	5.9 / 0.49	77 / 3.35	6.2 / 0.16	0 / 0.00	216 / 3.54	43 / 0.90	28 / 0.79	0.6 / 0.03	12.5 / 0.20	0.11	45	Fe 0.03	355	60	101	0	D
-9J1	6/10/58	Qal, Qpl	172	1	60	500	7.4	40 / 2.00	11 / 0.90	71 / 3.09	6.2 / 0.16	0 / 0.00	224 / 3.67	81 / 1.68	23 / 0.65	0.9 / 0.05	4.0 / 0.06	0.35	33	Fe 0.01	379	50	147	0	D
26N/16E-15E1	5/30/56	Qpl, Tl	700	1	57	559	7.2	41 / 2.05	11 / 0.93	66 / 2.87	4.1 / 0.10	0 / 0.00	208 / 3.41	82 / 1.71	18 / 0.51	0.6 / 0.03	6.3 / 0.10	0.34	37	Fe 0.00	368	48	149	0	I
	7/17/58			1	60	572	8.0	40 / 2.00	13 / 1.04	66 / 2.87	4.0 / 0.10	0 / 0.00	206 / 3.38	94 / 1.96	18 / 0.51	0.7 / 0.04	4.7 / 0.08	0.35	40	Fe 0.00	382	48	152	0	
	9/8/59			1	59	525	8.4	38 / 1.90	11 / 0.87	62 / 2.70	3.3 / 0.08	6 / 0.20	194 / 3.18	79 / 1.64	17 / 0.48	0.4 / 0.02	2.8 / 0.05	0.3	40	Fe 0.01; Al 0.02; Cu 0.05	355	49	138	0	
-21J1	6/10/58	Qps	58	1	60	350	8.4	49 / 2.45	16 / 1.32	18 / 0.78	2.4 / 0.06	7 / 0.23	229 / 3.75	14 / 0.21	7.0 / 0.20	0.4 / 0.02	17 / 0.27	0.00	52	Fe 0.01	295	17	190	0	D

(Field Data)
County: Lassen
T 2_, R 15 ¼ Sec 24
Sample No. Region:
Field No:
Investigation:
G. W. Basin: Honey Lk. V.
Location: 5 or 6 miles south of Calneva

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.P.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner: L.T. Gould

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance: (micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks, Inc.

	Parts Per Million	Equivalents Per Million	%r
SiO_2	20.7		
Fe			
Ca	10.0		
Mg	1.87		
Na	22.0		
K			
Cation Totals:			
CO_3			
HCO_3	39.5		
SO_4	37.8		
Cl	12.3		
F			
NO_3			
B			
Anion Totals:			

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Region

Ground Water Basin

County

DWR Location No. T N/S R E/W Section and Lot B & M

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

(Field Data)

County: Lassen
T 25, R 17 ¼Sec. 8
Sample No. Region:
No:
Investigation:
G. W. Basin: Honey Lk. V.
Location:
Doyle

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.F.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: 415 Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner: Rowland

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance:
(micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks

	Parts Per Million	Equivalents Per Million	% r
SiO_2	16.5		
Fe			
Ca	12.5		
Mg	3.1		
Na	10.3		
K			
Cation Totals:			
CO_3			
HCO_3	84.4		
SO_4	4.09		
Cl	3.48		
F			
NO_3			
B			
Anion Totals:			

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Region

Ground Water Basin

County

DWR Location No. T ____ N/S R ____ E/W, Section and Lot ________ B & M

(Field Data)
County: Lassen
T 25, R 17, ¼Sec 8
Sample No. Region:
Field No.
Investigator:
G. W. Basin: Honey Lk.V.
Location: Doyle, Texaco Station

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.P.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner: Dixon's Texaco

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance: (micromhos at 25°C)
Total Dissolved Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$: N. C. Total
Remarks:

Anal: Abbot A.Hanks, Inc.

	Parts Per Million	Equivalents Per Million	%
SiO_2	12.6		
Fe			
Ca	33.1		
Mg	13.4		
Na	2.16		
K			
Cation Totals:			
CO_3			
HCO_3	90.2		
SO_4	8.77		
Cl	5.31		
F			
NO_3			
B			
Anion Totals:			

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Region

Ground Water Basin

County

DWR Location No. T N/S R E/W   Section and Lot B & M

Compiled by 19

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

(Field Data)
County: Lassen
T 2[illegible], R 17 ¼Sec 8
Sample No. Region:
Id No:
Investigation:
G. W. Basin: Honey Lk Vly.
Location:
W.P.R.R. Station,
Doyle
Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.P.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner:

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance:
(micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks, Inc.

	Parts Per Million	Equivalents Per Million	%r
SiO_2	16.6		
Fe			
Fe oxide	3.9		
Al oxide	0.9		
Ca.	12.6		
Mg	5.35		
Na	20.[illegible]		
K			
Cation Totals:			
CO_3)			
HCO_3)	80.9		
SO_4	11.9		
Cl	6.72		
F			
NO_3			
B			
Anion Totals:			

UNPUBLISHED RECORDS, SUBJECT TO REVISION

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Region

Ground Water Basin

County

DWR Location No. T N/S R E/W Section and Lot B & M

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

(Field Data)
County: Lassen
T 25, R 17, ¼Sec. 8
Sample No. Region:
'd No:
Investigation:
G. W. Basin:
Location: Doyle

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.P.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: 116 Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner: A. Johnson
Well #1

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance:
(micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks

	Parts Per Million	Equivalents Per Million	%
SiO_2	17.9		
Fe			
Ca	10.0		
Mg	1.01		
Na	27.7		
K			
Cation Totals:			
CO_3			
HCO_3	78.4		
SO_4	2.15		
Cl	5.25		
F			
NO_3			
B			
Anion Totals:			

UNPUBLISHED RECORDS, SUBJECT TO REVISION

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Region

Ground Water Basin

County

DWR Location No. T ____ N/S R ____ E/W Section and Lot .... B & M

(Field Data)
County: Lassen
T 25, R 17 ¼Sec. 5
Sample No. Region:
Well No:
Investigation:
G. W. Basin: Honey Lk. V.
Location: Doyle

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: W.P.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: 400 Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner: A. Johnson
Well #2

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance:
(micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks, Inc.

	Parts Per Million	Equivalents Per Million	%
SiO_2	10.5		
Fe			
Ca	2.8		
Mg	0.0		
Na	30.5		
K			
Cation Totals:			
CO_3 } HCO_3	45.9		
SO_4	51.3		
Cl	17.8		
F			
NO_3			
B			
Anion Totals:			

UNPUBLISHED RECORDS, SUBJECT TO REVISION

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Region

Ground Water Basin

County

DWR Location No. T ____ N/S R ____ E/W Section and Lot ________ B & M

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
ANALYTICAL STATEMENT
GROUND WATER

(Field Data)
County: Lassen
T 24, R 17 ¼Sec.
Sample No. Region:
'd No:
Investigation:
G. W. Basin: Long Valley
Location: [illegible].P.Sta., Constantia

Samp. Pt:
Pumptime: Disch:
Depth to water:
Ref. Pt:
Temp: °F
Coll. by: [illegible].F.R.R.
Agency:
Date: 1934 Time: PST

WELL DATA
Type: Drilled:
Depth: Ft. Diam: in.
Cased: Ft. Perf:
Gravel Packed:
Use:
Owner:

Lab. No.
Analyst
Date completed
Checked by
Date transmitted

Specific conductance:
(micromhos at 25°C)
Total Dissolved
Solids TAF
Sum TAF
Ignition loss
Percent Sodium
Total Iron (Fe)
Color pH
Turbidity
Hardness as $CaCO_3$:
N. C. Total
Remarks:

Anal:
Abbot A. Hanks, Inc.

	Parts Per Million	Equivalents Per Million	% r
SiO_2	9.0		
Fe			
Ca	9.36		
Mg	3.2[illegible]		
Na	37.7		
K			
Cation Totals:			
CO_3			
HCO_3	103.7		
SO_4	2.[illegible]		
Cl	10.6		
F			
NO_3			
B			
Anion Totals:			

UNPUBLISHED RECORDS, SUBJECT TO REVISION

COPIED FROM ORIGINAL RECORD

Region

Ground Water Basin

County

DWR Location No. T N/S R E/W, Section and Lot B & M