

HYDROGEN AND OXYGEN ISOTOPE GEOCHEMISTRY OF COLD AND  
WARM SPRINGS FROM THE TUSCARORA, NEVADA THERMAL AREA

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ABSTRACT

Eighteen cold and warm spring water samples from the Tuscarora, Nevada KGRA have been analyzed for hydrogen and oxygen isotope composition and fluid chemistry. Warm springs have  $\delta D$  values (-128 to -137 permil) significantly lower than those of cold springs to the north and east of the area, but similar to the  $\delta D$  values of cold springs to the west and south (-131 to -135 permil). The recharge area for the warm springs is unlikely to be to the immediate north, which is the local topographic highland in the area. The hydrogen isotope data would permit recharge from areas to the southwest or from high elevations to the southeast (Independence Mountains), a sector consistent with electrical resistivity evidence of fluid flow.

Warm springs are  $HCO_3^-$ -rich waters, enriched by a factor of 3 to 10 in Na,  $HCO_3^-$  and  $SiO_2$  relative to local cold springs. Average quartz (no steam loss) and Na/K/Ca geothermometer estimates suggest subsurface temperatures of 145° and 196°C, respectively. The warm springs exhibit poor correlations between either hydrogen or oxygen isotope composition and water temperature or chemistry. The absence of such correlations suggests that there is no single coherent pattern of cold water mixing or evaporation in the thermal spring system.

INTRODUCTION

The Tuscarora, Nevada Geothermal System has been an area of geological, geophysical and geochemical investigation in recent years for evaluation as a geothermal resource. Of prime importance in this evaluation is the characterization of thermal water chemistry, estimation of subsurface temperatures, and definition of recharge areas for the thermal waters. Acquisition of stable isotope and fluid chemistry is required for the quantification of these parameters. These data are also important for the evaluation of near-surface mixing and water-rock interaction in the geothermal reservoir. In order to fulfill this requirement, water samples were collected from eight warm springs and ten cold springs in the Tuscarora area

(Fig. 1). These samples were analyzed for major cations and anions, and hydrogen and oxygen isotope compositions. The results of these analyses form the basis of this summary.

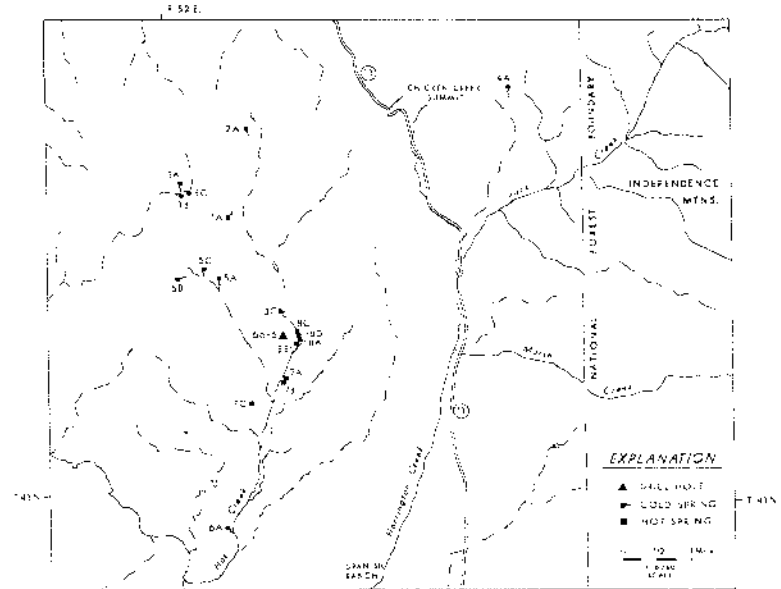


Figure 1. Location map of cold and hot springs.

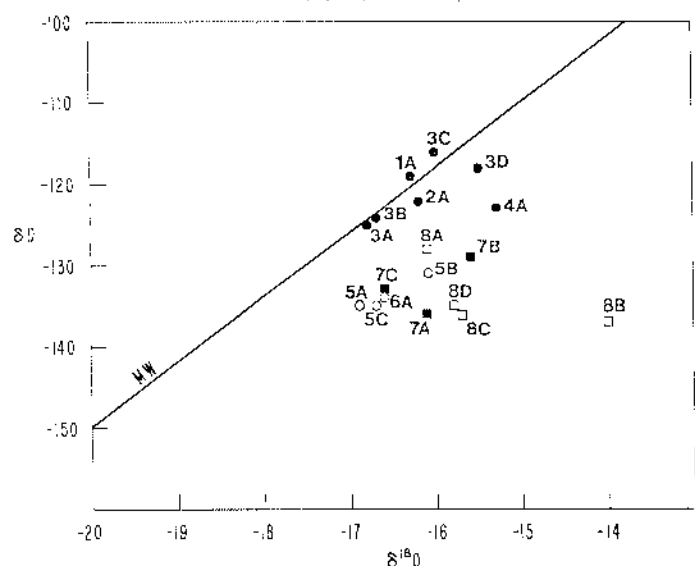
STABLE ISOTOPE GEOCHEMISTRY

Hydrogen and oxygen isotope analyses of the cold and warm springs are shown in Table 1 and plotted in Figure 2. The isotope analyses were determined using standard extraction (Epstein and Mayeda, 1953; Friedman, 1953) and mass spectrometric techniques. The data are expressed in the delta ( $\delta$ ) notation relative to SMOW for oxygen and hydrogen. In Figure 2, cold springs north of Hot Sulphur Springs (Samples 1A through 4A) are plotted as solid circles, cold springs northwest and southwest of Hot Sulphur Springs (5A through 6A) are plotted as open circles, hot springs of Hot Sulphur Springs (7A through 7C) are plotted as solid squares and hot springs north of Hot Sulphur Springs are plotted as open squares (8A through 8D).

The cold springs can be divided into two distinct groups. The group of cold springs north of the Hot Sulphur Springs system plot, with two exceptions, close to the meteoric water line, with

TABLE 1. Hydrogen and oxygen isotope compositions of cold and warm springs.

Sample #	$\delta^{18}O$	$\delta D$	Spring Temperature ( $^{\circ}C$ )
Cold Springs			
1A	-16.3	-119	10.5
2A	-16.2	-122	11.5
3A	-16.8	-125	15.0
3B	-16.7	-124	16.5
3C	-16.0	-116	10.0
3D	-15.5	-118	9.6
4A	-15.3	-123	8.0
5A	-16.9	-135	14.5
5B	-16.1	-131	18.5
5C	-16.7	-135	18.5
6A	-16.6	-134	20.0
Hot Springs			
7A	-16.1	-137	89.0
7B	-15.6	-129	82.0
7C	-16.6	-133	55.5
8A	-16.1	-128	73.0
8B	-14.0	-137	95.0
8C	-15.7	-136	59.0
8D	-15.8	-135	85.00

Figure 2.  $\delta D$  and  $\delta^{18}O$  values of cold and warm springs. MW (meteoric water line).

$\delta D$  values ranging from -116 to -125 permil and  $\delta^{18}O$  values from -15.3 to -16.8 permil. Samples 3D and 4A have apparently experienced  $\delta^{18}O$  enrichment of 0.5 and 1.3 permil, respectively. Both samples come from very low-volume seeps, consistent with the possibility of evaporation. However the spring temperature of sample 4A is the coolest--8.0 $^{\circ}C$ --of all cold springs sampled and is characterized by the lowest Cl,  $HCO_3^-$  and TDS contents of all springs sampled (Table 2). The cold springs from the northwest and southwest of Hot Sulfur Springs constitute the second group. These waters have significantly lower  $\delta D$  values (-131 to -135 permil) and plot off the meteoric water line. All these samples (5A through 5C, 6A) have experienced  $\delta^{18}O$  enrichments of at least 1.2 permil. These waters are significantly warmer (14.5 to 17.5 $^{\circ}C$ ) and contain generally higher TDS,

$SiO_2$ , Cl and  $SO_4^{=}$  contents (Table 2). The  $\delta^{18}O$  enrichment and increased salinity in these samples may be in part the result of kinetic evaporative effects. However  $\delta D$ - $\delta^{18}O$  trends of low temperature (< 90 $^{\circ}C$ ) evaporation (Craig et al., 1963) would result in intersection with the meteoric water line at  $\delta D$  values below (<-140 permil) those of any spring water measured by us in the area or reported for this part of the Basin and Range province (Friedman, 1953). Alternatively,  $\delta^{18}O$ -enrichment could result from either a mixture of  $\delta^{18}O$ -enriched thermal fluid or from low temperature water/rock interaction in the ground water aquifer.

All seven warm spring samples plot to the right of the meteoric water line, with  $\delta D$  values of -128 to -137 permil and  $\delta^{18}O$  enrichments of 1.3 to 4.3 permil. With the exception of sample 8B ( $\delta^{18}O$  = -14.0 permil), warm springs from the Hot Sulfur Springs area (solid squares) and those from the hot springs area to the north (open squares) are indistinguishable with respect to both hydrogen and oxygen isotope composition. There is considerable range in temperature of the warm springs from 55 to 95 $^{\circ}C$ .  $\delta^{18}O$  and  $\delta D$  values of both cold and hot springs are plotted versus spring temperature in Figure 3A. The warm springs and the two groups of cold springs define distinct T -  $\delta D$  fields as expected. The hottest spring (8B) does have the highest  $\delta^{18}O$  value, perhaps reflecting more extensive interaction with the high  $\delta^{18}O$  carbonate rocks present at depths greater than about 4500 feet (Sibbett, 1982). Otherwise, there is no significant difference in either hydrogen or oxygen isotope composition between the two coolest warm springs (7C and 8C) and the hotter springs. As shown in Figure 3B, a plot of  $\delta D$  and  $\delta^{18}O$  values versus  $SiO_2$  content (Table 2), there also are no significant differences in  $SiO_2$  content between the two coolest warm springs and the remaining warm springs. Further inspection of the chemical data in Table 2 reveals no apparent correlation between isotope compositions, other chemical parameters (Cl $^-$ ,  $HCO_3^-$ ) and temperature. The absence of trends suggests that the warm springs are not simply related by progressive dilution of thermal fluids by cool surface water or by evaporation processes. The low chloride contents of all warm springs (8 to 19 ppm) indicate that these waters are not derived from deep high temperature saline brines of formation or connate origin unless they represent steam condensates. However, the high pH and comparatively low  $SO_4^{=}$  contents argue against such an origin.

#### RECHARGE AREA FOR THE THERMAL FLUIDS

All the cold springs sampled north of Hot Sulfur Springs in the Hot Creek drainage (the local topographic highland) and drainages to the east (4A) have  $\delta D$  values (-125 permil or heavier) significantly greater than those of the warm springs (-128 to -137 permil). If the thermal waters are derived predominantly from these springs, they must represent steam condensates to explain their lighter  $\delta D$  values. The thermal

TABLE 2. SUMMARY OF CHEMICAL COMPOSITIONS AND GEOTHERMOMETER TEMPERATURES FOR SELECTED COLD AND THERMAL SPRINGS AT TUSCARORA, NEVADA.

	1A	2A	3A	4A	5A	6A	7A	7C	8A	8B	DH 66-5
T°C	10.5	11.5	15	8	14.5	21	89	55.5	73	95	110
pH(20°C)	6.1	6.2	6.4	6.4	7.5	7.5	6.9	6.9	7.6	7.4	8.4
Na (ppm)	7	6	10	41	14	80	151	169	145	148	163
K (ppm)	3	4	<2.5	<2.5	6	5	15	<11	19	20	25
Ca (ppm)	5	4	6	2	6	11	10	19	17	1	14
Mg (ppm)	2	1	2	1	2	3	<0.5	3	2	<0.5	2
Fe (ppm)	0.04	0.13	0.32	0.04	0.025	<0.025	<0.025	0.09	<0.025	0.04	0.06
Sr (ppm)	0.06	0.07	0.06	0.10	0.05	0.13	0.61	0.39	0.59	0.25	1.01
B (ppm)	<0.125	<0.125	<0.125	<0.125	<0.125	0.2	0.8	0.9	0.9	0.90	0.8
SiO <sub>2</sub> (ppm)	43	48	40	17	61	52	129	122	103	104	109
SO <sub>4</sub> (ppm)	5	4	6	2	7	17	52	34	50	55	47
Cl (ppm)	6	4	5	6	7	13	18	19	16	6	26
F (ppm)	0.2	0.2	0.1	<0.1	0.2	1.6	11	8.9	8.7	8.2	8
HCO <sub>3</sub> (ppm)	33	47	47	22	65	232	352	484	382	345	397
Geothermometers (a)											
Qtz adia.	97	101	94	64	111	104	145	142	134	135	137
Qtz Cond.	95	100	92	57	111	104	152	149	139	139	142
Chalcedony	64	70	61	25	82	74	127	123	112	113	116
NaKCa	61	73	56	69	87	87	184	159	194	225	208
NaKCaMg	---	---	---	---	77	77	---	108	144	187	158

(a) Geothermometer temperatures (°C) were calculated from equations given in Fournier (1981), Qtz adia = Quartz adiabatic geothermometer, Qtz cond = Quartz conductive geothermometer.

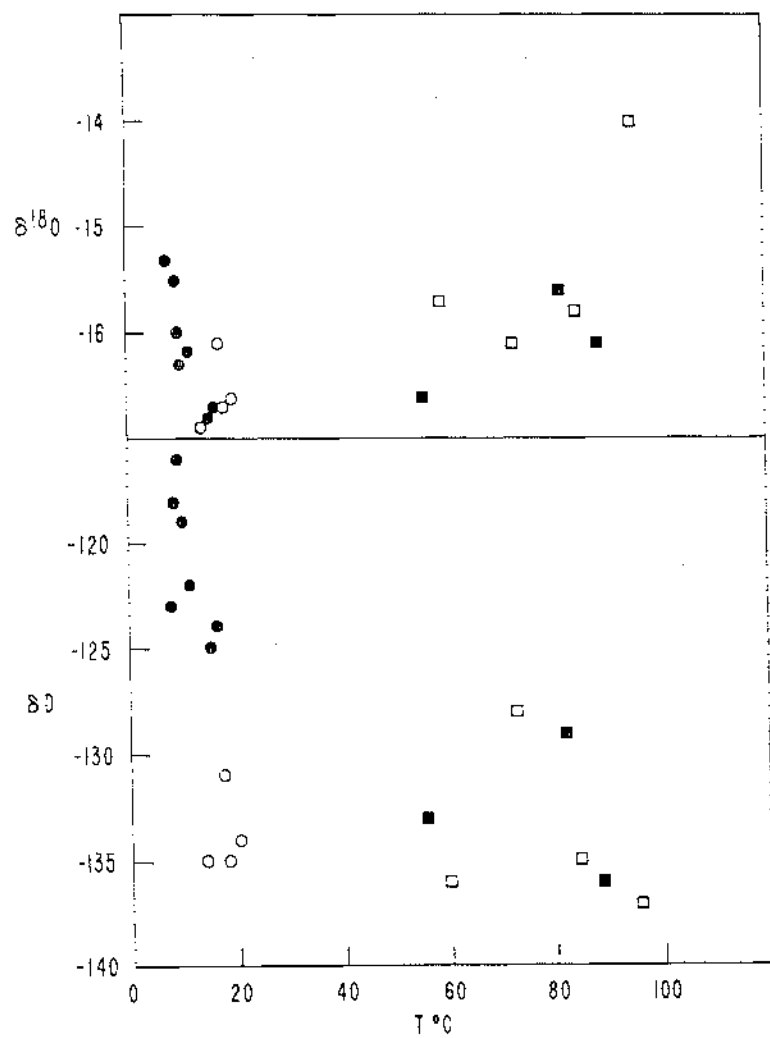


Figure 3A.  $\delta D$  and  $\delta^{18}O$  values versus spring temperature.

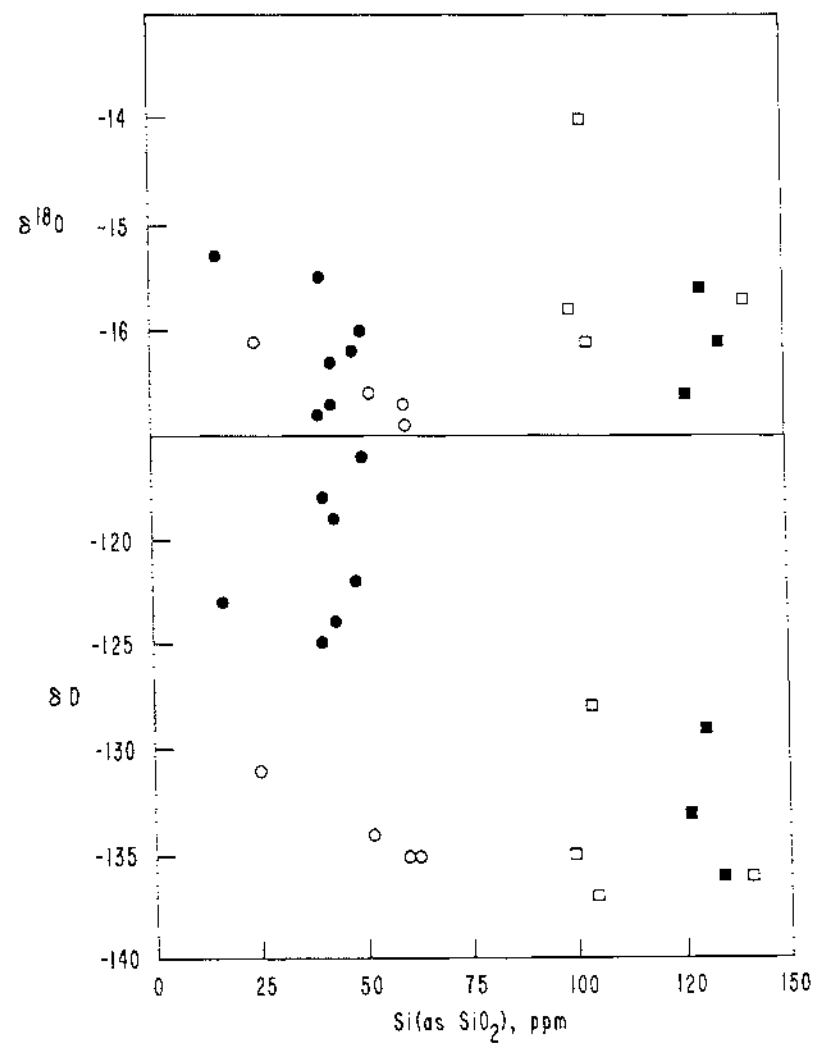


Figure 3B.  $\delta D$  and  $\delta^{18}O$  values versus SiO<sub>2</sub> contents.

waters do have low chloride contents characteristic of steam condensates, but the process is not consistent with observed SiO<sub>2</sub> contents, pH values greater than 7.0 or comparatively low SO<sub>4</sub><sup>=</sup> contents (Table 2). The cold springs west-northwest (5A to 5D) and south (6A) of the thermal springs have  $\delta D$  values equivalent to those of the thermal waters, demonstrating that surface waters exist in the area with appropriate  $\delta D$  values to directly produce the thermal waters. Alternatively, these cooler, low  $\delta D$  fluids may represent the conductively cooled equivalents of thermal fluids that have leaked south and west-northwestward along faults.

Geophysical evidence from a resistivity survey (Mackelprang, 1982) does suggest fluid flow from southeast to northwest in the area. A 2 ohm-meter zone is thought to indicate thermal fluids issuing from aquifers within Tertiary tuffaceous sediments and Paleozoic quartzites, cherts and carbonates at depths in excess of 4000'. The fluids rise to the surface via fracture zones to the Hot Creek and Hot Sulfur Springs area where they exit as hot springs. The presence of a low resistivity area at the surface northwest of these hot springs indicates that leakage of thermal fluids persists beyond the major existing zones along Hot Creek and Hot Sulfur Creek. These near surface fluids appear to have cooled approximately 50°C or more, but have retained their low  $\delta D$  isotopic signature. Further sampling in the areas south and west of the present hot springs area is needed to actually locate the recharge area. The isotope data do indicate that recharge for the geothermal system is unlikely to the immediate north of Hot Sulfur Springs.

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