

STEAMBOAT SPRINGS, GEOTHERMAL AREA

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This area is approximately 10 miles south of downtown Reno and largely just west of U.S. #395 (fig. 1). Thermal waters and gases have discharged from an area of approximately 5 km², with post-glacial (post-Lake Lahonton) hot spring discharge restricted to the Main Terrace just west of the highway and the Low Terrace to the southeast adjacent to Steamboat Creek. This hot spring system has the longest and most complex geologic history of any active geothermal area yet studied in detail in the world (White and others, 1964; Silberman and others, 1979; fig. 2).

The area has attracted interest in its geothermal potential for many years. Hot spring water was used in the local spas for bathing and heating by the early 1900's, and efforts were made to pipe the water to Reno for heating purposes in 1916 (White, 1968, p. C6, C7, and C15-16). The first geothermal well at Steamboat Springs was drilled about 1920 in efforts to obtain a dependable supply of hot water for the local resort (White, 1968, p. C45-C55), and the first well specifically searching for steam for generation of electricity was drilled in 1950 (Rodeo well). During the late '50's and early '60's, 8 to 10 additional geothermal exploration wells were drilled in the immediate area, ranging from 218 to 558 m deep; maximum measured temperature was 186°C (White, 1968), but these early geothermal efforts were not successful in identifying a reservoir of adequate temperature and permeability. Chemical geothermometers predicted reservoir temperature ranging from about 180°C to 230°C (Brook and others, 1979; Nancy Nehring, written communication, 1979¹). A 930 m-deep geothermal test well was then drilled in 1979 by Phillips Petroleum Company 2.5 km SW of the Main Terrace near the crest of Steamboat Hills. Its maximum temperature is near the geochemical maximum but detailed data have not been released.

The Steamboat area has been of long-standing interest to economic geologists for its bearing on hydrothermal ore deposits, and it now viewed as the present-day equivalent of geothermal systems of Tertiary age that formed epithermal gold-silver deposits throughout the Great Basin of the western United States and elsewhere (White and others, 1964; White, 1967, 1968, in press). At Steamboat, hot-spring sinter deposits, chemical sediments in spring vents, and veins intersected in drill holes all contain significant concentrations of gold, silver, mercury, antimony, arsenic, thallium, and boron (table 1). The oldest hot spring sinter was deposited about 3 million years ago, prior to the extrusion of basaltic andesite from a vent near the crest of Steamboat Hills 2.5 km

¹ Nehring's data, included in her Master's thesis, San Jose State University, 1979, predicts $T_{SiO_2} = 183^\circ C$, $T_{Na/K} = 230^\circ C$, $T_{NaKCa} = 230^\circ C$, and T_{180} of $SO_4-H_2O = 210^\circ C$.

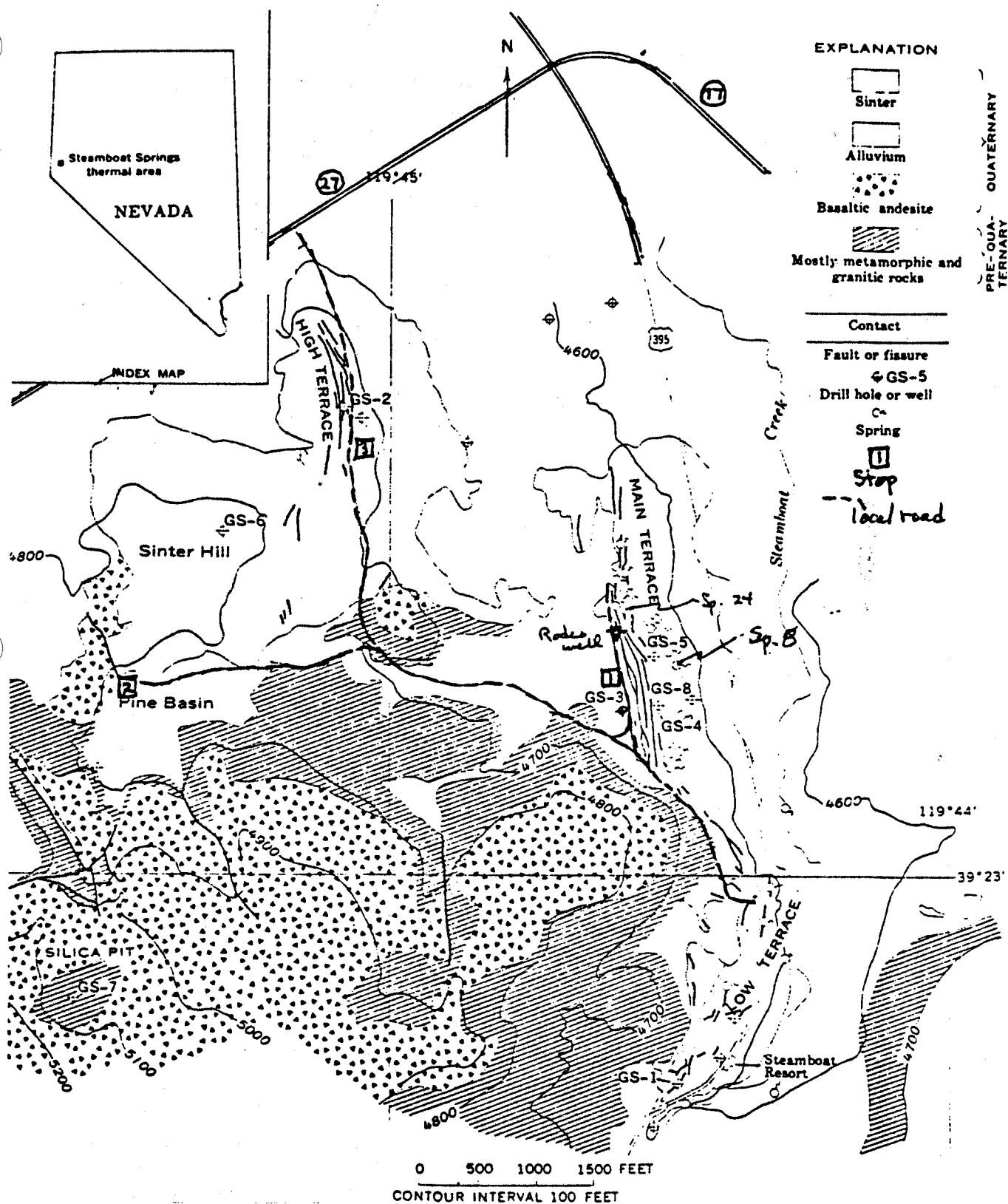


FIGURE 1. Generalized geologic map of Steamboat Springs thermal area, Washoe County, Nev. (Modified from detailed map, White and others, 1964.)

Table 1. Spectrographic analyses of chemical precipitates, Steamboat Springs thermal area, Nevada; in ppm except where noted¹.

| | T, °C | Au | Ag | As | Sb | Hg | Tl | B | Cu | Zn | Pb |
|--------------------------------------|-------|------|------|-----|-------|------|-------|--------|--------|--------|------|
| -50, siliceous mud, Spring 24 | 95.5 | 15 | 150 | 700 | 1.5% | 100 | 700 | 500 | 20 | 50 | 7 |
| -310d, sinter & stibnite, Spring 8 | 95 | 1.5 | 1 | 50 | 1.0% | 30 | 70 | 1,000 | 1 | 0.2 | --- |
| -94lc, metastibnite & opal, erupting | 96 | 60 | 400 | 600 | >0.2% | <80 | 2,000 | >2,000 | >2,000 | >2,000 | 400 |
| Nevada Thermal #4 well | | | | | | | | | | | |
| 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) chalcodonic sinter | 122 | n.d. | <0.2 | 70 | 100 | 3 | 1.5 | 20 | 1.5 | 7 | n.d. |
| 113 (34.5) vein chalcodony | 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- | 171 | n.d. | 0.7 | 1.5 | 20 | n.d. | n.d. | 15 | 2 | 10 | n.d. |
| calcite | | | | | | | | | | | |

¹Semi-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.

southwest of the Main Terrace. This andesite is 2.53 ± 0.11 m.y. old (Silberman and others, 1979) and is a key unit in understanding the history of the spring system. The basaltic andesite under Sinter Hill in the western part of the thermal area (GS-6 drillhole) was locally replaced almost completely by adularia (Schoen and White, 1967) that yielded a K/Ar age of 1.1 ± 0.1 m.y.; this alteration probably occurred during deposition of the overlying chalcedonic sinter deposits. Thermal activity that formed the younger sinter deposits has probably been continuous but varying in magnitude for at least the past 0.1 m.y. and possibly longer. Other intervals of activity probably have occurred (fig. 2) but are not clearly decipherable from preserved evidence.

The thermal area lies approximately on a line that connects four rhyolite domes, the largest of which is 5 km southwest of the springs and is 1.14 ± 0.04 m.y. old. Three domes from 1.5 to 5 km northeast of the springs yielded ages of 1.2 and 3.0 m.y. old. Vertical uplift under Sinter Hill is likely to have been caused by a shallow intrusion correlative with these younger domes (White and others, 1964; fig. 2).

White (1968) estimated that magma volume equivalent to 100 km^3 must have cooled and crystallized just to supply the convective heat losses assumed at present rates for 100,000 years. Three thousand km^3 would be required for 3 m.y. of continuous activity at present rates, but this seems improbable, judging from mass- and heat-flow constraints. However, intermittent activity during at least 10 percent of the total interval (≈ 0.3 m.y.) is viewed as a reasonable estimate, especially in view of the complex history of activity.

The long time span from the earliest hydrothermal activity to the present and the puny volume of rhyolite domes extruded during this time interval may be best explained by a huge magma chamber underlying the area but at great depth. In view of the complex histories of most large silicic volcanic systems, two or more cycles of evolution of the magma system seem likely. None culminated in the ash-flow tuff eruptions and caldera collapse that many other such systems have undergone, perhaps due to the great depth of the Steamboat system (R. L. Smith, U.S. Geological Survey, oral communication, 1975).

Sinter at Steamboat Springs generally contains detectable quantities of Au and Ag, and dark siliceous muds deposited in the present springs contain as much as 15 ppm of Au, 150 ppm of Ag, 0.01 percent Hg, and 3.9 percent of Sb as stibnite and metastibnite (Brannock and others, 1948; White, 1967; table 1). Hg is notable in some chalcedonic sinter, and has been mined and recovered in small quantities from acid-leached opaline residues resulting from solfataric alteration of granodiorite and basaltic andesite in the Silica pit (White and others, 1964; Schoen and others, 1974). Hg^0 has been identified in vapor from several drillholes and hot spring vents, cinnabar is common in small amounts with native S where vapor escapes through porous acid-decomposed sinter, and clusters of small crystals of cinnabar have been deposited on test specimens of sulfide minerals, especially galena, immersed for several months in non-producing geothermal wells. Stibnite has been deposited as needlelike crystals on the walls of several hot-spring pools such as spring 8

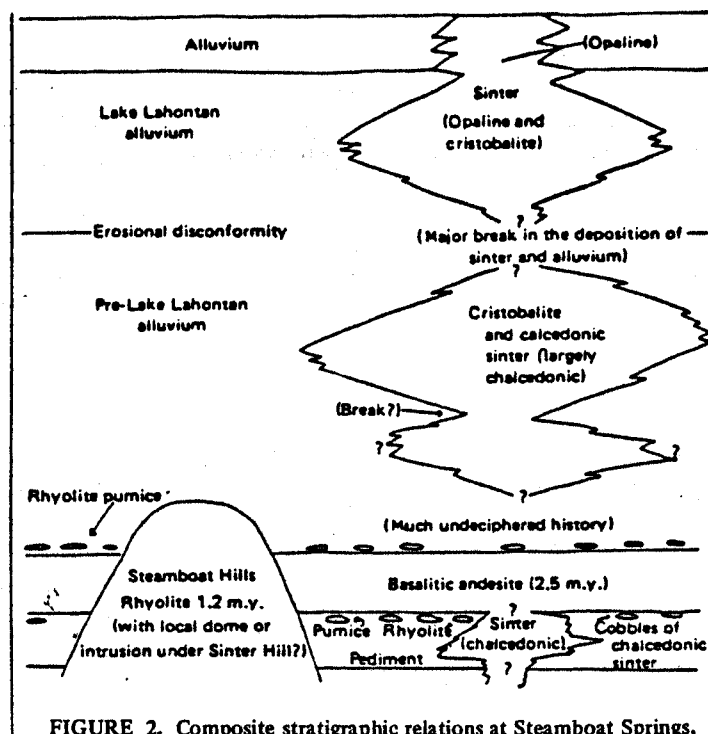


FIGURE 2. Composite stratigraphic relations at Steamboat Springs, from Silberman and others, 1979.

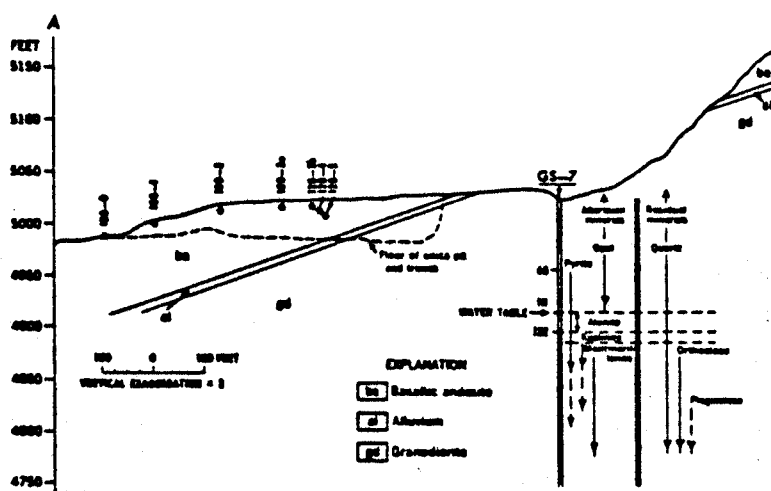


FIGURE 3. Geologic cross-section of silica pit showing locations of samples and mineralogy of core from drill-hole GS-7, from Schoen and others, 1974.

(table 1 and fig. 1). Coatings of orange-red metastibnite (amorphous Sb_2S_3) also formed on the discharge apron of spring 8 at some unknown time after systematic spring measurements were terminated in 1952, and has also formed in the discharge blast of at least three erupting geothermal wells. Sample W-941c of table 1 has the highest contents of Au, Ag, and other metals in any surface-formed deposit yet analyzed.

All cinnabar identified in the Steamboat thermal area occurs within 15 m of the present topographic surface, and no Hg was found analytically in drillcore at depths below 26 m (table 1). Some cinnabar occurs in acid-leached rocks above the water table in environments indicating deposition from a vapor phase, as in the Silica pit (fig. 3). These relations may provide the keys for understanding the "opalite-type" of Hg deposits that are rather common in western Nevada (Bailey and Phoenix, 1944).

Stibnite was recognized in veinlets and cavities in drill core to a maximum depth of 45 m below the surface. In six drillholes in the active Low and Main Terraces, the deepest observed stibnite occurred at temperatures that ranged from 100° to 146°C but trace quantities of Sb occur at greater depths (table 1). In spite of the much higher concentrations of As in the waters relative to Sb (White, 1967, table 13.3), no arsenic sulfides were recognized in surface deposits and drill core.

Spectrographic analyses of eleven samples of core from GS-5 drillhole (table 1) consist mainly of chemically precipitated SiO_2 (sinters to -25.6 m and chalcedony-quartz-calcite veins at greater depths). These were analyzed spectrographically by Chris Heropoulos of the U.S. Geological Survey, utilizing standard and newly-developed short wavelength radiation (SWR) techniques to attain lower levels of detection for critical elements not sufficiently sensitive by routine emission spectrographic methods. Visible pyrrargyrite (Ag_3SbS_3) had been identified previously in sample 273 and subsequently in core samples 238 and 353 (not analyzed), but silver minerals were not recognized in other core from this hole.

These data demonstrate that Au, As, Sb, Hg, Tl, and B all tend strongly to concentrate in the near-surface deposits of this active system, with contents commonly one to two orders of magnitude higher than in deeper deposits. Ge also shows some upward concentration, but Ag generally favors the middle and deep parts of the explored system. Sample W-310d of table 1 is representative of metal-enriched deposits of thermal water that has flowed slowly to the surface; contents of the "epithermal" elements (Au, As, Sb, Hg, Tl, and B) are relatively high in comparison with the "base-metal" elements (Cu, Zn, Pb). Ag favors the second group but also occurs with the first group. Sample 941c formed in the discharge blast of water erupted from a depth of 220 m in Nevada Thermal No. 4 well (west border of fig. 1 west of Pine Basin), where the temperature was approximately 185°C . Any base-metal elements in erupted water from this depth rapidly by-passed the natural environments of intermediate depths. Thus, both groups of metals were still available for rapid precipitation in these unusual surface deposits. A metal-bearing dark siliceous mud (W-50, spring 24, table 1) has high concentrations of the epithermal elements and also has modest concentrations of the base-metal group. These muds were flushed out of the system as

black suspended matter conspicuous only during periods of near-maximum discharge (Brannock and others, 1948, p. 223); precipitation had already occurred, largely below the surface at unknown depths. However, Au, As, Sb, Hg, and Tl may have continued to precipitate as lower temperatures and depths were attained.

Stable isotopes of Steamboat's thermal waters indicate a great dominance of meteoric water in the system but as much as 10 percent of magmatic water could have been present but not identifiable isotopically (Craig, 1963; White and others, 1963). The isotope relations show an increase in $\delta^{18}O$ of 2 to 3 per mil in the hot water relative to the cold meteoric recharge, with no change in the hydrogen isotopes. This "oxygen-shift" is a phenomenon common in high-temperature geothermal waters, and results from interaction at high temperatures between meteoric water (low in ^{18}O) and rock silicates (high in ^{18}O) during hydrothermal alteration.

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