A HYDROGEOCHEMICAL COMPARISON of the WAUNITA HOT SPRINGS, HORTENSE, CASTLE ROCK and ANDERSON HOT SPRINGS

by

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PURPOSE OF THIS REPORT

The Waunita Hot Spring area is located northeast of Gunnison, Colorado. This property has been offered to us by Austral Oil. A memorandum of April 2, 1975, indicated that the two contained hot springs exhibited some dry steam characteristics. This report endeavors to continue the discussion of the Waunita Hot Springs water and compare it to two thermal springs in the producing Geysers dry steam field, Lake County, California. The Waunita Hot Springs are also compared to Hortense Hot Spring, Mt. Princeton.

INTRODUCTION

Thermal water samples were collected from the two hot springs at the Waunita Dude Ranch on April 12, 1975. The southern most spring (X90475) has been used for space heating and bathing since the 1900's. The maximum recorded temperature is 75°C with a discharge of approximately 1000 gpm. The northern spring (X90476) was used for bathing but the bath houses are now ruins and the waters are unused. The northern spring produces water at 70.5°C with a flow of about 500 gpm. Both springs deposit small amounts of white, amorphous sulfate salts and both issue out of Dakota sandstone.

Plates 1 and 2 are pictorial descriptions of the southern and northern springs, respectively. Spring locations are shown on Figure 1.

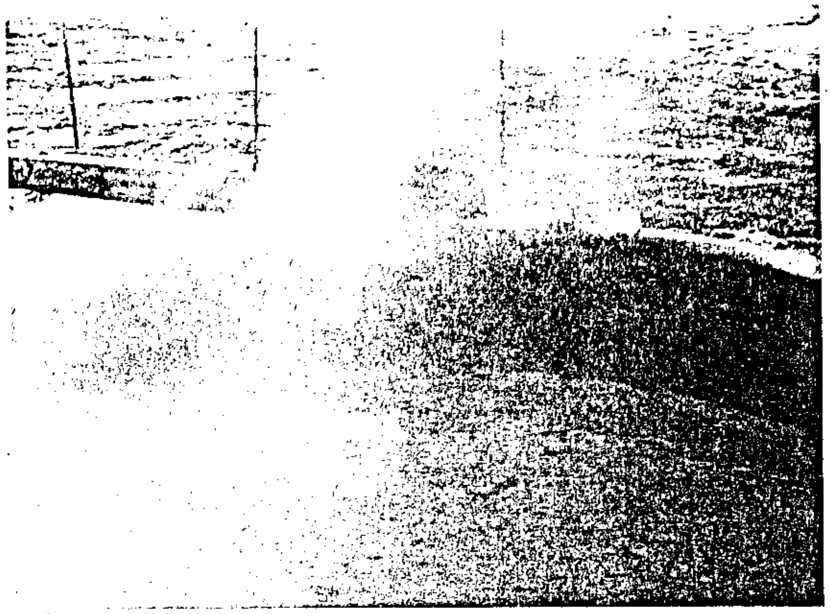

Plate 1. Waunita Hot Spring - south
T=75°C X90475

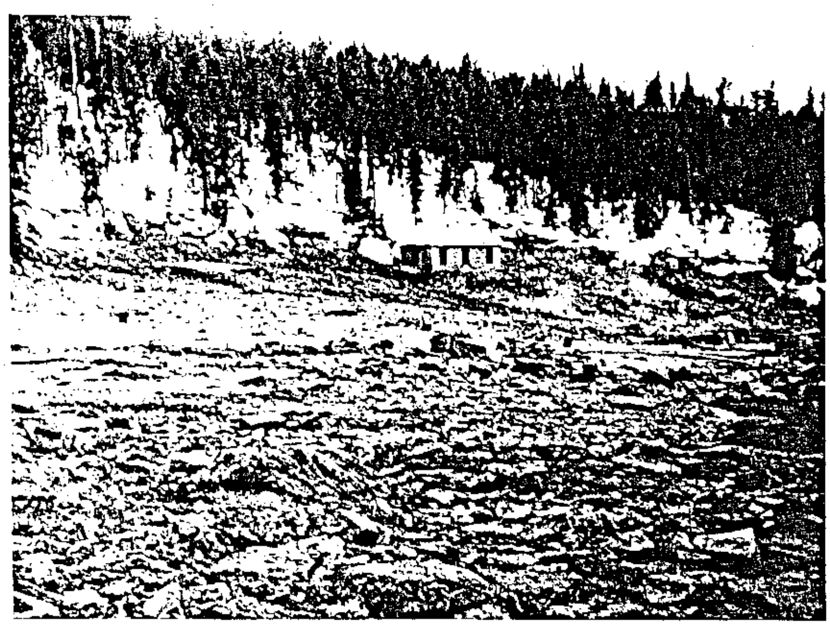

Plate 2. Waunita Hot Spring - north
T=70.5°C X90476

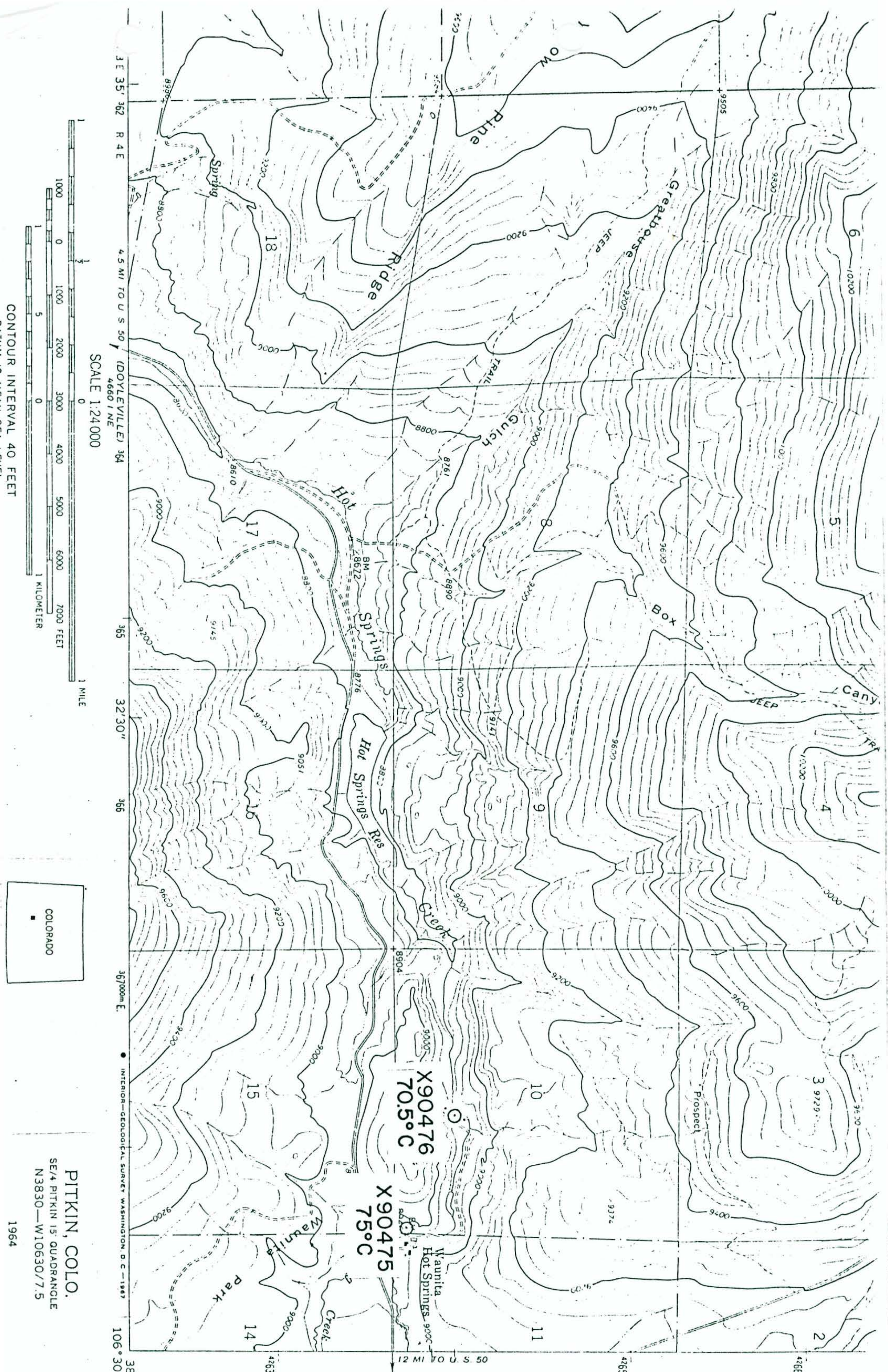

Figure 1. Location of the Waunita Hot Springs

CHEMISTRY

The chemistry of the southern and northern Waunita Springs is almost identical as seen in Table 1. The pH is basic, fluoride concentrations are very high at 27 mg/l, and chloride concentrations are very low at 16 mg/l. Cl/SO_4 and Cl/F ratios are well below unity. These thermal waters are described as follows:

Waunita: SO_4 HCO_3 Cl Na K Ca Mg

An analysis of Hortense Hot Spring, Mt. Princeton, Colorado, is listed for comparison in Table 1. It is a sulfate-bicarbonate-chloride water as seen below:

Hortense: SO_4 HCO_3 Cl Na Ca K Mg

Bicarbonate-sulfate and sulfate bicarbonate waters with low chloride concentrations are associated with the Geysers dry steam system. Castle Rock Hot Spring is intimately associated with Geysers steam production and an analysis of this spring is listed in Table 1. The Castle Rock Hot Spring water is described as follows:

Castle Rock: HCO_3 SO_4 Cl Na Ca K Mg

Anderson Hot Spring also issues out near the Geysers production area. It is somewhat acid and would be expected to liberate quantities of Ca and Mg as the waters rise to the surface. An analysis of Anderson Hot Springs is seen in Table 1. The major anions and cations are described as follows:

Anderson: SO_4 HCO_3 Cl Na Ca K Mg

Table 1. Analyses of the Waunita Hot Springs, Hortense Hot Spring, Mt. Princeton, Colorado, Castle Rock and Anderson Hot Springs and condensate of geothermal steam from the Geysers production area, California. Units are mg/l unless otherwise noted.

	Gunnison County, Colorado		Chaffee County, Colorado	Lake County, California		
	Waunita Hot Spring (South) X90475	Waunita Hot Spring (North) X90476	Hortense Hot Spring X89644	Castle Rock Hot Spring X89918	Anderson Hot Spring X89919	Geyser Steam Condensate X90507
pH	8.70	8.19	9.60	7.70	6.40	8.01
Cl	15	16	8.8	8.2	1.4	2.2
F	22	27	16	0.6	0.4	<0.1
HCO_3	90	128	46	154	104	18
CO_3	18	0	16	0	0	0
SO_4	170	180	100	15	270	6
SiO_2	127	98	85	128	52	5
Na	170	170	100	70	35	0.1
K	9.4	9.0	4.0	2.9	6.7	0.1
Ca	6	9	15.0	16	9.1	<0.1
Mg	0.1	0.4	0.1	2	38	0.1
Li	0.2	0.2	0.1	<0.1	0.2	<0.1
B	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
NH_3	0.05	0.1	0.4	0.45	1.0	20
H_2S	1.7	0.9	0	<0.5	4.1	2
TDS	635	644	394	404	689	60
T°C	75	70.5	85	58	52.5	74
Flow(gpm)	1000	500	50	5	10	--
$TSiO_2$°C	151	136	125	151	104	18
TNa/K°C	124	120	97	100	274*	835*
TNa-K-Ca°C	160	155	75	60	45	7.4
Cl/SO_4	0.24	0.24	0.24	1.5	1.4	1.0
Cl/HCO_3	0.20	0.21	0.19	0.09	0.01	0.21
Cl/F	0.37	0.32	0.29	7.3	1.8	12
Cations mg/l	8.0	8.1	5.3	4.1	9.5	0.2
Anions mg/l	7.2	7.7	4.5	3.1	8.4	0.5

* Does not reflect true subsurface temperature conditions.

A sample of fresh-clean steam condensate was collected from a leaking wellhead fitting at the Geysers. The well has been venting into a muffler since 8-74 when the leak was first noted. The major constitutes of the condensate are NH_3 and HCO_3. The pH is basic. Note that small amounts of chloride (2.2 mg/l) are carried by this density steam, probably as an aerosol. The cations and anions are described as follows:

Geyser Condensate: HCO_3 SO_4 Cl Na=K=Mg Ca

The aforementioned waters beg a comparison. The concentrations of Cl, Na, K, Ca, B, NH_3, H_2S, SiO_2 and TDS in Hortense Hot Springs are very similar to these concentrations in Castle Rock Hot Spring. The ratios shown at the bottom of Table 1. for the Hortense Hot Spring are more similar to those given for the Waunita Hot Springs than to those for Castle Rock and Anderson Hot Springs. Of the two Geyser Springs, the Waunita Springs are most similar to Castle Rock Hot Spring based on total dissolved solids, Cl, HCO_3, SiO_2, and B. The Waunita Springs are similar to Anderson Hot Spring in HCO_3, K, Li, B, Ca, Cl, SO_4 and TDS. The Waunita Springs are similar to both Anderson and Castle Rock Hot Springs in HCO_3, Cl and B. Table 2 and Figure 2 show similarities between all springs mentioned thus far. In a gross sense, similarities do exist between the Waunita Springs and those thermal springs mentioned from the Geysers. Precise similarities do not exist.

CHEMISTRY

The chemistry of the southern and northern Waunita Springs is almost identical as seen in Table 1. The pH is basic, fluoride concentrations are very high at 27 mg/l, and chloride concentrations are very low at 16 mg/l. Cl/SO_4 and Cl/F ratios are well below unity. These thermal waters are described as follows:

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Anderson Hot Spring also issues out near the Geysers production area. It is somewhat acid and would be expected to liberate quantities of Ca and Mg as the waters rise to the surface. An analysis of Anderson Hot Springs is seen in Table 1. The major anions and cations are described as follows:

Anderson: SO_4 HCO_3 Cl Na Ca K Mg

Table 2. The distribution of shared ions in Waunita, Hortense, Castle Rock, and Anderson Hot Springs.

Waunita H. S. Hortense H. S.	Waunita H. S. Castle Rock H. S.	Hortense H. S. Castle Rock H. S.	Waunita H. S. Anderson H. S.	Waunita, Hortense, Castle Rock and Anderson Hot Spring
Cl	Cl	Cl	Cl	Cl
F	HCO_3	SiO_2	HCO_3	B
HCO_3	SiO_2	Na	SO_4	
SO_4	B	K	K	
Na		Ca	Ca	
Ca		NH_3	Li	
Mg		H_2S	B	
Li		B	TDS	
B		TDS		
Cl/F				
Cl/HCO_3				
Cl/SO_4				

A sample of fresh-clean steam condensate was collected from a leaking wellhead fitting at the Geysers. The well has been venting into a muffler since 8-74 when the leak was first noted. The major constitutes of the condensate are NH_3 and HCO_3. The pH is basic. Note that small amounts of chloride (2.2 mg/l) are carried by this density steam, probably as an aerosol. The cations and anions are described as follows:

Geyser Condensate: HCO_3 SO_4 Cl Na=K=Mg Ca

The aforementioned waters beg a comparison. The concentrations of Cl, Na, K, Ca, B, NH_3, H_2S, SiO_2 and TDS in Hortense Hot Springs are very similar to these concentrations in Castle Rock Hot Spring. The ratios shown at the bottom of Table 1. for the Hortense Hot Spring are more similar to those given for the Waunita Hot Springs than to those for Castle Rock and Anderson Hot Springs. Of the two Geyser Springs, the Waunita Springs are most similar to Castle Rock Hot Spring based on total dissolved solids, Cl, HCO_3, SiO_2, and B. The Waunita Springs are similar to Anderson Hot Spring in HCO_3, K, Li, B, Ca, Cl, SO_4 and TDS. The Waunita Springs are similar to both Anderson and Castle Rock Hot Springs in HCO_3, Cl and B. Table 2 and Figure 2 show similarities between all springs mentioned thus far. In a gross sense, similarities do exist between the Waunita Springs and those thermal springs mentioned from the Geysers. Precise similarities do not exist.

Table 2. The distribution of shared ions in Waunita, Hortense, Castle Rock, and Anderson Hot Springs.

Waunita H. S. Hortense H. S.	Waunita H. S. Castle Rock H. S.	Hortense H. S. Castle Rock H. S.	Waunita H. S. Anderson H. S.	Waunita, Hortense, Castle Rock and Anderson Hot Spring
Cl	Cl	Cl	Cl	Cl
F	HCO_3	SiO_2	HCO_3	B
HCO_3	SiO_2	Na	SO_4	
SO_4	B	K	K	
Na		Ca	Ca	
Ca		NH_3	Li	
Mg		H_2S	B	
Li		B	TDS	
B		TDS		
Cl/F				
Cl/HCO_3				
Cl/SO_4				

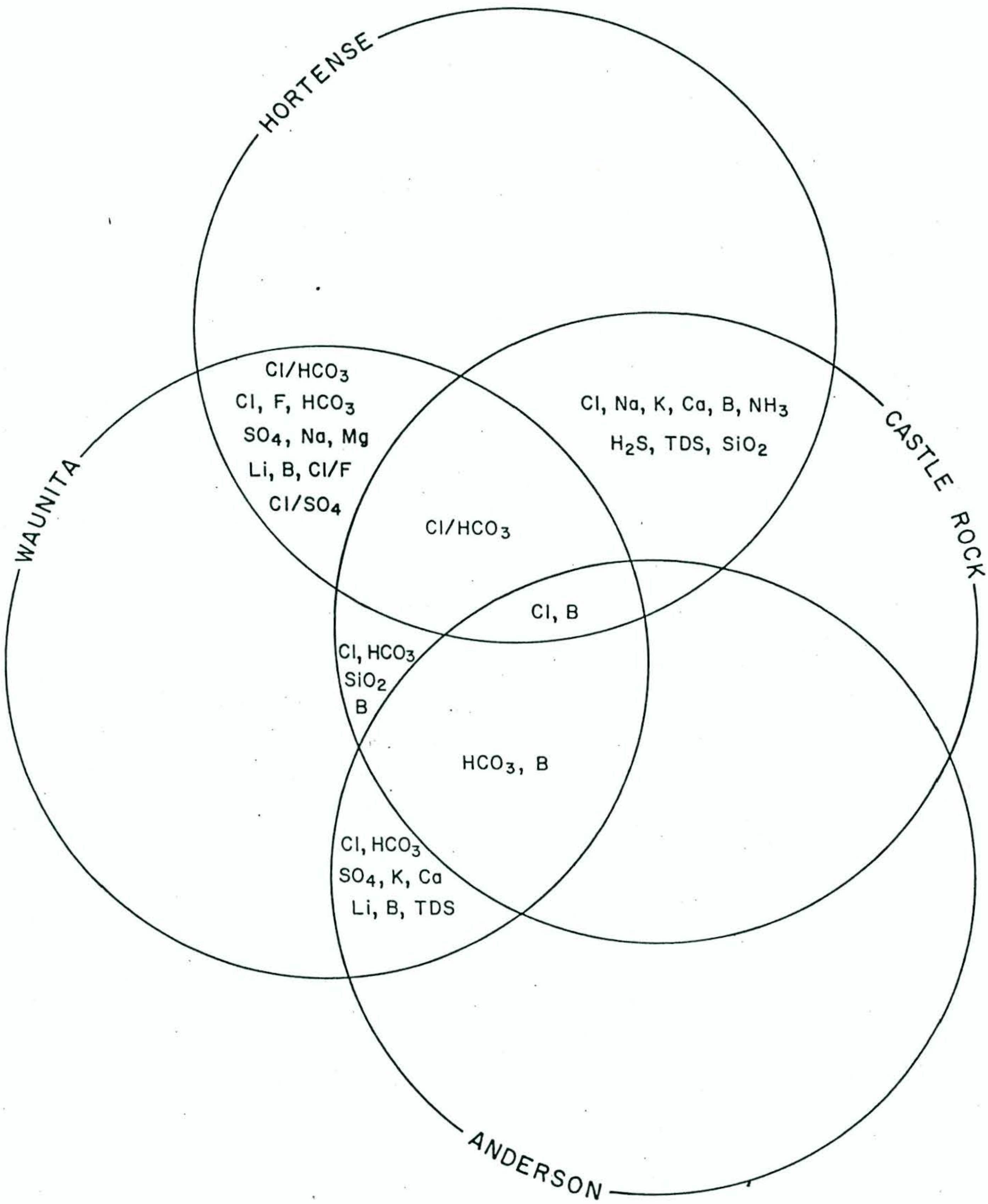

Figure 2. Distribution and congruence of various ions and ratios for the Waunita Hot Springs, Castle Rock, Anderson and Hortense Hot Spring.

SUBSURFACE TEMPERATURES

Hot springs associated with steam systems do not give accurate equilibrium temperatures for the following reasons:

1. Ions are left in the deep, old liquid on steam separation.
2. The very low ionic strength steam condenses at some shallow depth and re-equilibriates with ground water.
3. Maximum equilibrium temperatures can not exceed the original steam temperature plus normal gradient of the area.
4. The volatiles in steam, NH_3 and H_2S, suffer much greater damage via cold water dilution than would the same volatile in hot water.

"Steam heated springs" are at best reflections of shallow conditions and subsurface temperatures should be in the vicinity of 100°C or below.

Subsurface temperatures for Castle Rock and Anderson Hot Springs are generally below 100°C as seen in Table 1, and fit the aforementioned model. Hortense Hot Spring is very similar to Castle Rock Hot Spring with regard to subsurface temperature.

The Waunita Hot Springs exhibit excellent subsurface temperature correlation. Subsurface temperatures are probably in the range of 130-150°C. This correlation does not fit the shallow re-equilibriation model previously mentioned. However, the depth of re-equilibriation is the controlling factor and the possibility of condensing steam at greater depths exists.

MINERAL EQUILIBRIA

The Gibbs Free Energies of saturated minerals for all all springs discussed thus far are listed in Table 3. The most important constraints on whether or not a mineral is saturated are:

1. Water pH
2. Subsurface and surface water temperature
3. Presence of a specific mineral at depth
4. Ionic exchange of thermal water with minerals present
5. Equilibria between ions dissolved in water.

Waunita, Hortense and Castle Rock Hot Springs contain similar numbers of saturated minerals. The same springs share only two minerals, talc and tremolite. Waunita and Castle Rock Hot Springs share seven minerals: tremolite, talc, magadite, quartz, kenyaite, chalcedony, and cristobalite. Hortense and Castle Rock Hot Springs have only talc and tremolite in common. Waunita and Hortense Hot Springs have termolite, talc, dropside, and crysotile in common as seen in Figure 3 and Table 3.

The minerals listed for Hortense Hot Spring fit the minerals found in the Chalk Cliffs exceptionally well. Note the showing of zeolites and chlorite which have been described in the literature (Sharp, 1970).

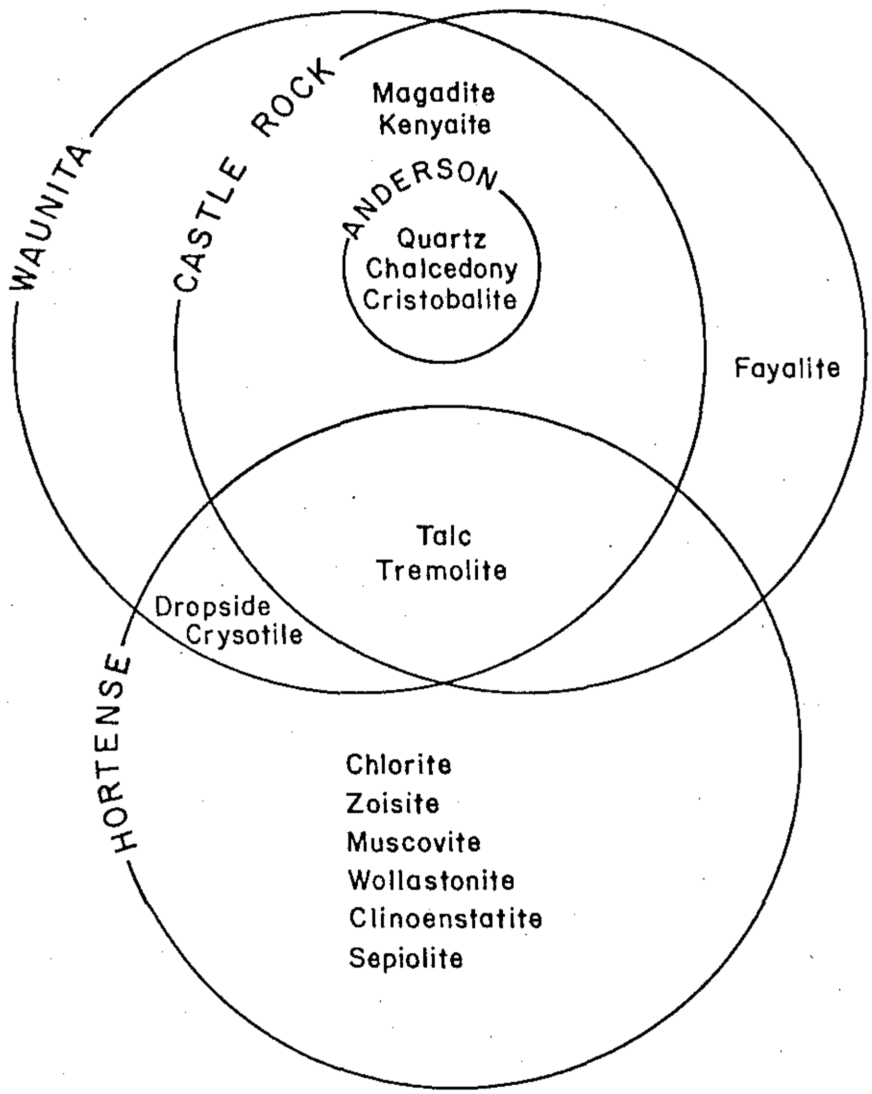

Figure 3. Distribution and congruence of various hypothetical minerals for the Waunita-South, Castle Rock, Anderson and Hortense Hot Springs.

Table 3. Gibbs Free Energies of various hypothetical minerals in Kcal/mole. Positive values indicate saturation, 0 indicates equilibrium and negative values indicate undersaturation.

	Waunita Hot Spring South X90476	ΔG	Hortense Hot Spring X89644	ΔG	Castle Rock Hot Spring X89918	ΔG	Anderson Hot Spring X89919	ΔG	Geyser Steam Condensate X90507	ΔG
Carbonates	Calcite	0.5			Calcite	0.01				
	Aragonite	0.4								
Silicates	Tremolite	24.0	Tremolite	35.1	Tremolite	12.5	Quartz	0.8	Talc	2.8
	Talc	12.5	Chlorite	28.0	Talc	9.3	Chalcedony	0.3		
	Diopside	4.2	Talc	16.1	Fayalite	1.5	Cristobalite	0.0		
	Crysotile	3.5	Crysotile	8.6	Quartz	1.3				
	Magadite	1.6	Diopside	8.0	Magadite	1.1				
	Quartz	0.8	Zoisite	7.2	Chalcedony	0.8				
	Kenyaite	0.6	Muscovite	6.3	Kenyaite	0.6				
	Chalcedony	0.4	Wollastonite	1.3	Cristobalite	0.5				
	Cristobalite	0.1	Clinoenstatite	0.6						
			Sepiolite	0.2						
Zeolites			Phillipsite	11.5						
			Prehnite	7.4						
			Laumontite	5.3						
TDS		635		394		404		689		60
pH		8.70		9.60		7.70		6.4		8.1

The strong showing of metamorphic minerals in the water of the Waunita Hot Springs would indicate that the "reservoir" is in metamorphic rock probably at great depth.

CONCLUSIONS

The Waunita Hot Springs are similar to the two Geysers thermal springs as follows:

1. Qualitative anion relationships, SO_4, HCO_3, K, Li, B and TDS with Anderson Hot Spring
2. TDS, Cl, HCO_3 SiO_2 and B with Castle Rock Hot Spring.
3. HCO_3, B and the Cl/HCO_3 ratio with Anderson and Castle Rock Hot Springs.

The Waunita Hot Springs exhibit dissimilarities with the Geysers Springs as follows:

1. pH, F, Na, NH_3 and the Cl/SO_4 and Cl/F ratios
2. Subsurface temperature correlation
3. Mineral suites at reservoir depth
4. Spring discharge

Correlation between the Waunita Hot Springs and the Geyser Springs is not exact; however, exact correlation would seem improbable. The correlation between Hortense Hot Spring and the Geyser Springs is more satisfactory.

The Waunita Springs prospect is interesting but somewhat ambiguous. The writer suggests that the property be acquired but be given a low priority. Success at the Mt. Princeton property will add much flavor to the Waunita Springs prospect owing to the similarities between them.

Bibliography

Sharp, W. N. (1970), Extensive zeolitization associated with hot springs in Central Colorado, U.S.G.S. Prof. Paper 700-B, pages B14-B20.