153. HYDROTHERMAL ALTERATION IN DRILL HOLES GS-5 AND GS-7, STEAMBOAT SPRINGS, NEVADA

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Sigvaldason and White (1961) described briefly the hydrothermal mineral assemblages in two drill holes (GS-1 and GS-2) in the Low and High Terraces, respectively, at Steamboat Springs and included bibliographic references to previous work.

DRILL HOLE GS-5

Drill hole GS-5 is on the Main Terrace near the principal flowing springs and is between the drill holes previously described on the low and high terraces respectively. Semiquantitative abundance of the principal minerals and other pertinent data are shown in figure 153.1; analyses of the altered rocks are shown in table 153.1. The most abundant clay mineral is mixed-layer illite-montmorillonite. The expandable montmorillonite component constitutes about 20 to 25 percent of the mixed layers in much of the granodiorite, but 10 percent or less in the dikes and in the most completely altered granodiorite. Below 350 feet, a relatively well-crystallized hydrothermal mica occurs with $n_\alpha > 1.55$ and with high birefringence, and is here called "sericite." This mineral probably grades into the more abundant illite-montmorillonite, characterized optically by finer grain size, $n_\alpha < 1.55$ and typically near 1.53, and lower birefringence. All of the hydrothermal mica is of the 1 Md dioctahedral type, now recognized also in cores from GS-2, and with less certainty in cores from GS-1 and GS-7, where it is greatly dominated by montmorillonite. Chlorite with a relatively high iron content is present in small amount throughout the core and is generally more abundant in the altered dikes than in granodiorite. The intensity ratios of the (001) and (002) X-ray peaks suggest that chlorite has a higher Mg content in the upper part of the andesite dike than elsewhere.

Hydrothermal K-feldspar is relatively abundant from about 100 to 300 feet in depth, generally replacing plagioclase irregularly, and is commonly marginal to patches of completely argillized plagioclase. The sodic rims of zoned plagioclase crystals are very resistant to alteration. The andesine cores of crystals are commonly replaced completely in the upper part of the hole by illite-montmorillonite and K-feldspar. Below 300 feet K-feldspar is increasingly scarce, and the original zoned plagioclase is commonly "homogenized" to albite or sodic oligoclase with abundant patches and flecks of clay minerals or calcite; excess calcium is removed. Original hornblende and biotite are completely altered throughout the hole, but original quartz and orthoclase are stable or metastable. Chalcedony-quartz-calcite veins occur below 84 feet, with calcite as an abundant component below 175 feet; vein thicknesses range up to about 8 feet. Stibnite is relatively common near the surface, decreasing in abundance downward to 94 feet; it has not been observed from greater depths.

The mineral assemblages in drill hole GS-5 are similar to those of GS-2 of the High Terrace in the downward decrease in hydrothermal K-feldspar and plagioclase, and in the general increase downward in clay minerals (see Sigvaldason and White, 1961, for possible explanations). Addition of potassium is nowhere as notable in GS-5 as in the upper 300 feet of GS-2. At least in part this is related to proportions of reactive calcic plagioclase and perhaps even to structural states of plagioclase in plutonic rocks and in volcanic rocks. The present composition of the thermal waters of the two terraces is similar (Sigvaldason and White, 1961, p. D121).

DRILL HOLE GS-7

Drill hole GS-7 is situated in the Silica Pit area on higher ground a mile west of the flowing springs (White, 1955, p. 110–111). Although thermal potassium-bearing waters probably discharged from this area several hundred thousand years ago, activity at present and in the recent past consists of the rise of steam, CO_2, and H_2S into a perched body of water dominantly of meteoric origin, with a well-defined water table near a depth of 112 feet. In contrast to the discharging water of the active spring terraces, the perched water body contains bicarbonates and sulfates almost to the exclusion of chloride, boron, and cations of external origin. Possible origins of this type of water have been reviewed briefly by White (1957, p. 1649–1651, 1655). H_2S rises above the water table and oxidizes near the surface to form sulfuric acid.

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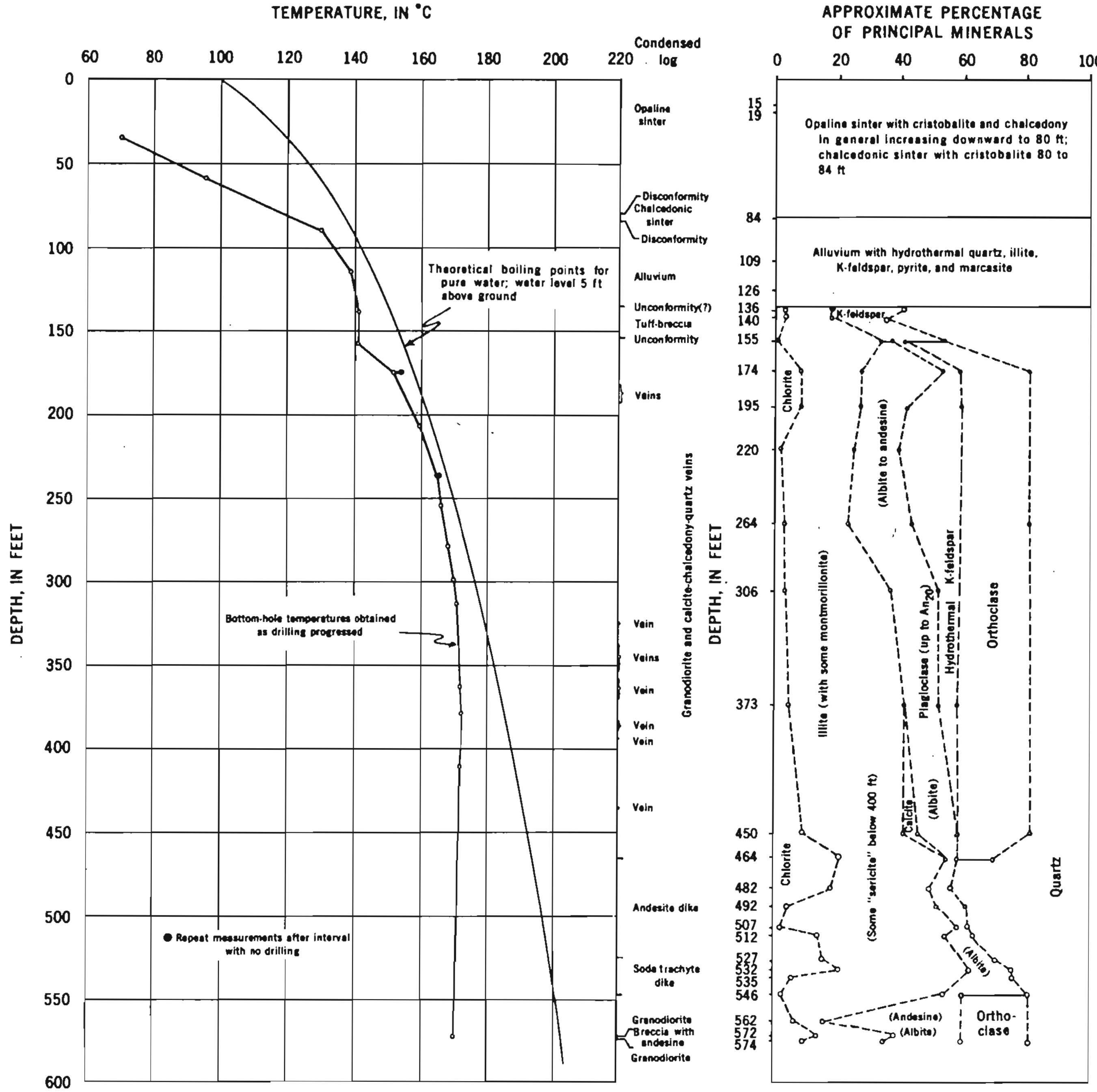

FIGURE 153.1.—Data from drill hole GS–5, main terrace, Steamboat Springs. Altitude of ground level is 4,661 feet.

The striking differences in the mineral assemblages (fig. 153.2 and table 153.2) from the surface to depths of more than 150 feet are related to downward percolation of very acid water (pH probably initially 1 to 2) through porous siliceous residues of previously leached granodiorite. Opal has the X-ray pattern of

TABLE 153.1.—*Analyses of hydrothermally altered rocks of drill hole GS-5*

[Analyzed by rapid methods by L. Shapiro, H. F. Phillips, K. E. White, S. M. Berthold, and E. A. Nygaard]

	Rock type, and depth, in feet						
	Opaline sinter	Black opal sinter	Chalcedony-opal sinter	Arkosic sediments	Chalcedony vein (?)	Granodiorite	Granodiorite
	15	19	84	109	126	155	306
SiO_2	95.2	91.9	96.3	97.2	89.2	81.0	69.9
Al_2O_3	.25	.11	.72	10.3	4.8	9.6	14.6
FeO	.0	.0	.05	.5	.8	.3	.0
Fe_2O_3[1]				.4	.0	.3	
MgO	.04	.00	.02	.25	.30	.31	.44
CaO	.18	.70	.26	.92	.30	.45	.93
Na_2O	.22	.26	.24	1.1	.22	.66	2.4
K_2O	.10	.18	.16	5.6	1.3	4.3	5.8
TiO_2	.00	.06	.16	.34	.16	.16	.30
P_2O_5	.00	.01	.00	.02	.00	.00	.07
MnO	.00	.01	.00	.01	.00	.00	.01
CO_2	<.05	<.05	<.05	<.05	<.05	<.05	<.05
H_2O	3.7	6.6	1.6	1.6	1.3	1.3	1.2
FeS_2	.13	.11	.52	1.4	1.6	1.5	3.6
Total as reported	99.8	99.9	100.0	101.6	100.0	99.9	99.3
Specific gravity (powder)	2.16	2.06	2.40	2.58	2.66	2.64	2.68
Specific gravity (lump)	2.04	1.92	2.07	2.41	2.55	2.56	2.52
Prominent hydrothermal minerals.[2]	Opal, (chalcedony, stibnite, calcite).	Cristobalite, (quartz, stibnite).	Chalcedony, cristobalite, (pyrite, calcite).	Quartz, K-feldspar, illite-montmorillonite, (pyrite).	Chalcedony, illite-montmorillonite, (K-feldspar, pyrite, marcasite.)	Quartz, illite-montmorillonite, (K-feldspar, calcite, pyrite, hematite).	Illite ($n\gamma \sim 1.545$) chlorite, K-feldspar, (albite, pyrite).

	Granodiorite	Andesite dike	Andesite dike	Trachytic andesite dike	Granodiorite	Granodiorite
	450	482	512	532	562	574
SiO_2	65.4	65.4	66.6	64.0	68.0	67.1
Al_2O_3	13.6	16.4	16.1	16.5	16.0	14.5
FeO	.3	.8	.3	.7	2.1	1.9
Fe_2O_3[1]	.1	.4	.0	.7	.8	.4
MgO	1.0	.70	1.4	1.1	.61	.68
CaO	4.2	.65	.31	.94	2.5	1.4
Na_2O	2.0	.66	.54	2.8	3.2	3.2
K_2O	4.4	4.2	4.2	4.0	3.5	4.6
TiO_2	.30	.52	.47	.49	.47	.49
P_2O_5	.08	.20	.23	.09	.12	.08
MnO	.10	.06	.00	.03	.10	.11
CO_2	2.6	<.05	<.05	.08	.68	.67
H_2O	2.0	5.2	3.4	4.2	1.3	2.8
FeS_2	3.2	5.2	5.8	4.3	.80	.77
Total as reported	99.3	98.4	99.4	99.9	100.2	98.7
Specific gravity (powder)	2.66	2.68	2.76	2.68	2.66	2.62
Specific gravity (lump)	2.29	2.21	2.33	2.38	2.49	2.35
Prominent hydrothermal minerals [2]	Illite-montmorillonite, "sericite", albite, chlorite (calcite, pyrite).	Illite-montmorillonite, quartz, chlorite, albite, (pyrite).	Illite-montmorillonite, quartz, chlorite, albite, (pyrite).	Illite-montmorillonite, quartz, albite, chlorite, (pyrite, calcite).	Illite-montmorillonite, chlorite, (calcite, "sericite", pyrite).	Illite-montmorillonite, chlorite, albite, (calcite, hematite).

[1] Or total Fe as Fe_2O_3.
[2] Approximate order of abundance; minor minerals in parentheses.

cristobalite to a depth of 32 feet but is amorphous at greater depths. The perched body of ground water is strongly acid immediately below the water table to 132 feet, where kaolinite is most abundant. At 133 feet montmorillonite abruptly becomes dominant and is abundant at all greater depths. Kaolinite was not found below 238 feet, marking the lower limit of influence of sulfuric acid of surficial origin. The basal (001) X-ray reflection of the montmorillonite is uniformly near 15 A, indicating a Ca-Mg type similar to the dominant type in GS-1 (Sigvaldason and White, 1961), and this is supported by double low-temperature differential thermal analysis peaks characteristic of many Ca-montmorillonites. Chlorite is

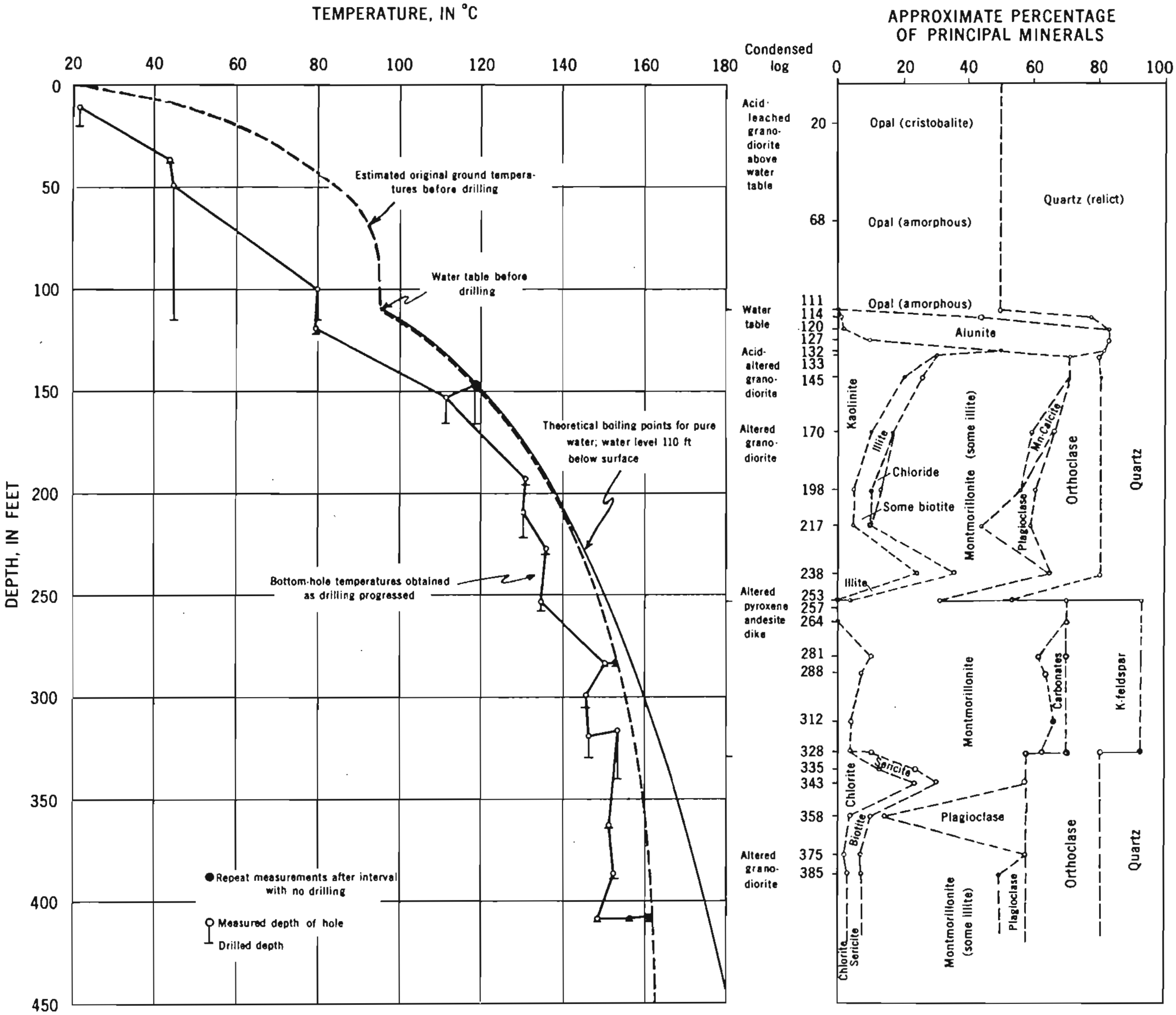

FIGURE 153.2.—Data from drill hole GS–7, Silica Pit area, Steamboat Springs. Altitude of ground level is about 5,025 ft.

present below 270 feet and also occurs in small amounts at 198 feet. Below 330 feet "sericite," optically similar to that of GS–5, is found. Relict biotite occurs only in relatively fresh rocks containing some unreplaced andesine.

The active agent for the deep alteration in drill hole GS–7 is CO_2. Potassium is not being supplied from depth at the present time but probably was in the past. Excess potassium and aluminum in the rocks immediately below the water table (table 153.2) were supplied by acid leaching of rocks near the surface.

TABLE 153.2.—*Analyses of hydrothermally altered rocks of drill-hole GS-7*

[Analyzed by rapid methods by L. Shapiro, H. F. Phillips, K. E. White, S. M. Berthold, and E. A. Nygaard; Sb by F. N. Ward]

	Rock type, and depth, in feet							
	Granodiorite	Granodiorite	Granodiorite	Granodiorite	Granodiorite	Granodiorite	Granodiorite	Granodiorite
	20	68	111	114	120	127	133	145
SiO_2	95.4	92.0	90.5	56.9	21.8	26.8	69.4	69.6
Al_2O_3	.68	.76	.58	15.1	29.0	27.9	15.6	12.0
FeO	.06	.0	.0	.0	.0	.0	.0	.1
Fe_2O_3 [1]								.0
MgO	.01	.01	.00	.03	.00	.00	2.1	2.6
CaO	.14	.04	.12	.04	.12	.08	.53	.62
Na_2O	.18	.18	.18	.20	.31	.32	.22	.28
K_2O	.08	.14	.16	4.1	7.9	7.4	3.0	2.2
TiO_2	.38	.44	.56	.28	.26	.30	.32	.22
P_2O_5	.00	.01	.02	.16	.42	.30	.06	.04
MnO	.00	.01	.00	.00	.01	.00	.09	.12
CO_2	<.05	.07	.06	.23	.18	.08	.12	<.05
H_2O	3.8	2.2	1.9	6.9	11.4	10.5	7.3	8.7
FeS_2	.04	3.0	5.8	3.0	1.6	1.4	2.2	3.4
SO_3	0	0	0	13.7	27.7	25.7	0	0
Total as reported	100.8	98.9	99.9	100.6	100.7	100.8	100.9	99.9
Sb (in ppm)	.9	2.2	2.0	1.6	.8	.8	----	1.0
Specific gravity (powder)	2.17	2.32	2.36	2.52	2.79	2.76	2.50	2.46
Specific gravity (lump)	1.52	1.30	1.57	2.26	2.36	2.41	----	2.21
Prominent hydrothermal minerals.[2]	Cristobalite, (anatase, barite).	Opal, (pyrite, anatase).	Opal, pyrite, (marcasite, anatase, barite).	Alunite, opal, (pyrite, marcasite, anatase?).	Alunite, (opal, pyrite, marcasite, kaolinite?).	Alunite, kaolinite, (marcasite, pyrite).	Montmorillonite, kaolinite, (alunite, pyrite).	Montmorillonite, kaolinite, (illite, marcasite, pyrite).

	Granodiorite	Granodiorite	Andesite dike	Andesite dike	Granodiorite	Granodiorite	Granodiorite
	170	217	264	281	335	358	385
SiO_2	61.3	66.9	58.0	54.2	68.6	68.8	69.7
Al_2O_3	12.5	14.6	17.8	17.1	15.4	14.8	15.2
FeO	.5	.0	.16	1.2	1.2	1.6	.8
Fe_2O_3 [1]	.0		.5	.4	.4	.4	.1
MgO	1.6	2.0	1.9	2.9	1.8	1.2	1.0
CaO	4.5	1.4	2.2	5.0	.71	2.2	1.6
Na_2O	.40	1.2	.64	1.8	.35	3.6	2.3
K_2O	3.6	4.1	3.2	3.0	5.3	3.9	4.1
TiO_2	.26	.30	.46	.50	.37	.30	.31
P_2O_5	.06	.07	.20	.36	.07	.06	.07
MnO	.25	.13	.06	.73	.04	.04	.02
CO_2	2.9	.07	.18	3.0	<.05	.08	<.05
H_2O	8.1	7.5	13.8	8.5	5.3	1.4	4.4
FeS_2	3.7	1.7	.77	1.5	.56	.28	.41
SO_3	0	0	0	0	0	----	----
Total as reported	99.7	100.0	99.9	100.2	100.1	98.7	100.0
Sb (in ppm)	1.0	.7	.5	----	2.3	1.0	1.3
Specific gravity (powder)	2.44	2.52	2.28	2.46	2.60	2.62	2.53
Specific gravity (lump)	2.30	2.35	1.98	2.42	2.16	2.57	2.41
Prominent hydrothermal minerals.[2]	Montmorillonite, kaolinite, illite, Mn-calcite, (pyrite).	Montmorillonite, kaolinite, illite, (pyrite).	Montmorillonite, K-feldspar (pyrite, calcite)	Montmorillonite, K-feldspar(?) ankerite(?) chlorite, (pyrite).	Illite-montmorillonite, chlorite, sericite, (pyrite).	Illite-montmorillonite, chlorite, (pyrite, calcite).	Illite-montmorillonite, (chlorite, sericite, pyrite).

[1] Or total Fe as Fe_2O_3.
[2] In order of abundance; minor minerals in parentheses.

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Rocks, Structure, and Geologic History of Steamboat Springs Thermal Area, Washoe County Nevada

By DONALD E. WHITE, G. A. THOMPSON, *and* C. H. SANDBERG

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TABLE 3.—*Logs of wells, drill holes, and auger holes*—Con.

GS–4 diamond-drill hole

[Main Terrace, 7 E., traverse 3; land-surface alt, 4,664.7 ft]

	Depth (ft)
Opaline sinter:	
At top nearly white to gray; below 20 ft, dark gray with some dark, glassy sinter. Largely opal-cemented fragmental type with low initial dips but some primary sinter, generally with abundant plant casts; geyserite near 16 ft; diatoms common in lower part but poorly preserved. Clastic fragments generally rare, but some angular quartz throughout; granitic debris, fragments of andesite, metamorphic rocks, soda trachyte, and probable Steamboat basaltic andesite abundant from 49 to 51 ft; basal layers also include older acid-altered fragments from below contact. Opaline sinter in part chalcedonized below 20 ft, in place(?). Stibnite below 9 ft, some Sb oxides above; pyrite below 16 ft	0–51
Disconformity or slight unconformity.	
Pre-Lousetown alluvium:	
Dominantly silt, sand, and fine gravel, angular to subrounded, fragments seldom larger than 1 cm above 100 ft in depth but as large as 1½ in. in lower part; dominantly granitic but some soda trachyte throughout, minor metamorphic fragments in upper part, andesite in lower part; Steamboat basaltic andesite not found. Color white to light gray near top from acid leaching earlier than opaline sinter; generally light-gray, greenish-gray, or light mottled colors below. Opal is dominant replacement mineral near upper contact, with increasing kaolinite below, and recognizable acid alteration to about 67 ft. Illite-montmorillonite then becomes dominant clay mineral but most plagioclase unaltered to 95 ft, where hydrothermal potassium feldspar becomes abundant. Pyrite is common throughout, stibnite from upper contact to 90 ft, rare or absent below; veinlet of pyrite of radial habit after marcasite(?) at 67 ft, vein calcite at and below 131 ft (none above), a few white chalcedony veinlets in middle and lower part; no major veins or crush zones. Bedding uncommon but some initial(?) dips as much as 30°	51–149
Unconformity, contact dips 15°.	
Granodiorite:	
Moderately to strongly altered rock, no relatively fresh rock as in GS–3, nor much greenish alteration like the dominant type in GS–3. In most abundant bleached type, plagioclase largely replaced by illite-montmorillonite, chlorite, potassium feldspar, except for soidc rims; below 400 ft, part of plagioclase replaced by illite-montmorillonite, remainder albitized; hornblende and biotite entirely replaced by illite-montmorillonite and chlorite. Hydrothermal pyrite common throughout, replacement calcite rare. Principal zones of intense bleaching and alteration: 192–203 ft (60° dip), 208–221 ft (70°?), 246–263 ft (50° to 60°), 346–374 ft (70°?), 398–403 ft (75°?), 409–413 ft (65°?), 427–452 ft (unclear—10°–60°?), 472–476 ft (60°?). Some bleaching very obviously related to chalcedony-calcite veins but much may be related to shear zones without major veins; principal shear zones near 400, and 430–452 ft. Veins largely white chalcedony, generally containing calcite, rare pyrite at 159–160 ft (70°); 181–185 (50°); 188–190; 198–200; 211–212 (70°); 226–230 (88°); 323–327 (87°); 334–337; 395; 466–467; calcite uncommon near top, most abundant 195–350 ft; veins decrease below 350 ft and are rare below 400 ft; minor hematite and pyrite near top and bottom	149–150

GS–5 diamond-drill hole[1]

[Main Terrace, 400 ft N. of GS–4; land-surface alt, 4,661 ft]

	Depth (ft)
Opaline sinter:	
White, gray, and nearly black opaline sinter, in part geyserite and other primary sinter types but much opal-cemented fragmental sinter. With increasing depth the color is generally darker, porosity decreases, chalcedonization of opal increases, and remaining opal gives increasingly sharp X-ray patterns of β-cristobalite. Clastic fragments rare but some angular granitic debris, very rare andesite, soda trachyte(?), and metamorphic fragments; hot-spring diatoms, plant remains generally rare, poorly preserved, but locally common in middle and lower part. Stibnite below 11 ft, chalcedony below 19 ft as cavity fillings and below 28 ft as incipient chalcedonization of opal. Veinlet of opal (β-cristobalite) at 73 ft, minor vein calcite at 84 ft, none above; potassium feldspar absent	0–80
Disconformity(?).	
Chalcedonic sinter:	
Clastic deposits and chalcedonic sinter with silicate minerals and part of chalcedony opalized by acid attack prior to deposition of sinter, originally opaline type but now largely chalcedonized. Remaining opal gives sharp cristobalite X-ray pattern	80–84
Disconformity or unconformity.	
Pre-Lousetown alluvium:	
Dominantly silt, sand, fine gravel but locally gravel up to 15 mm; some drill core shows bedding, dips near 30°; fragments angular to subrounded, dominantly granitic with minor soda trachyte, metamorphic rocks; no recognizable sinter, diatoms, andesite or Steamboat basaltic andesite. Hydrothermally altered but hard, with acid leaching absent at upper contact; chalcedony-adularia cement, considerable replacement of plagioclase by potassium feldspar, some illite-montmorillonite, chlorite; remaining plagioclase altered to albite or sodic oligoclase. First chalcedony vein at 85 ft, none above; calcite is part-	

[1] See Sigvaldason and White (1962).

TABLE 3.—*Logs of wells, drill holes, and auger holes*—Con.

GS-5 diamond-drill hole—Con.

	Depth (ft)
Pre-Lousetown alluvium—Continued	
ly leached at 112 ft, absent above; some stibnite to 94 ft, none seen below. Greenish masses of chalcedony, illite-montmorillonite, pyrite, generally with octahedral(?) habit; marcasite(?) common below 121 ft—probably veins but may be replacement of volcanic rocks with no evident relict textures	84–135
Unconformity(?).	
Kate Peak Formation:	
Andesitic tuff-breccia and possibly flow breccia hydrothermally altered, mottled light reddish-gray; gray and gray-green fragments with green-gray matrix. Original silicate minerals replaced by potassium feldspar, chalcedony, chlorite, illite-montmorillonite, pyrite, some marcasite. Abundant veins at 135–136 ft, 140–152 ft, largely chalcedony, quartz, some calcite, dipping 75°–80°	135–154
Unconformity.	
Granodiorite (and veins):	
Granodiorite at top, largely mottled, reddish, with hematite-stained quartz 154–162 ft, 171–173 ft, and slight staining 167–181 ft, 194–196 ft, 317–319 ft, and a little at other depths. Down to about 200 ft, much granodiorite is green, with chlorite fairly abundant, particularly as replacement of ferromagnesian minerals and as tiny veinlets in feldspar; illite-montmorillonite abundant near unconformity and below 200 ft, where most granodiorite is bleached, generally with light-colored inconspicuous relicts of ferromagnesian minerals, chalky argillized plagioclase (except for albitic borders). Some albitized plagioclase and replacement calcite below 400 ft. Pyrite is common, almost always cubic but some octahedral(?) in upper part. In shear zones, 379–402 ft (dip unclear), and particularly 452–465 ft (65° dip?), most granodiorite is "rotten," disintegrates readily, but some cemented by chalcedony and fine-grained quartz. Veins particularly abundant, dominantly chalcedony near top, calcite abundant below 174 ft; thickest veins at 181–192 ft (5 ft thick, dip 65°±), 324–326 ft (45° dip), 337–354 ft (7–8 ft thick, avg dip 65°), 357–370 ft (dip unclear; probably at least 4 ft thick), 383–388 ft (dip unclear; mostly very coarse-grained calcite), 393–395 ft, 434–436 ft (45° dip). Largest vein quartz crystals of area between 181 and 192 ft, as much as 7 mm in length, 1 mm in diameter, eubedral, rarely with basal pinacoid crystal form; coarsest calcite of area between 357 and 388 ft	154–465
Fault and intrusive contact, dip 65°(?).	
Kate Peak Formation:	
Dike, ligbt-gray to greenish-gray porphyritic volcanic rock, highly argillized with no original minerals remaining. Original plagioclase phenocrysts as much as 5 mm in diameter; relict shapes of biotite, hornblende, and pyroxene also recognized. Hydrothermal minerals include illite-montmorillonite, "sericite" (with optical properties close to muscovite), chlorite, potassium feldspar, and pyrite, generally in well-formed cubes. Original rock was biotite-hornblende-pyroxene andesite dike with a few rounded inclusions. Contact of coarse-grained rock against chilled andesite at 524 ft, dipping 75°	465–525
Fault and intrusive contact, with brecciated granodiorite fragments in breccia zone; dip unclear.	
Alta Formation:	
Nearly white argillized dike or extrusive volcanic rock with relict low-dipping (30°) planar structure resembling that of soda trachyte of Alta Formation. Phenocrysts inconspicuous but recognizable relict forms of plagioclase and hornblende, more abundant than in normal soda trachyte. Hydrothermally altered to illite-montmorillonite, "sericite," albite, quartz, chlorite, cubic pyrite, apatite, and calcite; cut by veinlets of red hematite and of calcite. Basal breccia contains iron-stained quartz	525–546
Fault contact, brecciated, dipping 50°.	
Granodiorite:	
Generally somewhat bleached, hydrothermally altered to illite-montmorillonite, albite, chlorite, calcite, minor pyrite (cubic?), hematite. Freshest granodiorite of hole at 562 ft, with biotite mostly fresh (some altered to chlorite), hornblende entirely argillized, plagioclase partly altered to illite-monmorillonite, "sericite," and calcite. Reddish quartz with hematite in places	546–572
Kate Peak Formation:	
Breccia zone containing fragments of granodiorite and hornblende andesite with texture similar to that at 500 ft, hydrothermally altered to illite-montmorillonite, "sericite," chlorite, albite, calcite, pyrite	572–573
Granodiorite:	
Contains chalky plagioclase and conspicuous ferromagnesian relicts, similar to 546 to 572 ft, with illite-montmorillonite, "sericite," albite, chlorite, calcite, and very minor pyrite (not cubic?)	573–575

GS-6 diamond-drill hole

[Sinter Hill, 10 E., traverse 9 and 0, traverse 24; land-surface alt, 4,837 ft. Minerals identified optically and by D.T.A.; some incomplete X-ray study]

	Depth (ft)
Post-Lousetown chalcedonic sinter:	
Sinter, white to gray, largely low in porosity, chalcedonized; opaline sinter, still porous fragmental type and only partly chalcedonized but remaining opal is cristobalite by X-ray, 4–10 ft, 48–50 ft, and to some extent at other depths. Angular clastic quartz and potassium feldspar grains from granodiorite are rare, no fragments of rocks other than sinter found; some hot-spring dia-	

Hydrology, Activity, and Heat Flow of the Steamboat Springs Thermal System, Washoe County Nevada

By DONALD E. WHITE

GEOLOGY AND GEOCHEMISTRY OF THE STEAMBOAT SPRINGS AREA, NEVADA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 458-C

The present physical activity and detailed behavior of a notable hot-spring system, where water of surface origin circulates deeply in rocks of low bulk permeability

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1968

TABLE 5.—*Altitudes of some wells, natural vents, and water levels in the Steamboat thermal area*

[Measurements in feet]

Well or spring	Location	Ground altitude	Range in recorded depths to water level	Best value for depth to water table	Approximate altitude of water table
GS–1	Low Terrace	4,622.9	[1] −6.0–+52	−5	4,618
2	High Terrace	4,720.8	−37.1–−51.7	−41	4,680
3	Main Terrace	4,676.3	−6.3–−14.4	−8	4,668
4	do	4,664.7	[1] −3±–+65	−3±	4,662
5	do	4,661	−6.4–+60	−5	4,656
6	Sinter Hill	4,838	−143–−154	−148	4,690
7	Silica pit	5,027	−106–−121	−112	4,915
8	Main Terrace	4,607.2	−15.1–−30.0	−30	4,577
Auger hole:					
4	East of Main Terrace	4,572	−6.5	−6.5	4,565
5	do	4,572	−7.8	−7.8	4,564
6	do	4,676	−9.4	−9.4	4,667
12	West of Main Terrace	4,680.6	−15.4	−15.4	4,665
13	do	4,677.1	−10.2	−10.2	4,667
South Steamboat well	Low Terrace	4,611.1	−12.4–+2.1	−7	4,604
Steamboat well 4	do	4,612.8	−6.7–−24	−13.5	4,599
No. 32 Geyser well	do	4,623.4	[2] −0–−3	.5	4,623
Murray	Northeast of Main Terrace	4,533	−12.9	----------	4,520
Harold Herz 1	North of Main Terrace	4,606.4	−53.6–−60.2	−56	4,550
Harold Herz 2	do	4,598.0	−55.1–−55.6	−55	4,543
Mount Rose	do	4,595.1	−52.8–−56.5	−56	4,539
East Reno	do	4,588.2	−6.1–−9.3	−6	4,582
West Reno	do	4,607.5	−26.2	−26	4,581
Senges	Northwest of Main Terrace	4,649.6	[3] −11–−38.4	−11	4,639
Murray well	Pine Basin	4,787.0	[3] −70?–−112	−70?	4,717?
Rodeo	Main Terrace	4,676.7	−6.7–−15.6	−8.6	4,668
Nevada Thermal Power Co.:					
4	West of Pine Basin	[4] 4,870	−217	[5] −95	~4,775
5	do	[4] 4,875	−234–−282	[5] −120	~4,775
6	Pine Basin	[4] 4,790	−95–−115	[5] −86	~4,705
Vent 35	Main Terrace	4,676.8	−7.5–−10.3	−8.9	4,667.9
Vent 36	do	4,675.5	−6.7–−8.3	−7.5	4,668.0
Spring:					
22	do	4,666.8	0 when flowing	near 0	4,666
21sw	do	4,667.3	−6.0	−6	4,661
21	do	4,653.1	−1–0	near 0	4,653
16	do	4,654.9	−2–0	−1	4,654
8	do	4,647.8	0	0	4,648
21n	do	4,648.8	−10.5–−12+	−12	4,637
6	do	4,634.0	−1–0	−1	4,633
25	Low Terrace	4,612.7	0	0	4,613
33	do	4,594.7	0	0	4,595
50	do	4,594.4	0	0	4,594
53	do	4,567.9	−2–0	−1	4,567

[1] Positive wellhead vapor pressure highest during or immediately after eruption, expressed as feet of water.
[2] Immediately after an eruption, water level is much lower than indicated here.
[3] From drillers' old reports.
[4] Estimated.
[5] See text.

DRILL HOLES, U.S. GEOLOGICAL SURVEY

Diamond drilling for research purposes was done under contract for the Geological Survey from June 1950 published by White, Thompson, and Sandberg (1964, table 3); the hydrothermal alterations have been studied by Sigvaldason and White (1961, 1962) and by Schoen and White (1966).

Diamond drilling excels in yielding core for petrographic and chemical study. Data obtained from the eight diamond-drill holes are shown in tables 27–34 and figures 31–38. The data suggest that repeat measurements made over a number of weekends were normally within several degrees centigrade of the daily temperature measurements and the probable original ground temperatures prior to entry of the hole. Some repeat measurements, however, demonstrate that no universal rules of behavior are applicable.

Water samples obtained from diamond-drill holes are generally not reliable because of introduction of drill water. Where positive pressures existed, water was leaked off and sampled, especially from drill holes GS–1, 4, and 5. A deep-hole water sampler was constructed during the course of the study, but did not operate satisfactorily. Water samples, unless otherwise noted, were obtained from the top of the water column, but in the tables and figures of this report, the analytical data from these samples are referred to the drilled depth of the time of sampling. This obviously does not give a true picture of actual water compositions at these referred depths. Each sample is actually a product of mixing of waters from various depths, plus contamination from any water added from previous drilling and still remaining in the hole.

Table 35 is a summary of the most reliable chloride contents from diamond-drill holes and other wells drilled in the thermal area, listed by 100-foot intervals in depth.

GENERAL TEMPERATURE RELATIONSHIPS AND THE ERUPTION PROCESS

Experience gained from recent exploration for geothermal power has shown that a well penetrating a permeable aquifer where temperatures are close to boil-

TABLE 31.—*Data from drill hole GS-5*

[East of crest of Main Terrace and 418 feet north of GS-4. Diamond drilled, circulating cold water. Measurements in parentheses considered less reliable than the others. Water samples from top of column unless otherwise noted]

Date	Depth drilled (feet)	Depth thermometer (feet)	Bottom temperature (°C)	Depth to water[1] (feet)	Temperature (°C at water level)	Cl (ppm)	pH	Specific conductance (micromhos, 25°C)	Remarks
1950									
Sept. 24	37	34.2	70.0	5.3	45.4	(304)	(5.5)	(1,400)	Drilled Sept. 23. 7 ft of 5-in. casing.
25	58½	58.3	95.3	6.4	44.2	(12)	(7.2)	(143)	50 ft NX casing.
				5.5	42.3	------	------	------	Water level outside NX casing.
26	90	89.9	129.8	+.6	34.6	(44)	(7.0)	(293)	
27	115	114.5	138.6	+3.1	30	(36)	(8.6)	(255)	
28	139	138.3	141.1	+3.1	29	(160)	(6.9)	(870)	Well erupts if permitted to discharge.
29	158	157.3	141.0	+3.3	24	(156)	(7.4)	(769)	Temperature 1 ft below ground, 32°C; cooling in pipe above ground, convection.
30	175	174.7	151.6	+3.4	25	(524)	(7.0)	(2,160)	
Oct. 1	175	174.6	153.7	+3.9	24	(764)	6.8	(3,050)	Repeat measurement.
2	175	174.6	153.8	+3.6	20	------	------	------	Do.
3	175	174.0	154.0	+4.0	38	820	(7.3)	3,290	Sampled after some discharge; first reliable sample.
4	208	206.7	159.2	+3.5	27	------	------	------	Discharge 1 min, sampled.
				+4.2	61	(780)	(7.1)	(3,050)	
5	238	236.4	164.7	+4.0	33	(736)	(7.2)	(2,900)	
6	238	236.4	165.2	+3.7	26	808	7.1	3,120	Repeat measurement.
7	256	254.6	165.9	+3.4	29	(772)	(6.8)	(3,060)	
8	281	279.1	168.0	+3.8	26	(770)	(6.8)	(3,030)	
9	300	298.6	169.7	+3.8	------	(768)	(7.1)	(3,020)	No water return 250–308 ft.
10	315	313.6	170.8	+3.7	------	(408)	(6.2)	(1,840)	308 ft BX casing.
				+(2.6)	------	(3)	(7.5)	(101)	Steamboat ditch—drill water, 4 p.m.
11	332	330.1	------	+6	------	794	6.1	3,170	
12	340	338.8	(166.9)	+16	------	(688)	(6.7)	(2,810)	Thermometer bounced coming up.
13	363	362.8	171.8	+14	------	810	6.3	3,270	
14	379	378.9	172.2	+33	95±	780	(7.7)	(2,910)	Valve leaking considerably all night.
15	412	410.9	171.8	+36	Hot	808	(7.2)	(3,340)	Do.
16	430	------	------	+48	95+	(882)	(8.0)	(3,440)	Strong leak, high temperature discharge, no measurements.
				—10–14	------	------	------	------	After 10 min, pumping cold water.
17	465	462.2	(172.1)	+18	------	824	6.3	3,270	Valve had been completely closed.
18	505	399.2	(172.2)	+17	------	820	6.3	3,270	Thermometer stuck at 399 ft; uninsulated.
19	545	543.1	(172.2)	+17	------	826	6.00	3,280	Thermometer uninsulated.
22	575	572.2	(172.2)	+20	------	820	6.2	3,270	Hole completed Oct. 19.
				8	------	------	------	------	Pressure decreased after escape of some gas.
23	575	572.2	169.6	+9	------	826	6.0	3,270	Bx casing left in but space between NX–BX not sealed. Thermometer insulated proving slight reversal.
1951									
Apr. 13	------	------	------	------	60±	820	6.2	3,310	
						832	6.9	3,345	Sample from top of column before eruption; thermometer blocked at 400 ft.
1952									
May 16	575	400	172.6	------	------	824	(7.8?)	3,230	
16	575	469.6	172.6	±23	47	------	------	------	Bottom temperature?after eruption; 105 ft sediment in hole.
30	575	469.6	------	+13	------	828	6.2	3,200	Before eruption.
	------	------	------	+60	------	------	------	------	After eruption.
1953									
June 20	575	------	------	------	40±	824	6.9	3,290	After slight discharge permitted.
					95+	864	8.7	3,340	Erupted sample.

[1] Positive values mean excess pressure in feet of water, as measured by pressure gage.

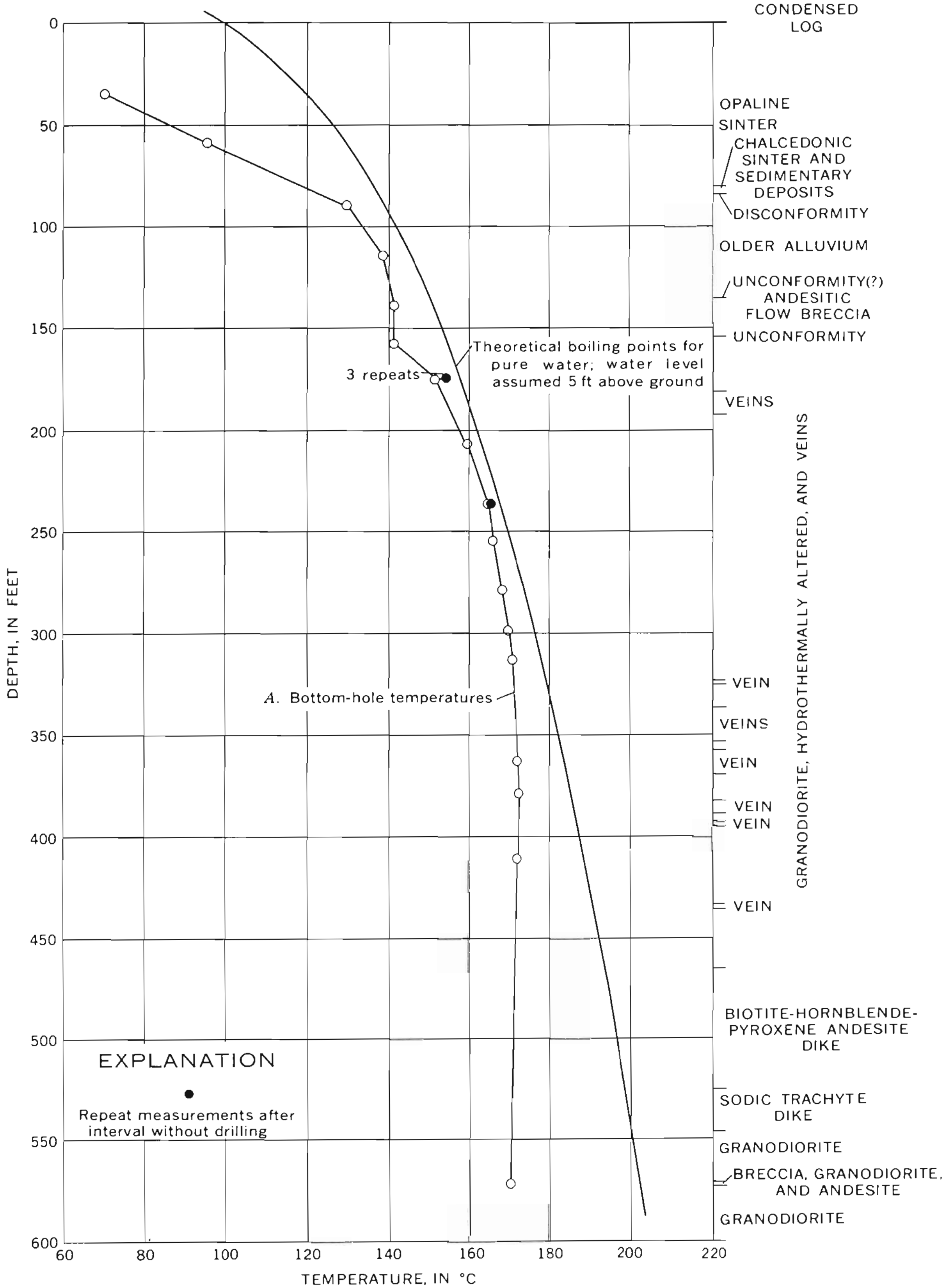


FIGURE 35.—Temperature and related data from drill hole GS-5 east of crest of the Main Terrace (and 417 ft north of GS-4).

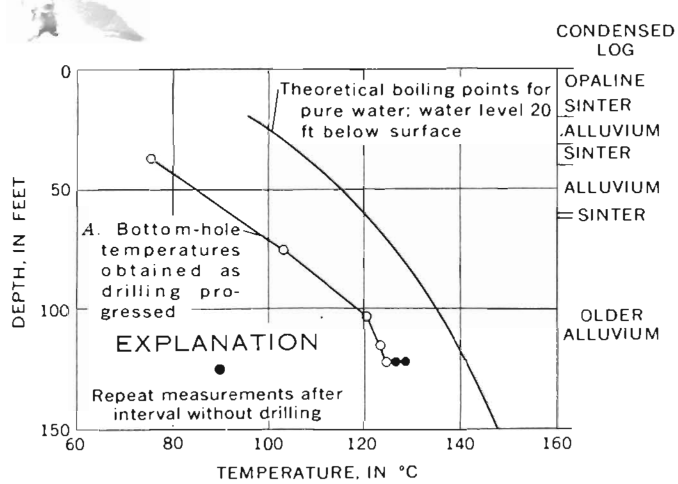


FIGURE 38.—Temperature and related data from drill hole GS–8 near east base of the Main Terrace.

OTHER CHANGES IN GEOTHERMAL WELLS WITH TIME

When a well is drilled, original temperature relationships and circulation patterns are almost certain to be upset to some extent and perhaps drastically. This is the reason why bottom-hole temperatures obtained as drillings progresses give far better data on original ground temperatures than a temperature log measured after completion of the hole. Data from the South Steamboat well (fig. 24), Rodeo well (fig. 26), GS–1 (fig. 31), and GS–2 (fig. 32) substantiate these conclusions. In each of these examples, previously existing circulation patterns were evidently changed by the drilling of the hole. A drill hole can be viewed as a new highly permeable channel that short-circuits tenuous interconnections of low permeability that existed in the structurally complex natural system.

TABLE 35.—*Chloride content of the most reliable water samples from drill holes of the Steamboat Springs thermal area, arranged by intervals of depth of drilled bottom when samples were collected*

Drill hole or well	Chloride content (ppm), by indicated depth intervals (feet) when sample was collected						
	0–100	100–200	200–300	300–400	400–500	500–600	>600
South Steamboat well	820	860	10	-----	-----	-----	-----
Harold Herz 1	240	430	-----	-----	-----	-----	-----
Harold Herz 2	-----	400	-----	-----	-----	-----	-----
Steamboat 4	870	620	-----	-----	-----	-----	-----
Rodeo well	890	930 (146 [1]) 500± (166 [1])	[1] 840	-----	-----	-----	-----
Auger hole:							
4	[2] 1,300	-----	-----	-----	-----	-----	-----
5	[2] 1,160	-----	-----	-----	-----	-----	-----
6	120	-----	-----	-----	-----	-----	-----
12	90	-----	-----	-----	-----	-----	-----
13	350	-----	-----	-----	-----	-----	-----
No. 32 Geyser well	890	-----	-----	-----	-----	-----	-----
Murray	510	-----	-----	-----	-----	-----	-----
Mount Rose:							
1	-----	824	-----	-----	-----	-----	-----
2	[3] 1,170	848	-----	-----	-----	-----	-----
3	-----	840	-----	-----	-----	-----	-----
East Reno well	-----	870	-----	-----	-----	-----	-----
West Reno well	-----	900	-----	-----	-----	-----	-----
Senges well	-----	830	-----	-----	-----	-----	-----
Mercury well	-----	600	-----	-----	-----	-----	-----
Nevada Thermal Power Co.:							
1	-----	-----	-----	-----	-----	-----	870
2	-----	-----	-----	-----	-----	-----	[3] 955
3	-----	-----	-----	-----	-----	-----	[3] 1,080
4	-----	-----	-----	-----	-----	45	[3] 874
GS–1	650	830	600	840	-----	-----	-----
2	←——?——560——?——→ (0–400)						
	←——?——800——?——→ (0–400)						
3	-----	-----	780	-----	760	780	790
4	-----	-----	830	790	800	-----	-----
5	-----	820	810	810	820	825	-----
6	-----	12	-----	-----	-----	-----	-----
7	-----	-----	-----	-----	10	-----	-----
8	860	900	-----	-----	-----	-----	-----

[1] Mixture from higher levels?
[2] Probably influenced by evaporative concentration at the surface.
[3] Generally 10–14 percent too high because of concentration by eruptive boiling.

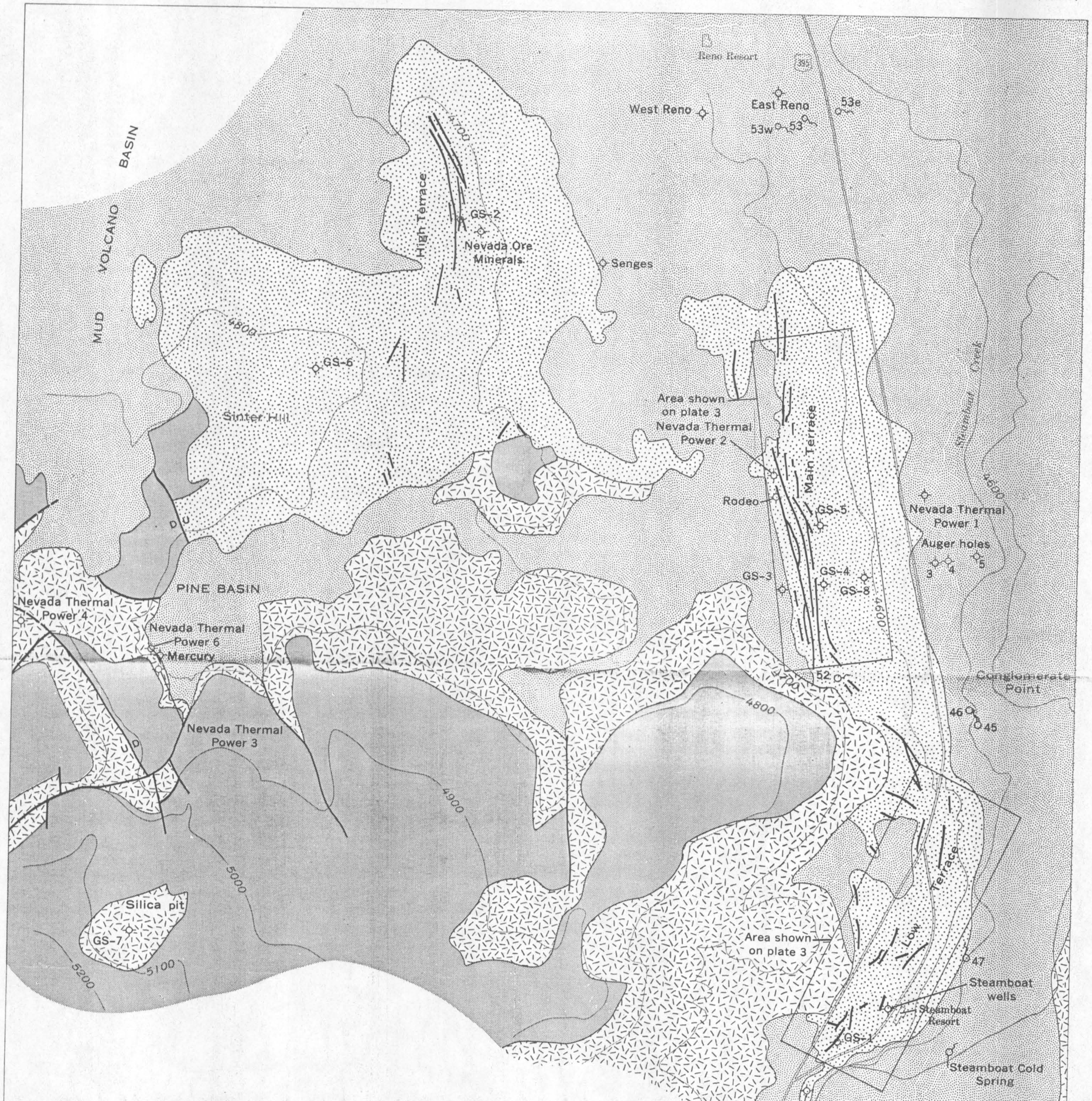
TABLE 39.—*Depths and temperatures of some wells in the Mount Rose and Virginia City quadrangles and adjacent areas, and other data*—Continued

Well				Reported depth (feet)	Bottom temperature (°C)	Other temperature (°C); remarks	Cl (ppm)	pH	Specific conductance (micromhos, 25°C)
No.	Location No.[1]	Location	Name						
82	32DB1	Steamboat	Cox	[2] 14.5	57.8				
83	32DB3	do	GS-7	[2] 407.8	161.0		0.5	6.66	158
84	33AB1	do	GS-8	[2] 121.8	128.7	80 at 25.6 ft	896	6.55	3,300
85	18/22 33AB2	do	Nevada Thermal Power Co.	1,830	([5])		870	8.4	3,560
86	18/20-33BA1	do	Rodeo	[2] 276.9	168.8	86 [3] at 7.6 ft	836	7.02	3,440
87	33BA2	do	GS-3	[2] 683.6	164.0	169.1 at 530 ft	791	6.60	3,280
88	33BA3	do	GS-4	[2] 503.0	171.1		816	6.55	3,180
89	33BA4	do	GS-5	[2] 572.2	169.6	172.2 at 543 ft	826	6.00	3,270
90	33DA1	do	Knox	[2] 6	13.5				
91	33DA2	do	do	[2] 56	29.9				
92	33DB	do	Carver	[2] 28.3	94.8	92 at 14.6 ft			
93	33DB2	do	Steamboat 2						
94	33DB5	do	Steamboat 4	[2] 184	154.8	96 at 17 ft	702		2,700
95	33DB6	do	GS-1	[2] 398.4	156.9	158.1 at 193 ft	817	6.05	3,250
96	33DB7	do	No. 32 Geyser well	[2] 43.2	114.6		[3] 885 [4] 986	7.4 8.7	3,335 3,810
97	33DC1	do	South Steamboat well	[2] 258	75.5		10	7.43	348
98	33DC2	Steamboat Valley	Carver	[2] 77	19.5		6	7.08	298
99	34AC1	Southeast of Truckee Meadows	Johnson	[2] 136.5	21.8	17.9 at 62 ft	12	7.20	1,947
100	34CD1	do	Frazier	[2] 160	22.0		8.4	8.03	367
101	34DB1	do	Schindler	[2] 125.4	19.1		5.6	7.23	583
102	10DB1	West of Reno	(?)	365	13		35		
103	11DB4	Reno	Magnin	140	12				
104	11DB5	do	Johnson and Davidson	190	13		14		
105	13BB1	do	Crystal Springs Ice Co	118	14				
106	13BC1	do	Sierra Pacific	785	29+	29 in pumped water	30		
107	14AD1	do	Diamond Springs Water Co.	210	18+	18 at tap	12		
108	21CA1	Southwest of Reno	Caughlin oil test	1,865	(?)	"hot water reported at 1,200 ft (Anderson, 1910).			
109	23DC1	South of Reno	Country Club	140	(?)	Reported "hot"			
110	25AB1	do	Moffat	662	41.5	41.5 at tap			
111	25AB2	do	do	500	40.5	40.5 at hose	26	7.85	836
112	25BA2	do	Moana Springs	571.45	53.0	40; flowing			
113	25BA3	do	do	(?)	51+	50.8; flowing	28	8.13	832
114	25BB7	do	Smith	60	31.5+	31.5 at hose	29	7.26	944
115	25BD1	do	Van Slyck	77	33.5	22 at 36 ft; 29 at 72 ft			
116	25BD2	do	Randall	260	45.5				
117	25BD3	do	do	111	45.5				
118	25BD4	do	Johnson	95	44.5				
119	25DA1	do	Pecknam	700	24.5	24.5 when pumped			
120	25DC1	do	University farm	500		Reported "hot"			
121	26AA2	do	Kimberly	155	41				
122	26AA3	do	Martic	600	76.5				
123	26AC1	do	Erskine	155	25.5				
124	26AD1	do	Moana	179	88.5		55		
125	26AD2	do	do		91+	90.8 at leak in discharge pipe.	52	7.94	1,320
126	26AD3	do	Yates	[2] 184.2	71				
127	26AD4	do	do	[2] 168.3	71				
128	26AD5	do	do	[2] 197.5	75.5				
129	26AD7	do	Frey	464	82+	Discharge, 82			
130	26DA2	do	Kelty	200	91				
131	26DB1	do	do	104	95.5	5 gpm discharge, 86.5	48	8.33	1,384
132	26DC1	do	Campbell	750	82+	82 at leak in discharge pipe.	48	7.89	1,327
133	36BB2	do	Allison	197	15+	15; pumped			
134	36BB3	do	Morgan	175	14+	14; pumped			
135	36DA2	do	Del Monte	400		13.5; pumped			
136	36DA3	do	Giroux	536		11.5; pumped largely from 21 ft.			
137	36DC2	do	Eddy	129	14.5				
138	36DC3	do	Ghiglieri	142	13.5		17		
139	19/20-19DA1	Southeast of Reno	United Airlines	116	14.5+	14.5; pumped			
140	19DCA1	do	Preston	29.5	13.5+	13.5; flowing			
141	19DCB3	do	Frazier	45	14+	14; flowing			
142	19DCC2	do	Holmes	53	12+	12; flowing			
143	19DCC3	do	Summers	20.4	13.5+	13.5; flowing			
144	19DCD1	do	Breaker	27.1	13.5+	13.5; flowing			
145	27CA1	East side Truckee Meadows	Birbeck	80	16		284	7.65	1,660
146	29AB1	Southeast of Reno	Niturnio?	68	14+	14; flowing	6.0	7.26	458
147	30BC1	do	Newton	360	29+	29; flowing			
148	30BD9	do	Allard	43	14+	14; flowing			
149	30CC1	do	Fife	400	26.5+	26.5; flowing			
150	30DA1	do	Model Dairy	220	15.5+	15.5; flowing			
151	30DB2	do	Sanderson	70			3.5	6.83	296
152	31AC1	do	Lehnert	143	16+	16; flowing			
153	31AC2	do	DeLucchi	167	16.5				
154	31BC2	do	Pollard	115	12				
155	31DA1	do	Capuro	139	14.5+	14.5; flowing			

[1] See footnote 1, table 37; denotes, in order, township, range, section, quarter section, quarter-quarter section, and sequence in quarter-quarter section.
[2] Measured depth.
[3] Nonerupting.
[4] Erupted sample.
[5] Not measured.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROFESSIONAL PAPER 458-C
PLATE 1



Generalized from White, Thompson, and Sandberg (1964, pl. 1)

EXPLANATION

QUATERNARY

- Sinter
- Alluvium
- Basaltic andesite of Lousetown Formation

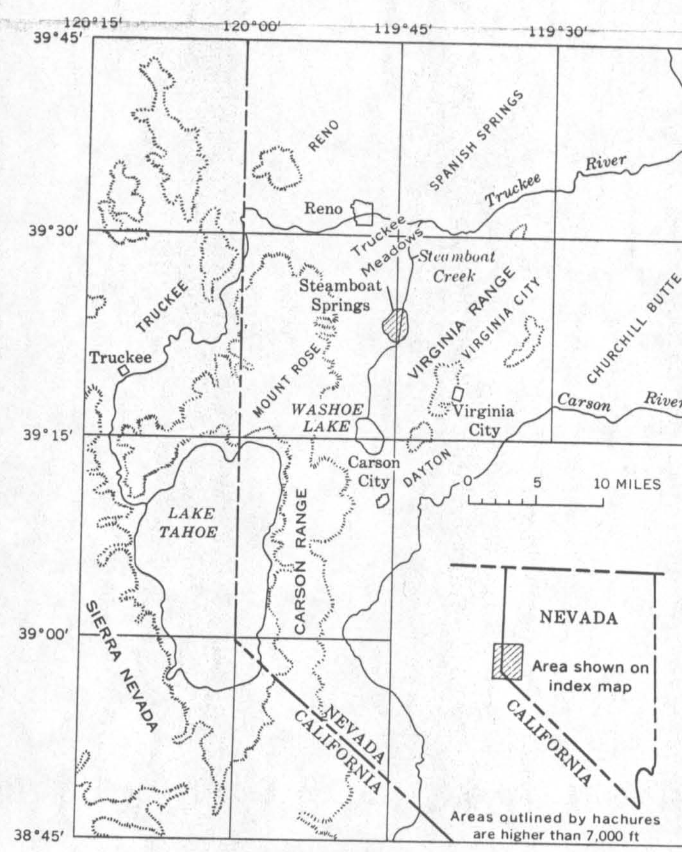
MESOZOIC

- Granitic and metamorphic rocks

U / D — Fault, fissure
U, *upthrown side*; D, *downthrown side*

GS-8 — Drill hole
Rodeo — Well
45 — Spring

N



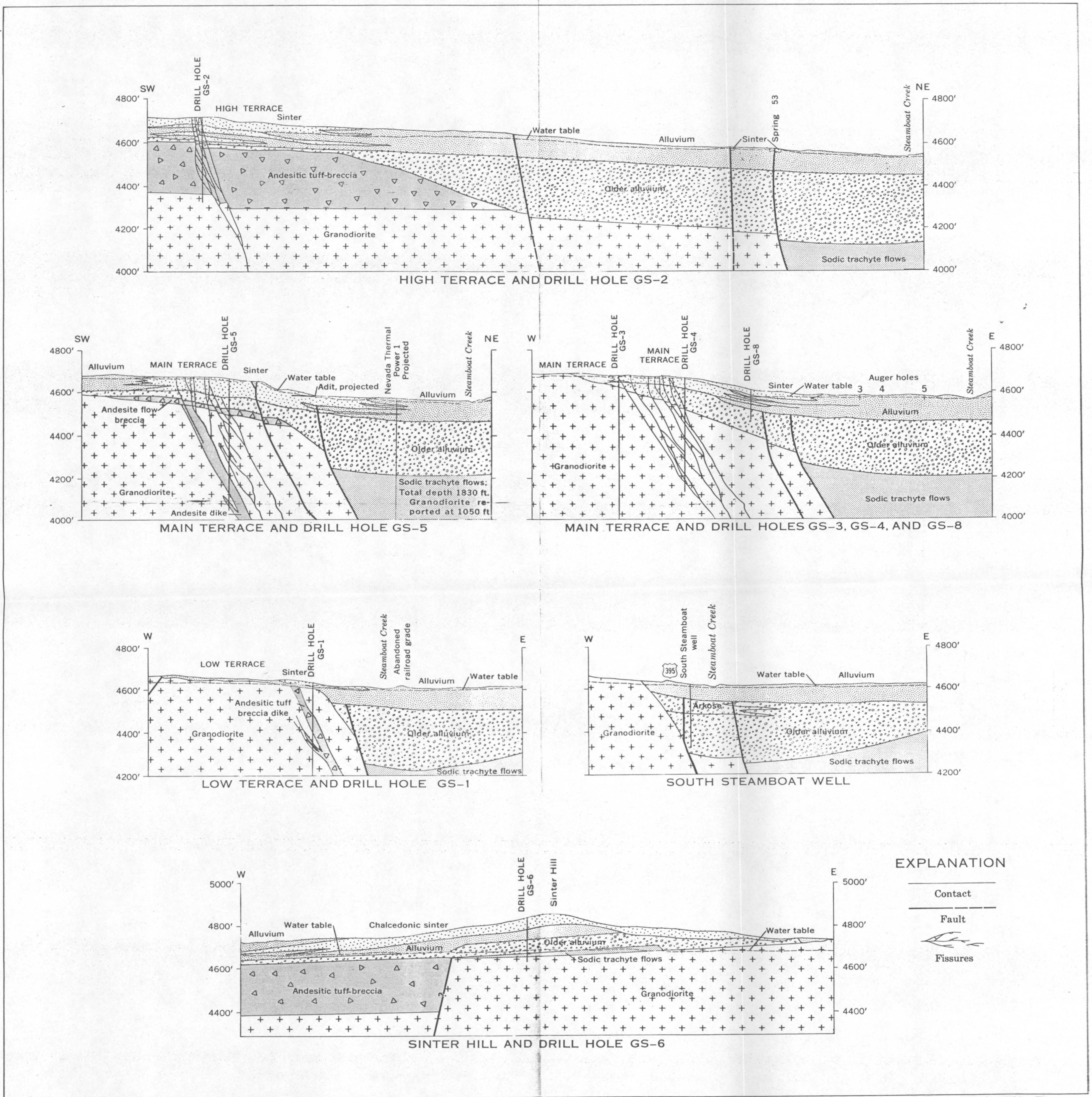
LOCATION OF STEAMBOAT SPRINGS THERMAL AREA, WASHOE COUNTY, NEVADA

GENERALIZED GEOLOGIC MAP OF STEAMBOAT SPRINGS THERMAL AREA WASHOE COUNTY, NEVADA

500 0 500 1000 FEET

CONTOUR INTERVAL 100 FEET

264-856 O - 67 (In pocket)

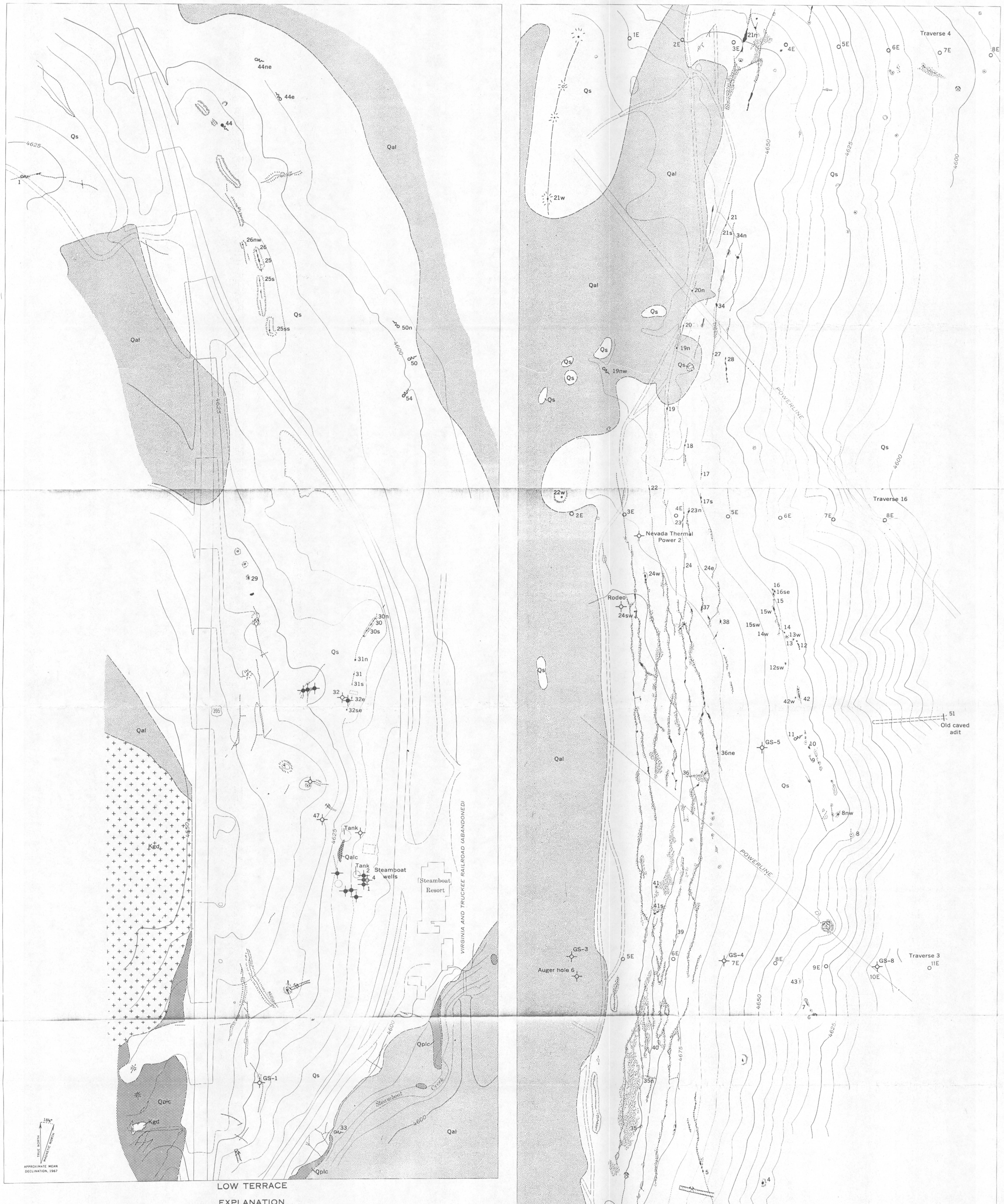


Sections are modified from White, Thompson, and Sandberg (1964, pl. 2)

STRUCTURE SECTIONS THROUGH THE PRINCIPAL HOT-SPRING DEPOSITS STEAMBOAT SPRINGS, WASHOE COUNTY, NEVADA

250 0 250 500 750 1000 FEET

264-856 O - 67 (In pocket)



GEOLOGIC MAP OF THE LOW TERRACE AND OF THE MAIN TERRACE, STEAMBOAT SPRINGS, WASHOE COUNTY, NEVADA

264-856 O - 67 (In pocket)

NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN 91

THERMAL WATERS OF NEVADA

LARRY J. GARSIDE
JOHN H. SCHILLING

Descriptions of Nevada's thermal waters in springs, wells, and mine workings: locations, geology, temperatures, flow rates, water chemistry, well depths, drilling and other exploration activities, and past and present uses.

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA · RENO
1979

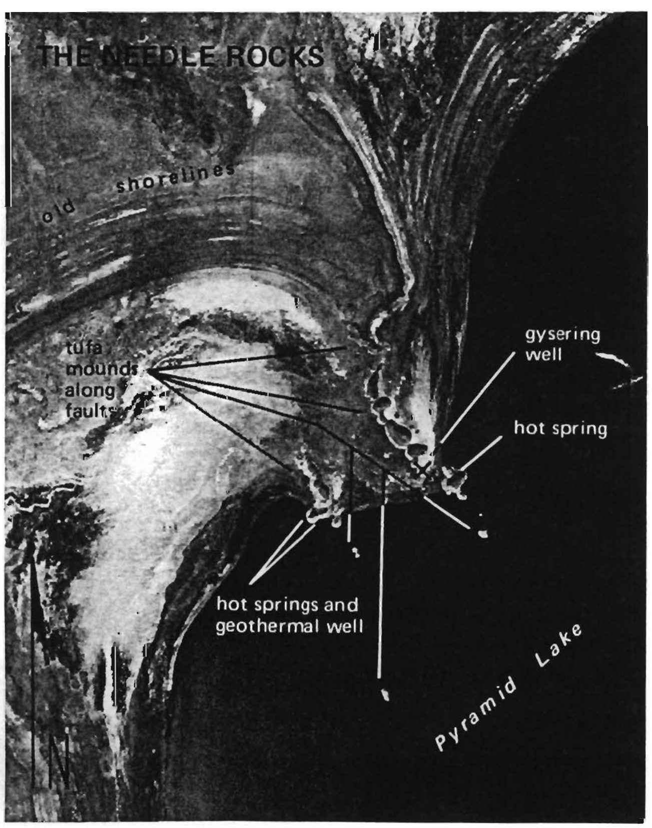
WASHOE COUNTY (continued)

1.5 miles south of Steamboat Hot Springs in C NE/4 S5, T17N,R20E, and a small deposit of spring travertine is located in SW/4 SW/4 SW/4 S5,T17N,R20E on the southeast flank of Steamboat Hills about 100 feet above the floor of Pleasant Valley (Thompson and White, 1964).

The springs at Steamboat are near boiling, and exploration steam wells have reported temperatures as high as 369°F. One well encountered temperatures of up to 280°F at only 160 feet (White, 1968). The hot water is reported to have 5% to 10% steam flashover (Koenig, 1970). Preferred estimated reservoir temperatures from chemical geothermometers are approximately 400°F (Mariner and others, 1974). Six steam wells, ranging in depth from 716 to 1,830 feet were drilled in the late 1950's and early 1960's by Nevada Thermal Power Co. (see Appendix 2). Also, the U. S. Geological Survey drilled eight core holes for a total of 3,316 feet, and, in the past, several other wells have been drilled in the area for spas. Several years ago the hot water from one steam well was used as a flameless source of heat for the manufacture of plastic explosives.

The Needle Rocks [269]

Pyramid Lake is on the Pyramid Indian Reservation, about 30 miles northeast of Reno and lies along the probable trace of the Walker Lane, a major right-lateral strike slip fault zone in western Nevada. The Needle Rocks are at the northeast corner of Pyramid Lake (S12,T26N,R20E and S6,7,T26N,R21E), along north-northeast-trending faults that are presumed to be part of this Walker Lane fault zone (Bonham, 1969). Warm springs are also present at Pyramid Island (S3,T24N,R22E) and on Anaho Island (S16?,T24N,R22E); both localities are also within the Walker Lane fault zone.



Western Geothermal Inc. Needles No. 1 well at Needle Rocks, Washoe County, shortly after drilling in 1965 (photo by Harold F. Bonham, Jr).

Both the Needle Rocks and Pyramid Island are spectacular masses of tufa which were deposited in Pyramid Lake when its level was higher than at present. The collection of tufa into needles, spires, and pyramids is believed to be related to underwater warm springs (Russell, 1885), and divers report that underwater hot springs are present near the Needle Rocks today.

Springs at the Needle Rocks are reported to range from 151°F (Grose and Keller, 1975b) to a maximum of 208°F (Waring, 1965) which is near boiling for that elevation. A number of the springs are shown on the Needle Rocks 7½-minute topographic map. The spring on Anaho Island is reported to be 120°F (Waring, 1965). In the early 1960's Western Geothermal, Inc. drilled 3 geothermal wells at the Needle Rocks. The deepest of these was 5,888 feet, and another was approximately 4,000 feet deep. The maximum recorded temperature was approximately 240°F. From examination of drill cuttings from the deepest well, it is believed that Tertiary basaltic andesites overlie Mesozoic metamorphic rocks at approximately 5,050 feet (H. F. Bonham, written communication, 1964). This well flowed continuously after its completion, but geysered or pulsed, a complete cycle taking about 1 minute. A 35-second eruption, with hot water reaching 30 feet in height above the well, was followed by 32 seconds of diminished activity. During this period the well flowed at a rate of about 100 gallons per minute. A thin film of siliceous sinter (geyserite) collected on the well casing during this time; a slight odor of H_2S was also noted (H. F. Bonham, Jr., written com-

Identification number, name, location	Temp. (°F)	Discharge (gpm)	Date	SiO_2 (ppm)	Fe (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	HCO_3 (ppm)	CO_3 (ppm)	SO_4 (ppm)	Cl (ppm)	F (ppm)	NO_3 (ppm)	B (ppm)	TDS (ppm)	SC (μmhos/cm)	pH	Reference
WASHOE COUNTY (continued)																				
Reno Press Brick well NW¼NW¼S32,T18N,R20E	158	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	White, 1968
	Remarks: Depth – 58 ft.																			
Nevada Thermal Power Co. No. 5 well NW¼NW¼S32,T18N,R20E	325	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	White, 1968
	Remarks: Depth – 826 ft.																			
U. S. Geological Survey GS-7 well NW¼SE¼S32,T18N,R20E	322	–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–	158	6.7	White, 1968
	Remarks: Depth – 407.8 ft.																			
Cox well NW¼SE¼S32,T18N,R20E	136	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	White, 1968
	Remarks: Depth – 14.5 ft.																			
spring SW¼NE¼S33,T18N,R20E	hot	–	25May56	125	0	7.8	1.2	665	69	212	62	118	889	2.0	1.0	36.9	2360	3555	8.3	Cohen & Loeltz, 1964
	Remarks: Li = 8.3.																			
U. S. Geological Survey GS-8 well NW¼NE¼S33,T18N,R20E	262	–	–	–	–	–	–	–	–	–	–	–	896	–	–	–	–	3300	6.6	White, 1968
	Remarks: Depth – 121.8 ft.																			
well NW¼NE¼S33,T18N,R20E	–	–	28Sep68	235	–	2.3	0.4	770	60	300	46	121	999	2.6	–	–	2536	3661	8.7	Bateman & Scheibach, 1975
spring NW¼NE¼S33,T18N,R20E	192	–	Aug49	293	–	5	0.8	653	71	305	–	100	865	1.8	–	49	2354	–	7.9	Bateman & Scheibach, 1975
	Remarks: As = 2.7, Li = 7.6.																			
spring NE¼S33,T18N,R20E	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Mariner & others, 1975
	Remarks: Al = 0.009, Rb = 0.70, Ce = 1.5, Sr = 1.9, Mn = 0.02, Cu = 0.01, Hg = 0.0005, δD(‰) = –116.7, δO^{18}(‰) = –12.16. Gas (volume %): O_2 + Ar = 2, N_2 = 6, CH_4 <1, CO_2 = 93.																			
spring NE¼S33,T18N,R20E	201	13	1973	270	–	16	0.7	680	66	364	2	73	837	2.1	–	47	–	3340	7.2	Mariner & others, 1974
	Remarks: Li = 7.5.																			
spring SE¼NW¼S33,T18N,R20E	136	–	5Feb57	205	0.08	14	1.9	644	59	328	0	142	790	2.2	0.4	2.2	2130	3240	6.7	Cohen & Loeltz, 1964
	Remarks: Al = 0, Mn = 0.05, U <0.1 ppb.																			
spring NE¼SE¼NW¼ S33,T18N,R20E	129	–	27Aug68	245	–	25	0.6	635	65	336	–	141	767	2.2	–	58	2275	2933	7.1	Bateman & Scheibach, 1975
spring NE¼NW¼S33,T18N,R20E	203	–	Jul45	317	–	12	0.5	707	75	292	20	129	949	2.2	–	30	2542	–	8.2	Bateman & Scheibach, 1975
	Remarks: As = 1.3, Li = 7.																			
spring NE¼NW¼S33,T18N,R20E	–	–	24Aug73	–	–	–	–	–	–	–	–	–	–	–	–	–	2700	–	–	D. Trexler, written communication, 1973
	Remarks: From spring on upper terrace.																			
spring 50 SW¼NW¼S33,T18N,R20E	136	5	5Feb57	79	0.08	14	1.9	644	59	328	0	142	790	2.2	0.4	2.2	2130	3240	–	Scott & Barker, 1962
	Remarks: Al = 0; Mn = 0.05; PO_4 = 2.7; Ra = 0.3μμc/l; U = <0.1 pppb.																			
Rodeo well NE¼NW¼S33,T18N,R20E	336	–	–	–	–	–	–	–	–	–	–	–	836	–	–	–	–	3440	7.0	White, 1968
	Remarks: Depth – 276.9 ft.																			
U. S. Geological Survey GS-3 well NE¼NW¼S33,T18N,R20E	327	–	–	–	–	–	–	–	–	–	–	–	791	–	–	–	–	3280	6.6	White, 1968
	Remarks: Depth 683.6 ft.																			
U. S. Geological Survey GS-4 well NE¼NW¼S33,T18N,R20E	340	–	–	–	–	–	–	–	–	–	–	–	816	–	–	–	–	3180	6.6	White, 1968
	Remarks: Depth – 503 ft.																			
U. S. Geological Survey GS-5 well NE¼NW¼S33,T18N,R20E	337	–	–	–	–	–	–	–	–	–	–	–	826	–	–	–	–	3270	6.0	White, 1968
	Remarks: Depth – 572 ft.																			
U. S. Geological Survey GS-1 well NW¼SE¼S33,T18N,R20E	314	–	–	–	–	–	–	–	–	–	–	–	817	–	–	–	–	3250	6.1	White, 1968
	Remarks: Depth – 398 ft.																			
No. 32 Geyser well NW¼SE¼S33,T18N,R20E	238	–	–	–	–	–	–	–	–	–	–	–	885	–	–	–	–	3335	7.4	White, 1968
	Remarks: Depth – 43.2 ft.																			
South Steamboat well SW¼SE¼S33,T18N,R20E	168	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	348	7.4	White, 1968
	Remarks: Depth – 258 ft.																			
Steamboat Hot Springs S33,T18N,R20E	–	300	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Lamke & Moore, 1965
Steamboat Hot Springs S33,T18N,R20E	167-203	825	9Aug49	293	0.05	5.0	0.8	653	71	305	0	100	865	1.8	–	49	–	3210	7.9	White, Hem & Waring, 1963; Waring, 1965, No. 56
	Remarks: Al = 0.5, Mn = 0.05, Sr = 0.5, Li = 7.6, As = 2.7, Sb = 0.4, I = 0.1, Br = 0.2, H_2S = 4.7.																			

Steamboat Springs, Geothermal Area by Donald E. White
(1980 SEG Field Trip; Complete report in NBMG Geothermal Files)

Table 1. Spectrographic analyses of chemical precipitates, Steamboat Springs thermal area, Nevada; in ppm except where noted[1].

	T, °C	Au	Ag	As	Sb	Hg	Tl	B	Cu	Zn	Pb
W-50, siliceous mud, Spring 24	95.5	15	150	700	1.5%	100	700	500	20	50	7
W-310d, sinter & stibnite, Spring 8	95	1.5	1	50	1.0%	30	70	1,000	1	0.2	---
W-941c, metastibnite & opal, erupting Nevada Thermal #4 well	96	60	400	600	>0.2%	<80	2,000	>2,000	>2,000	>2,000	400
GS-5 drillcore, depth in ft (m)											
11 (3.4) opaline sinter	42	0.3	2	150	700	2	10	1,000	15	15	n.d.
19 (5.8) " "	52	n.d.	0.3	30	500	500	5	500	3	5	n.d.
42 (12.8) " "	80	0.2	0.5	300	3,000	500	70	200	10	10	n.d.
84 (25.6) chalcedonic sinter	122	n.d.	<0.2	70	100	3	1.5	20	1.5	7	n.d.
113 (34.5) vein chalcedony	137	1.5	30	30	50	n.d.	1.5	15	5	15	n.d.
174 (53.1) " " -calcite	153	0.7	20	50	50	n.d.	1.5	15	10	10	n.d.
231 (70.1) " " "	163	0.3	70	70	30	n.d.	n.d.	15	3	30	n.d.
273 (83.2) " " "	168	n.d.	100	50	30	n.d.	n.d.	20	10	7	n.d.
346 (105.4) " " -quartz	171	n.d.	15	5	20	n.d.	n.d.	10	1	7	n.d.
363 (110.6) " " -calcite	172	n.d.	100	30	30	n.d.	<1	20	5	30	n.d.
446 (135.8) " " -quartz-calcite	171	n.d.	0.7	1.5	20	n.d.	n.d.	15	2	10	n.d.

[1] Semi-quantitative 6-step spectrographic analyses by Chris Heropolous, U.S. Geological Survey, including short wavelength radiation data; Bi, Se, and Te below detection; data on Be, G, and Sr not included.

GS - 1 4362123 N, 263760 E
2 4362390 N, 264580 E
3 4363230 N, 263740 E
4 4363245 N, 263820 E
5 4363360 N, 263810 E
6 4363670 N, 264365 E

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