TEC-6

A GEOLOGICAL AND HYDROGEOCHEMICAL STUDY OF THE VALE AREA, MALHEUR COUNTY, OREGON

by

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Amax Exploration, Inc.

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CONCLUSIONS

1. The Vale prospect lies at the western margin of the Snake River Graben in east central Oregon. Local structure is controlled by the Snake River Graben and the Basin and Range. Block faulting has created three broad topographic areas north of Vale: the upfaulted hills west of Bully Creek, the downfaulted Jameison Valley and the upfaulted hills near McCarthy Ridge. Major faults extend northwest through Bully Creek, the Jameison Valley and Alkali Springs. Inferred faults extend east-west through the Malheur River Valley and north-west along Lytle Boulevard.

2. The Vale area has been tectonically active since the Miocene. Pleistocene to recent movement amounts to minor crustal adjustments. No large recent inconformities were observed.

3. The youngest volcanism is a small 7 m.y. old pumice stone eruption at Sugarloaf Butte. Radiometric dates from the North Vale property resulted in 11.8 and 11.4 m.y. old rock ages.

4. Previous geological studies of the Vale area were found to be unreliable in stratigraphy and lithology. Rhyolite and andesite flows and a small rhyolite intrusion are proposed.

5. Hydrothermal alteration consisting of silica deposition is most profound and youthful in the Bully Creek area. Hydrothermal alteration also occurs south of Vale at Rhinehart Butte and in the north Vale property.

6. Miocene sediments and fractured basalt flows probably occur to a maximum depth of 3500 feet below surface. Silicified metasediments may occur at greater depths.

7. The Vale area contains 9 hot wells or springs and at least 8 warm wells or springs. Non-thermal waters generally contain less than 500 mg/l of dissolved solids and are bicarbonated. Thermal waters are of the chloride, sulfate or bicarbonate variety. Chloride concentrations indicate hot water systems at depth. Thermal waters last equilibrated with a combined metamorphic and igneous mineral suite.

8. Subsurface temperatures indicated by geothermometers range from 25°C to 183°C. Jordan Hot Spring is most interesting with silica and Na-K-Ca temperatures of 177°C and 183°C, respectively.

9. Stable isotope studies indicate that the waters of Vale and Jordan Hot Spring have been in storage for some time. Jordan Hot Spring shows a minimal δO^{18} shift indicating that the reservoir may be near the surface.

10. Geological and hydrogeochemical studies indicate two target areas: Jordan Hot Spring and Cow Hollow. Jordan Hot Spring is the most important because here subsurface temperatures are the highest, silica is presently being deposited, fossil silicification is most widespread and youthful, a preliminary gradient measurement is very encouraging and rock dates are the most youthful in the area at 7.0 m.y. Drilling may encounter 180°C+ temperatures with total dissolved solids not exceeding 2500 mg/l at depths of less than 7000 feet. The reservoir may consist of fractured Miocene basalt or metasediments.

A second target area near the intersection of Lytle Boulevard and Cow Hollow is based solely on favorable heat flow measurements.

11. The Jordan Hot Spring-Bully Creek area requires the following further work:

    a. At least ten shallow thermal gradient holes
    b. Microseismic studies
    c. A study of closely spaced helium soil gas samples
    d. Expanded geologic mapping west of the present boundary
    e. Resistivity studies
    f. A deep gradient measurement targeted by the aforementioned studies.

12. The Cow Hollow target requires a deep gradient whole targeted by our adequate shallow gradient holes and helium soil gas data.

PURPOSE AND SCOPE

AMAX, Inc., has acquired a substantial land position in the vicinity of the Vale area of eastern Oregon (Figure 1). This report will discuss the geology and hydrogeochemistry of the Vale area. Geology was studied through conventional surface mapping techniques, thin section study, partial rock chemical analysis, and the study of deep well logs (Newton et al, 1963). Special attention was given to hydrothermal alteration and mineralization, geologic structure, rock age, and the distribution of potential reservoir rocks at depth.

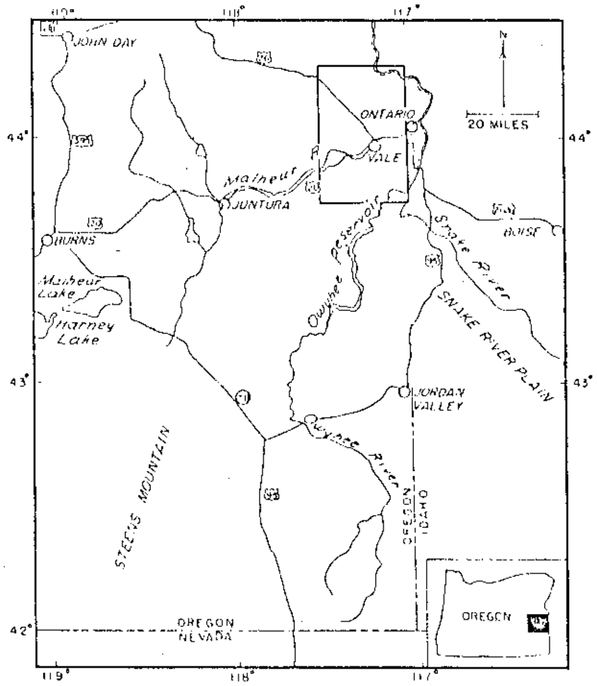

Figure 1. Location map of the Vale, Oregon, prospect.

ACKNOWLEDGEMENTS

John Deymonaz assisted in mapping and constructing geological cross sections. Dean Pilkington offered constructive criticism and suggestions during all stages of mapping. The writer of this report takes full responsibility for any errors.

PRIOR WORK IN AREA

Dean Pilkington assembled seven separate maps into a geological compilation of the Vale area. The southern two-fifths of this geological map was taken from the Mitchell Butte Quad by Corcoran (1962). The remaining maps are masters theses of the University of Oregon and other published and unpublished maps (Figure 2).

REFERENCE MAP

- ▥ Beeson, John, 1955, Geo. of the Southern Half of the Huntington Quad,: Univ. Ore. Mstrs. Thesis.
- ▩ Calkins,J.A.,1954, Geo. of the Northeastern Half of the Jamieson Quad.: Univ.Ore.Mstrs.Thesis.
- ▧ Carlat, James,1954,Geo. of the Southwestern Half of the Jamieson Quad.: Univ.Ore.Mstrs.Thesis.
- ╲╲╲ Corcoran,R.E.,1962,Geo. of the Mitchell Butte Quad: Ore.Dept. Geo.Min.Ind.Geo.Map Series #2
- × × Kirkham, V.R.D.,1931, Igneous Geo. of Southwestern Idaho: J.Geology, V.39,N.6
- + + Oregon Dept. Geo.Min.Ind.,1975, Geo of the Baker Quad.,(unpublished).
- ▨ Spiller,Jason,1958, Geo.of a Portion of the Olds Ferry Quad.: Univ. Ore. Mstrs. Thesis.

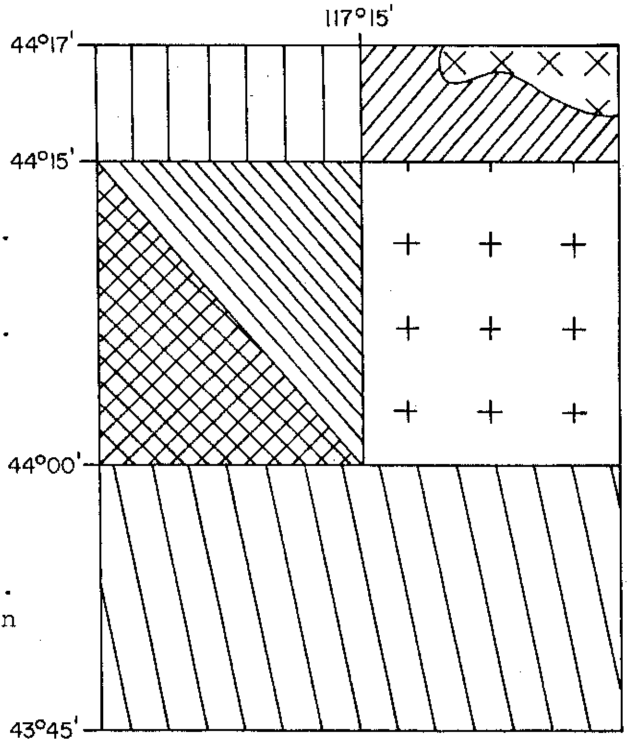

Figure 2. Source material for the Vale geological compilation.

The Mitchell Butte Quad is accurate with a few exceptions. The bulk of the field work was spent remapping the northern three-fifths of the compilation because of numerous omissions and errors by previous workers.

PHYSICAL AND ECONOMIC GEOGRAPHY

Eastern Oregon is sparsely populated. Vale (population 1710) is the largest town in the vicinity of the Amax property. Ontario (population 7,500), is located 17 miles east of Vale while Burns is located 114 miles to the west. U.S. Highways 20 and 26 roughly bisect the map east-west and north-south, respectively.

The broad valleys and terraces of the Malheur River and Willow Creek are cultivated for various grains, corn, sugar beets, onions, mint, potatoes, hops and hay. The remainder of the country consists of rolling to rugged uplands that average about 2700 feet in elevation. Upland vegetation consists of sage and grasses. Cattle graze over most of the uplands. Annual rainfall is about 10 inches and air temperature ranges from -34 to 43°C. The uplands are desolate and accessibility is generally very good via dirt roads.

Terrace gravels are mined locally for road metal and other construction needs. Bentonite and calcite were mined at one time. A few flasks of mercury were mined at Hope Butte during the 1960's.

REGIONAL GEOLOGY

The Vale area is bounded on the east by the Western Snake River Graben, on the southwest by the Steins Mountains, and on the north by the Blue Mountains (Figure 1). The area of interest lies near the intersection of two geologic provinces, the Basin and Range and the Snake River Graben. A precise boundary is not evident because of erosion and recent sedimentary cover. Basin and Range faulting is the result of a regional stress field applied 15 to 20 m.y. ago. Rock isotope data indicates that the maximum stress occurred during the middle Pliocene and other evidence indicates that this regional stress field is still present (Walker, G., personal communication). Basin and Range faulting is expressed in eastern Oregon by NW and NE trending faults. Movement is down dip and displacement is generally measured in hundreds of feet. Dips range from vertical to 30° and result from tilting of fault blocks. Faults are often obscured by a cover of up to several thousand feet of Pliocene continental sedimentary rocks that dip gently to the east. The Snake River Graben (Mallon, H.E., 1959), once thought of as a downwarped basin (Kirkham, V., 1931), is presently interpreted as a downwarped basin with peripheral normal faulting.

The Basin and Range structure of eastern Oregon and the Snake River Graben are probably related to Miocene to recent plate tectonic movements. The Brothers Fault Zone and the Olympic-Wallowa lineament may be deeply buried transcurrent faults. These faults exhibit right lateral transcurrent motion at depth while buckling rocks at the surface. The enormous volume of volcanic cover has significantly complicated resultant surficial structure. Large volumes of silicic and basaltic volcanics have been extruded along the Brothers Fault Zone , located south of Vale. Silicic volcanics become younger and display smaller extruded volumes moving from east to west. Silicic volcanics generally have isotopic ratios similar to basaltic rocks which may imply a comagmatic origin quite deep in the crust.

No large silicic eruptive centers occur locally although thin rhyolite and andesite flows are present. Miocene basalts are present in large volumes. One Pleistocene basaltic cinder cone, Malheur Butte, implies that major faults in the Vale area may tap the upper mantle.

TRIASSIC STRATIGRAPHY

Triassic Meta Sediments (Tru)

Triassic meta sediments are exposed in the northwest quadrant of the map area. The sediments include gray and pink crystalline limestones, calcareous shales and schist. Good exposures are seen at Limestone Butte. A partial section of 3000 feet was measured by Beeson (1955). Rocks are well cemented with secondary silica and calcite. Regional metamorphism has resulted in folding, bending and cementing of strata. These sediments are Upper Triassic in age.

MIOCENE STRATIGRAPHY

Owyhee Basalts (Tob)

The Owyhee basalts were first described by Russell (1902). They consist of a thick section of flows and interbedded tuffs of upper Miocene age. The most extensive outcrops of Owyhee basalt are exposed in the deep canyon of the Owyhee River. Other outcrops are located near the west map margin, near Little Valley and in the northeast quadrant near the Snake River.

The Owyhee basalts are similar megascopically and microscopically to the Columbia River basalt (Yakima Basalts) exposed in the north half of the map. Some workers believe that these basalts are contemporaneous while others feel the Yakima basalts are Pliocene. 1,500 feet of Owyhee basalt were measured near Owyhee lake, however, the flow is probably much thicker. Explosive phases of the Owyhee are represented by interbedded tuff and ash, common throughout the section. Individual 10 to 15 foot layers of pyroclastics may make up half of the total section.

Owyhee basalt is aphanitic, gray to jet black and displays massive to vesicular structure. Texture varies from seriate to microporphyritic. Little glass is seen in thin section. Plagioclase, augite, hypersthene, olivine and magnetite are primary minerals while calcite, chlorite, zeolites and iddingsite are secondary minerals. Seven optical determinations indicate that plagioclase grains are labradorite. Three chemical determinations of Owyhee basalt average 54 percent silica.

Columbia River Basalt (Tcr)

The Yakima basalts are Miocene in age (Walters, 1961). These basalts clearly overlay the Deer Butte sediments in the northwest quadrant of the map. Flows are generally variable in thickness and range from a few feet to several hundred feet. This basalt generally becomes thinner moving southward. Yakima basalts outcrop over most of the northern one-fifth of the map. Excellent exposures are seen in the deep canyon of Birch Creek.

Yakima basalt is generally dark gray, vesicular to massive and aphanitic. This basalt is easily confused with Owyhee basalt in hand sample. Thin sections reveal microporphyritic and seriate texture.

Plagioclase, olivine, augite, hypersthene and magnetite are primary minerals as groundmass and phenocrysts while iddingsite, hematite, calcite and natrolite occur as secondary minerals. The rock is holocrystaline. Chemical determinations on four different samples of Yakima basalt yielded an average of 54.7 percent silica.

Deer Butte Formation (Td)

The Deer Butte Formation is late Miocene in age and consists of fine-grained tuffaceous sediments overlain by massive sands and conglomerates. 1,248 feet of section is exposed at Deer Butte, however, thickness should be highly variable owing to the uneven erosional surface on which Deer Butte sediments were deposited.

The lower tuffaceous siltstone member is composed of fine-grained tuffaceous clay stones, siltstones, shales and thin basalt flows. The upper arkosic member is composed of highly resistant sands and fine to very coarse grained conglomerates; pebbles are generally quartz, granite, and ryholite.

Deer Butte sediments are exposed at Mitchell and Deer Butte, located near the south map boundary, at Vale and Rhinehart Buttes, located south of Vale and in the northwest quadrant of the map.

PLIOCENE STRATIGRAPHY

IDAHO GROUP

The Idaho Group consists of the Kern Basin Formation (Lower Pliocene), the Grassy Mountain Basalt (lower Pliocene?) and the Chalk Creek Butte Formation (Middle Pliocene).

Kern Basin Formation (Tik)

The Kern Basin Formation consists of tuff, tuffaceous siltstone, tuffaceous sandstone, graywake and conglomerate. The rocks are poorly lithified. Beds are generally white to light green. The formation has a minimum thickness of 750 feet. Kern Basin sediments are exposed near Double Mountain in the southwest quadrant of the map.

Grassy Mountain Basalt (Tig, Tigs)

The Grassy Mountain Basalt was first named by Kirk and Bryan (1929). Flows range from a few feet to several hundred feet thick and are generally interbedded with sediments. Flows are massive and weather to a rust brown color while a fresh surface has a distinctive green-black color. Well logs indicate a total thickness of at least 1000 feet. The Grassy Mountain Basalt is widely distributed in the southwest quadrant of the map.

Hand specimens are generally porphyritic but may be aphanitic. Phenocrysts of olivine and plagioclase are distinct. Flows are massive to vesicular. In thin section, olivine rimed with iddingsite and hematite, plagioclase and augite occur in a groundmass consisting of plagioclase. The rock is holocrystaline and generally microporphyritic. The basalt contains 48.8 percent silica.

Chalk Butte Formation (Tic, Ticb)

The Chalk Butte Formation is ubiquitous to the area. It overlies the Grassy Mountain Basalt and consists of tuffaceous sandstones and siltstones, tuff, conglomerate, and fresh water limestone. Small thin (30 feet) basalt flows erupted during Chalk Butte times are included in this formation and outcrop near the central western margin of the map. Chalk Butte sediments form subdued rolling hills and generally dip gently to the east. The Chalk Butte sediments are at least 550 feet thick and become much thicker east of the map area.

The Chalk Butte Basalt (Ticb) is jet black to brown, porphyritic, and generally massive. Augite and plagioclase are visible in hand specimen. The rock is holocrystaline and is depleted in olivine. The basalt contains 46.1 percent silica.

Coarse Grained Basalt (Tb)

The coarse grained basalt is 11.8 m.y. ± 0.5 m.y. old. This basalt is seen only as near vertical dikes on association with major faults in the north-central part of the area and indicates that the step faults are deep and may extend to the mantle.

The coarse grained basalt is black to gray, porphyritic, and massive. Megascopic plagioclase makes hand specimens distinctive.

Thin sections reveal ophitic to sub-ophitic, and glomeroporphyritic texture. Major minerals are plagioclase with multiple zoning, augite and magnetite. The rock shows no alteration. Silica content averages 53.6 percent.

Tertiary Pitchstone (Tpf)

Rhyolitic pitchstones are exposed in the northwest part of the map area. This rock was previously mapped by Carlat (1954) as Owyhee Basalt. Pitchstones clearly overlay the Owyhee basalts but the local stratigraphic relationship with the Chalk Butte is not known due to poor exposures. Outcrops show only flow relationships. No eruptive center was recognized. 210 feet of pitchstone is exposed in a canyon in section 33 of T17S, R43E.

The rock is generally a jet to rusty black, massive and exhibits a pitch like luster. Thin sections reveal orthoclase, sanidine and augite in a groundmass of andesine and glass. Texture is porphyritic to glomeroporphypitic. Two chemical analyses indicate 73.9 percent silica.

Tertiary Rhyolite (Tri)

Tertiary rhyolite flows were mapped west of Willow Creek. Flows generally are not thicker than 50 feet. The best exposure of rhyolite is seen at Sugarloaf Butte. The eruptive center is probably northwest of the map area. A sample of rhyolite located at Love Reservoir was dated at 11.4 m.y. ± 0.5 m.y.

Rhyolites are rusty-orange, porphritic and massive. Phenocrysts of orthoclase, sanidine and sodic augite lie in a groundmass of plagioclase and glass. Rhyolites are minerologically similar to the pitchstones previously described. Chemical analysis of three samples indicates 78.8 percent silica.

Dacite Vitrophyre (Tda)

Dacite vitrophyre is exposed at Double Mountain in the southwest part of the map area. Baked contacts and intrusive relationships indicate the rock is quite young. A K-Ar date by MacLeod (1975) indicates a 7.9 m.y. age. This is the second youngest rock in the area to date. Thin sections reveal phenocrysts of oliglase and pyroxene in a glassy groundmass.

Basalt Vitrophyre (Tba)

Basaltic vitrophyre is exposed in the southwest quadrant of the map. This rock exhibits both flow and intrusive relationships. The total geographic extent of this rock is limited.

Hand specimens are brown-red, aphanitic and vesicular. Thin sections reveal labradorite and andesine in a glassy groundmass. Vesicles are filled with silica and a radiating fiberous zeolite. A single analysis reveals 79.2 percent silica.

Sugarloaf Butte Pumice Stone (Tr)

About thirty feet of light gray, open textured, crystal-vitric pumice (pumice stone) caps the very top of Sugarloaf Butte, located on the central western map margin. The pumice stone was dated 7 m.y. ± 1.5 m.y. This is the youngest rock in the Vale area.

Sugarloaf Butte is interpreted as a Pliocene volcanic center.

Tub Mountain Andesite (Ta)

Tub Mountain is capped with about 50 feet of light gray, vesicular andesite which was previously mapped by Calkins (1954) as Owyhee Basalt. The andesite is aphanitic exhibiting seriate texture and consists almost entirely of sodic plagioclase. The rock is holocrystaline and contains 62.2 percent silica.

The remnant atop Tub Mountain is the only andesite in the map area. An eruptive center was not found, however the flow was probably erupted locally during Pliocene.

Post Idaho Basalt (TQb)

Post Idaho basalt forms mesas in the northwest corner of the area. The basalt is massive aphanitic and gray to black. A thin section reveals microphorphyritic texture, with labradorite in a groundmass of labradorite, augite, olivine and magnetite. The source of this basalt is likely Cinder Butte located just north of the map boundary. The basalt is consistently about 60 feet thick.

PLEISTOCENE STRATIGRAPHY

Pleistocene Basalt Centers (Qtbc)

A basaltic cinder cone known as Malheur Butte is located near the eastern map margin. The morphology of the cone indicates a very recent age. Flows associated with the eruption have been either covered or removed by the Malheur River. The basalt is dark brown to black, aphanitic and vesicular.

HOLOCENE DEPOSITS

Terrace Gravels (Qtg)

Terrace gravels are plastered onto recent sediments of the Idaho group in all quadrants of the map. Deposits range from a few to 30 feet thick. Gravels are fine to very coarse, very poorly consolidated and generally cross bedded. Pebbles and boulders are both granitic and basaltic. Gravels are probably Pleistocene in age.

Alluvium (Qal)

Recent alluvium is exposed in the major and minor valleys of the area. The allumium generally exhibits an ashy or sandy texture.

STRUCTURE

Faults

Most of the structure observed in the Vale area is associated with the Snake River Graben. Many northwest trending faults were mapped in the north half of the area. Faults are near normal and generally parallel to each other. Displacement is generally down dip and total movement is measured in hundreds of feet or less. Faults are easily recognized in Pre-Idaho rocks. Idaho rocks generally conceal even recent faulting due to their unconsolidated nature. Faults mapped in pre-Idaho rocks are probably much more extensive than this map would suggest.

Block faulting created three broad topographic areas in the north half of the area, the upfaulted hills west of Bully Creek, the downfaulted Jameison Valley and the gentle upfaulted hills near McCarthy Ridge. A large horst block of Deer Butte sediments was exhumed by major faults that extend through Alkali Springs and another that extends through Tub Mountain. Coarse grained basalt (Tb) was extruded along sections of the Alkali Springs fault and the faults that extend through Willow Springs Camp and Love Reservoir. Most movement occurred in the Miocene and early Pliocene, however, more recent faulting is probably obscured by Idaho sediments.

Folds

Gentle anticlinal folds were mapped in the Owyhee Basalt south of the Snake River, in the Deer Butte sediments northwest of Tub Mountain, in the Owyhee Basalts north of Little Valley and in the Idaho sediments surrounding Double Mountain. Folding in all but the last case occurred in the Miocene or early Pliocene. Folding at Double Mountain is probably associated at least in part to the local dacite intrusive.

HYDROTHERMAL ALTERATION

Several areas of intense hydrothermal alteration have been mapped. Alteration occurs as the deposition of silica in the forms of chert, chalcedony and opal, the deposition of calcite and the reduction of sediments to high grade kaolinite by high temperature acid fluids.

Rhinehart Butte, south of the town of Vale exhibits well silicified Deer Butte sediments extending south to Lytle Boulevard. Hot silica bearing waters arose along faults cementing and in some places totally replacing the sediments. Silica rich fluids also traveled horizontally along highly permeable beds, eventually sealing them, and then migrating elsewhere. Silicification probably extends to great depth. Field relationships indicate that silicic alteration occurred after deposition of the Deer Butte and before the deposition of the Chalk Butte sediments. Recent deposition of calcite is seen in the Chalk Butte sediments southwest of Vale Hot Spring. Calcite veins crosscut silica veins in the Deer Butte sediments along Rhinehart Butte. The Deer Butte sediments of Vale Butte also show cementing by silica.

The exhumed horst block of Deer Butte sediments at McCarthy Ridge include large volumes of chert and some calcite. Pods of alteration extend north to McDowel Butte and south to Alkali Spring. Several small pods of silicification were also mapped south of the Snake River. Field relationships indicate that alteration is probably early Pliocene in age.

Hope Butte exhibits spectacular silicification, bleaching and minor Hg mineralization. Silica is generally in the form of chert. Horizontal migration of silica bearing fluids is evident along the margins of Hope Butte. Hot silica rich waters probably arose along a normal fault extending through Hope Butte. This alteration is the most recent of the three areas described. South of Hope Butte, Jordan Hot Spring is actively depositing siliceous sinter. This water is saturated with silica and the sinter deposited exceeds 90 percent SiO_2.

THERMAL FEATURES

Fifty-three water samples were collected from the Vale, Oregon, area during July, 1974. Spring and well temperatures range from 11°C at Mud Cold Spring (X89857) to 96°C at Jordan (Neal) Hot Spring (X89828). The background temperature of the area is about 14°C. Seventeen of the fifty-three samples were warmer than 21°C.

Jordan or Neal Hot Spring is judged as the most interesting spring, chemically and physically. The other thermal features of the Vale area are listed in Table 1. in order of decreasing temperatures.

Complete descriptions of each thermal spring are listed in Appendix 1 at the conclusion of this report. Pictorial descriptions of thermal features are shown in Plates 1 through 11.

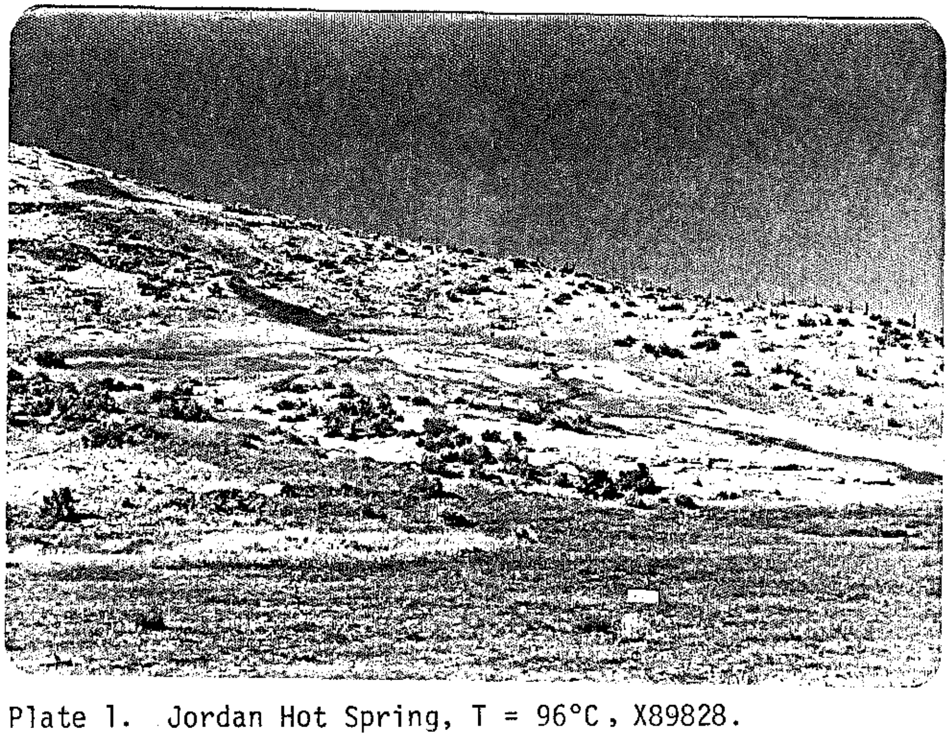

Plate 1. Jordan Hot Spring, T = 96°C , X89828.

Table 1. Thermal features of the Vale, Oregon, area.

		T°C	Flow (lpm)	Heat Discharge (cal/sec.)	Well Depth (Km)	Well Gradients (°C/Km)
X89828	Jordan Hot Spring	96	379	5.2×10^5	---	---
X89844	Vale Hot Spring	91	189	2.4×10^5	---	---
X89854	Rattlesnake Hot Spring	84	37	4.3×10^4	---	---
X89839	Bashon Hot Spring	72	1136	1.1×10^6	---	---
W10059	Weiser Hot Well	65	378	3.2×10^5	0.046	1109
X89851	Mitchell Butte Hot Spring	61	227	1.8×10^5	---	---
X89855	Snively Hot Spring	58	227	1.6×10^5	---	---
X89845	Hysell Hot Well	38	189	7.5×10^4	0.045	533
X89843	Dentinger Hot Well	38	189	7.5×10^4	0.168	143
W10080	Harper Warm Well	36	30	1.1×10^4	0.190	115
W10079	Page Warm Well	27	45	9.7×10^3	0.175	74
W10076	Sec. 22 Warm Well	27	57	1.2×10^4	0.207	63
X89822	Mud Warm Spring	26	75	1.5×10^4	---	---
W10077	Oil Well Warm Spring	25	38	7.0×10^3	?	?
X89831	Alkali Warm Spring	23	11	1.6×10^3	---	---
X89833	Carpenter Warm Well	22.5	189	2.7×10^4	0.149	57
X89824	McDowell Warm Spring	21.5	113	1.4×10^4	---	---
				2.8×10^6 cal/sec.		
				1.1×10^4 BTU/sec.		

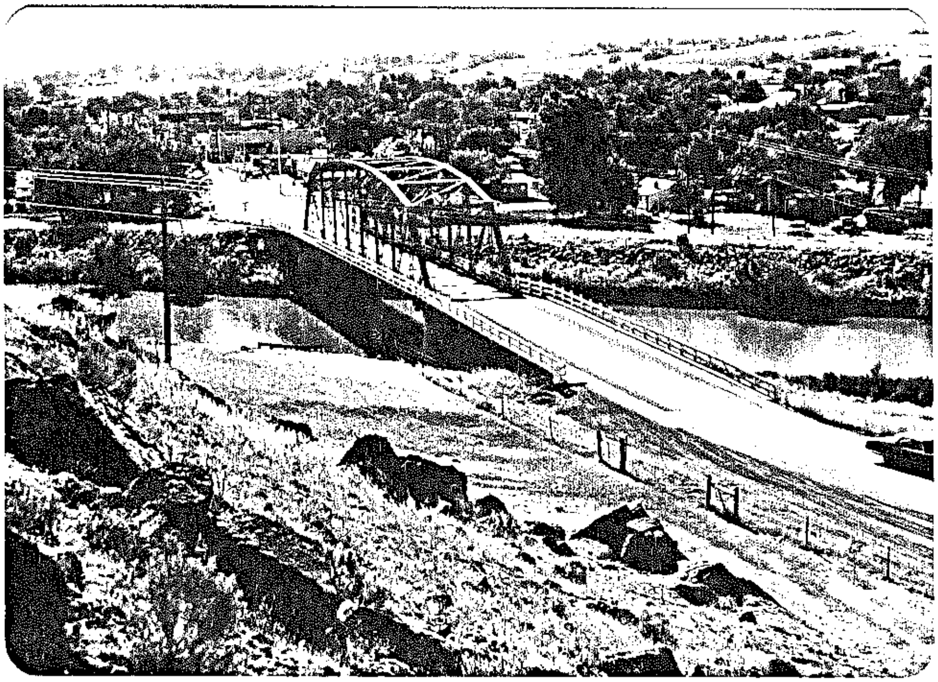

Plate 2. Vale Hot Spring seen from the south side of the Malheur River. Springs issue from the southern bank on both sides of the bridge. T = 91°C, X89844.

Plate 3. Rattlesnake Hot Spring issuing into the Owyhee River. T = 84°C, X89854

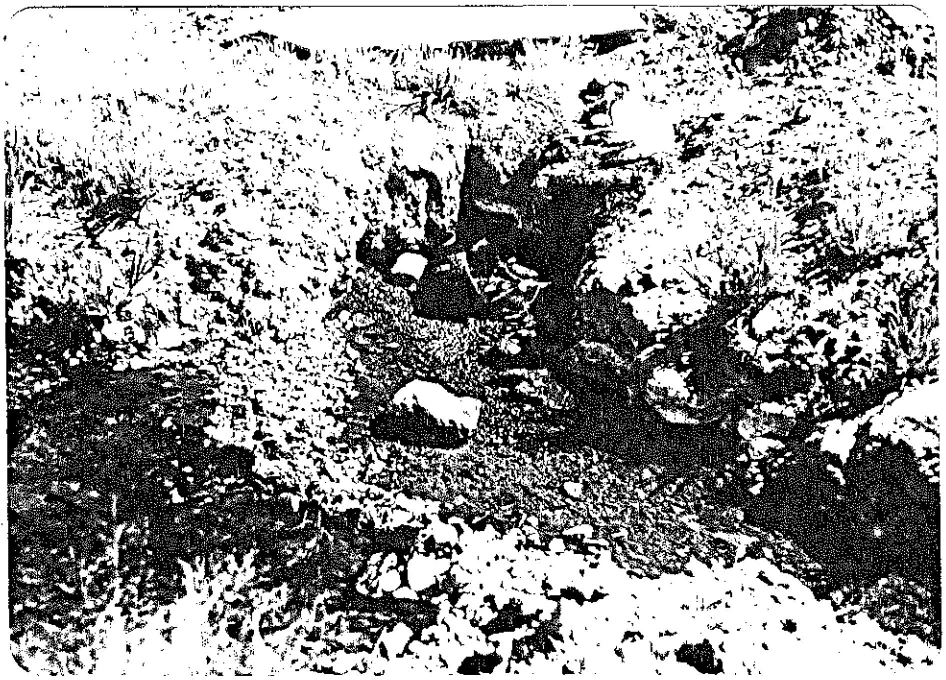

Plate 4. Bashon Hot Spring, T = 72°C, X89839.

Plate 5. Mitchell Butte Hot Spring, T = 61°C, X89851.

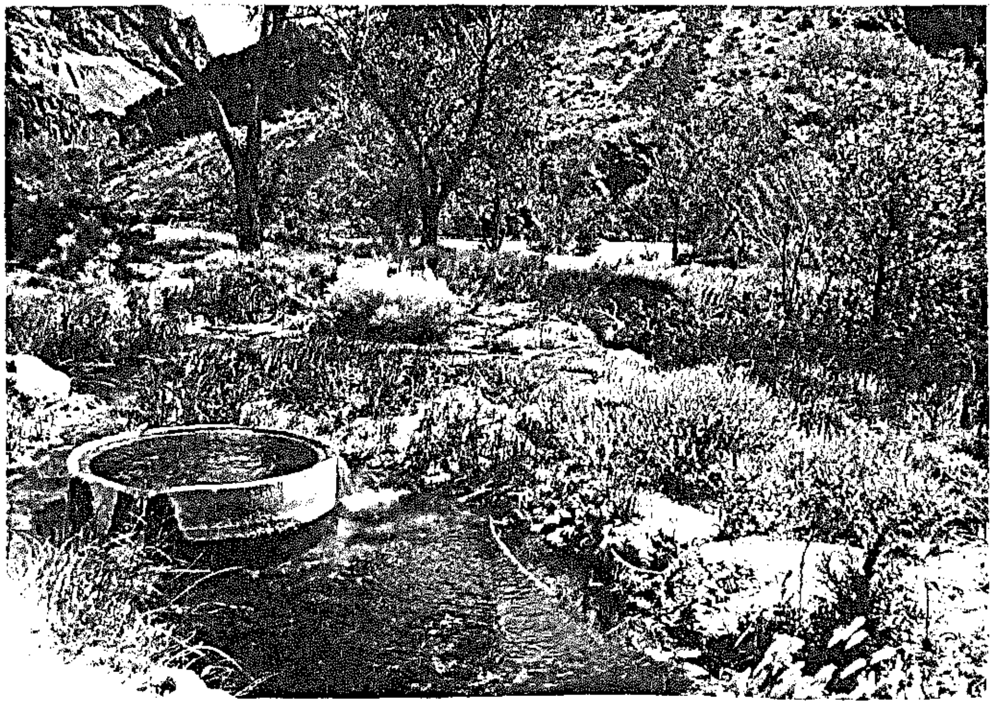

Plate 6. Snively Hot Spring, T = 58°C, X89855.

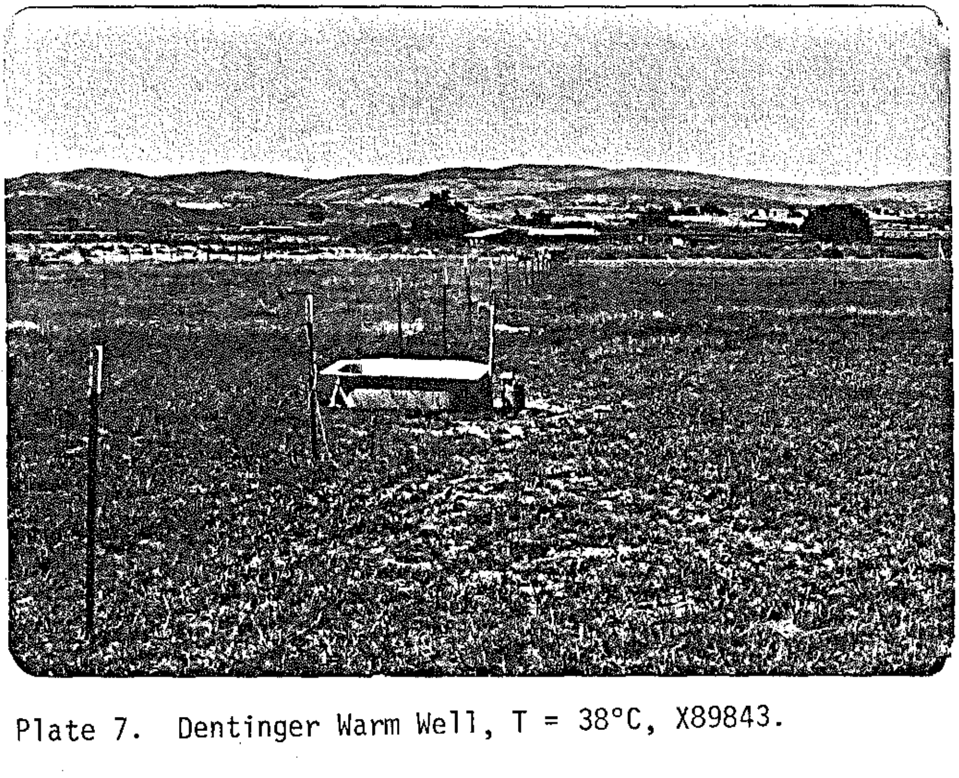

Plate 7. Dentinger Warm Well, T = 38°C, X89843.

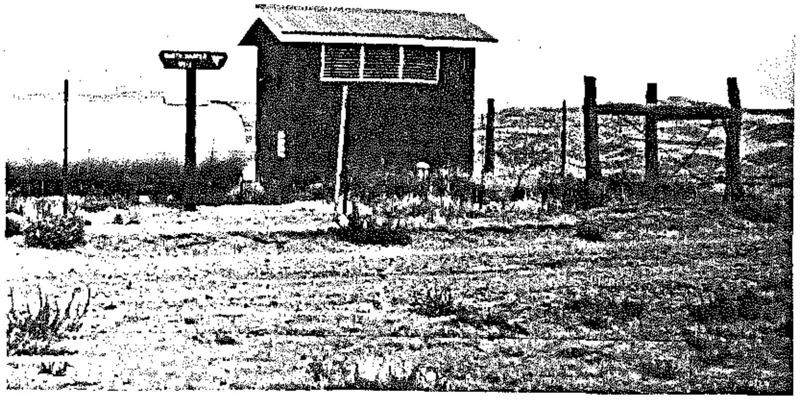

Plate 8. Harper Warm Well, T = 38°C, W10080.

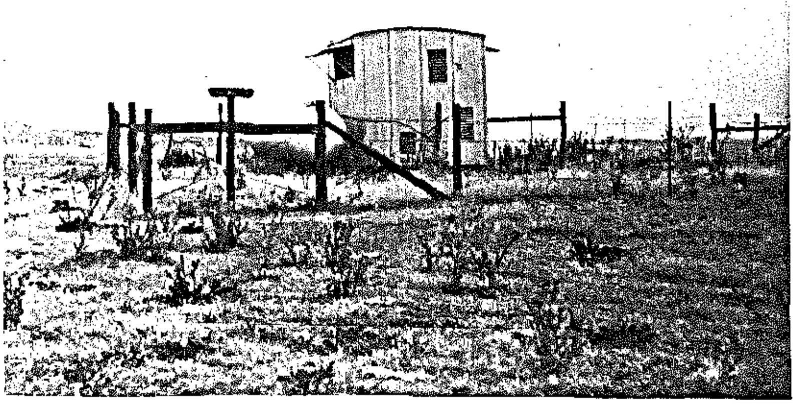

Plate 9. Page Warm Well, T = 27°C, W10079.

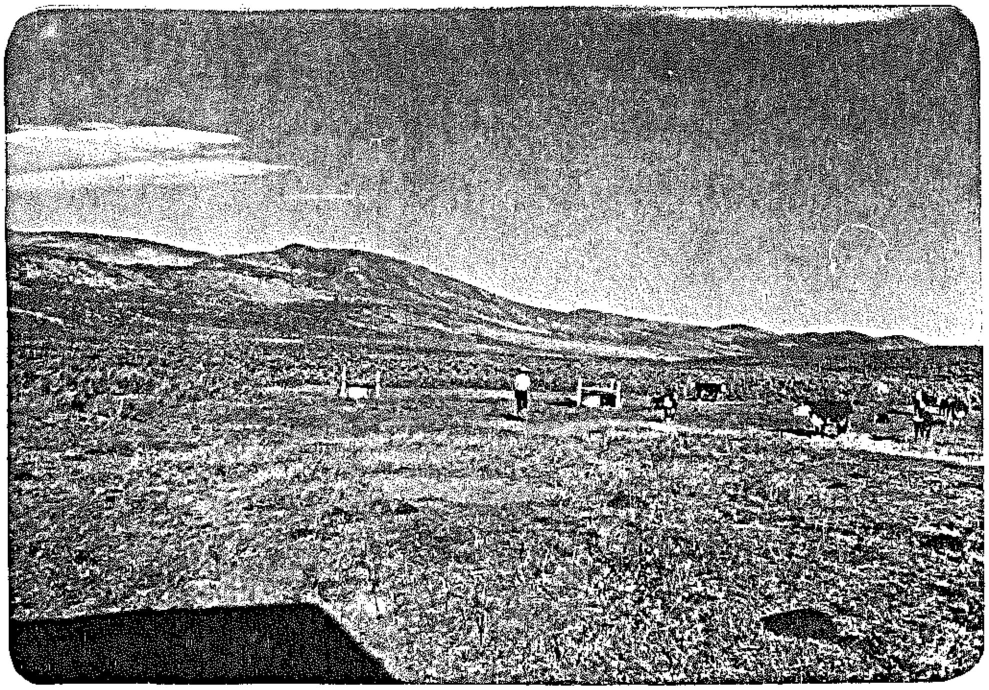

Plate 10. Mud Warm Spring, T = 26°C, X89822.

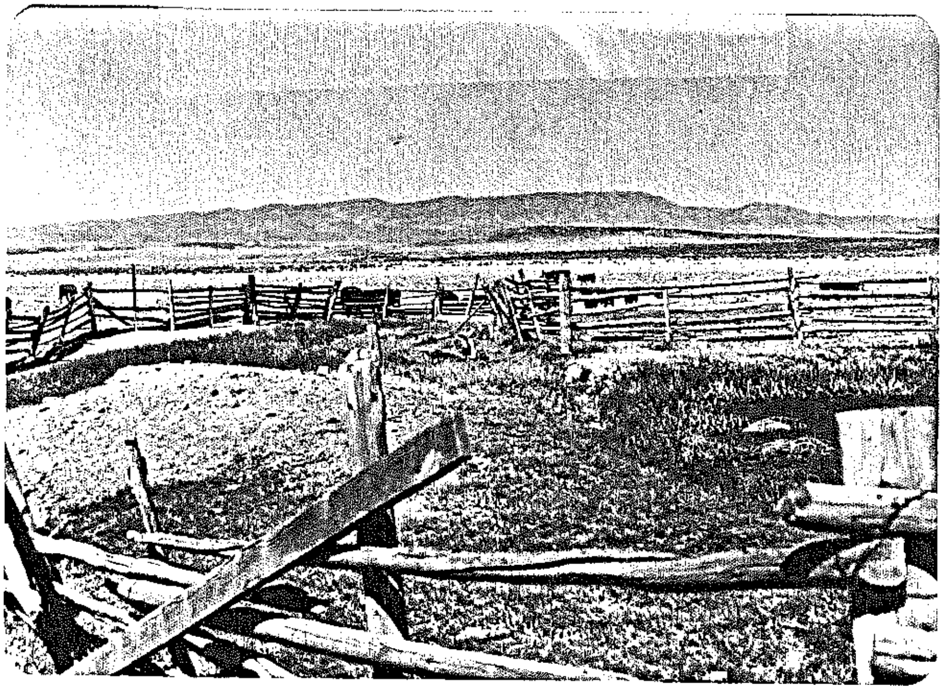

Plate 11. Alkali Spring, T = 23°C, X89831.

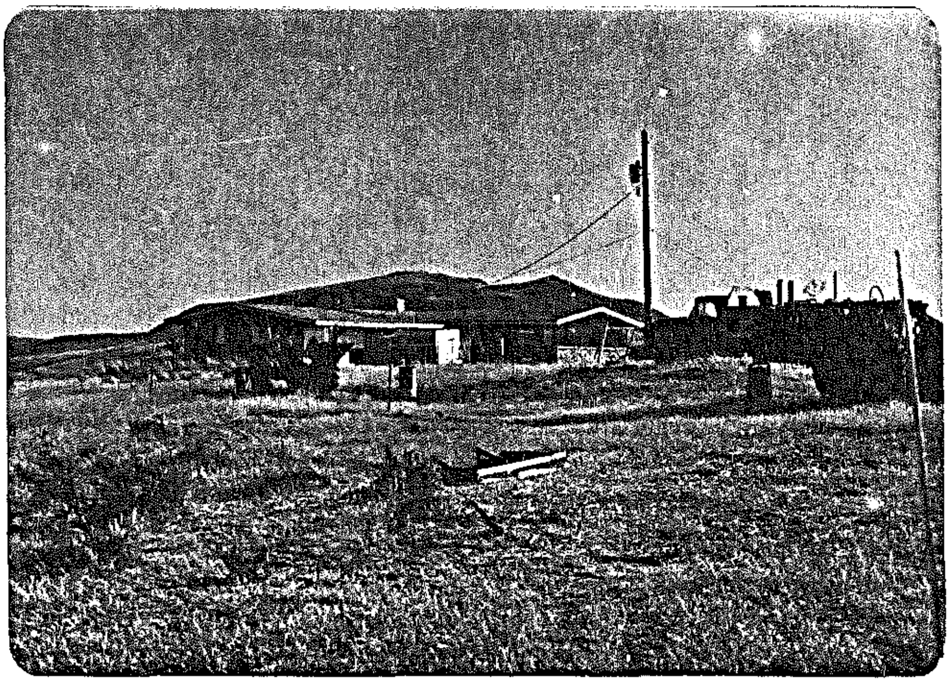

Plate 12. Carpenter Well, T = 22.5°C, X89833.

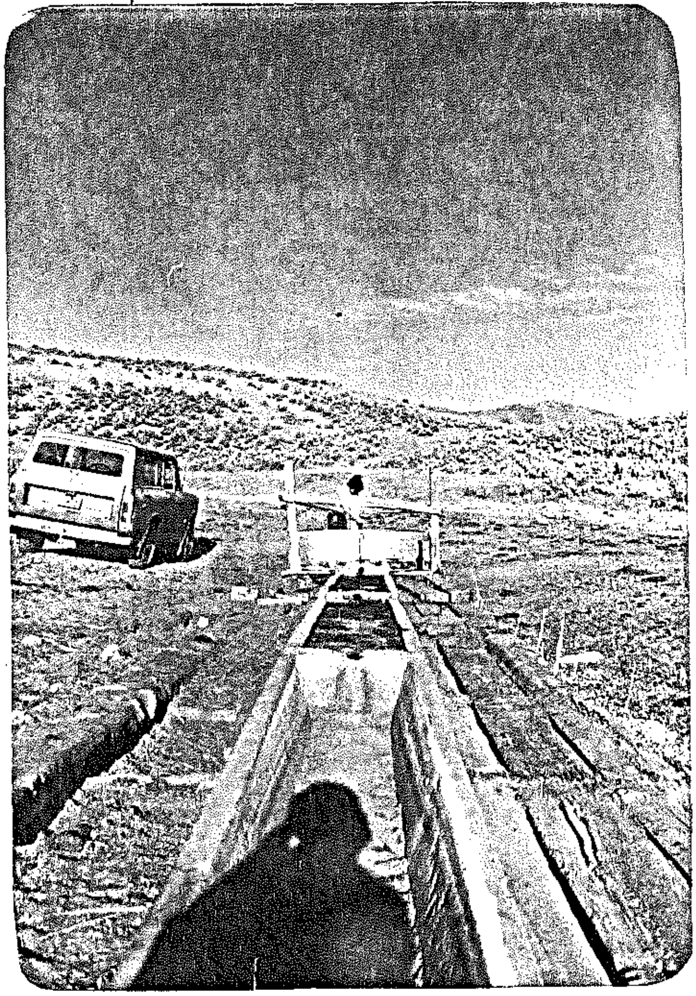

Plate 13. McDowell Spring, T = 21.5°C, X89824.

CHEMISTRY

The non-thermal waters of the Vale, Oregon, area generally contain less than 500 mg/l of dissolved solids and exhibit nearly neutral pH. Bicarbonate, silica, sodium, sulfate, chloride, magnesium and calcium are the principle ions. Cold springs average about 45 mg/l of silica. Rattlesnake Cold Spring (X89853) best represents average background chemical conditions and an analyses of same is listed in Table 2.

Chemical analysis of all the thermal waters collected from the Vale area are listed in Table 2. Water pH ranges from nearly neutral to basic (9.6). Dissolved solids range from 366 mg/l at Mud Warm Spring (X89822) to 1513 mg/l at Alkali Spring (X89831). Chloride concentrations range from less than 1 mg/l to 660 mg/l. These moderate chloride levels indicate igneous reservoir rocks. Fluoride values range from 0.4 mg/l to 15 mg/l at Snively Hot Spring (X89855). Lithium is found in highest concentration in Alkali Spring and Carpenter Well at 0.34 and 0.43 mg/l respectively. Alkali Spring contains the greatest amount of boron at 18 mg/l. Barlow Well (X89826) contains the highest level of sulfate at 900 mg/l. Jordan Hot Spring (X89828) contains the highest concentration of silica at 196 mg/l.

The thermal features of the Vale area show great diversity in water type. A listing of the principle anions and cations (Table 3) in thermal and cold waters reveals that: Vale Hot Spring (X89844) produces the oldest thermal water in the area; Mitchell Butte (X89851) Snively (X89855), and Rattlesnake Hot Spring (X89854) produce water of intermediate age; and Jordan Hot Spring (X89828) and Bashon Hot

Table 2. Chemical analysis of the thermal features of the Vale area, Oregon. Units are mg/l unless otherwise noted.

	Jordan Hot Spring X89828	Vale Hot Spring X89844	Rattle Snake Hot Spring X89854	Bashon Hot Spring X89839	Weiser Hot Well W10059	Mitchell Butte Hot Spring X89851	Snively Hot Spring X89855	Hysell Hot Well X89845	Dentiger Hot Well X89843	Mud Warm Spring X89822	Alkali Warm Well X89831	Carpenter Warm Well X89833	McDowell Warm Spring X89824	Barlow Well #1 X89826	Rattlesnake Cold Spring X89853
pH	7.59	7.78	9.42	8.82	9.38	9.42	9.60	8.0	8.7	7.95	7.70	8.10	8.30	7.7	8.0
Cl	140	340	18	72	56	26	16	332	2	2	660	<1.0	4	31	7.8
F	9.2	6.2	15.0	7.2	3.7	10.4	15.0	3.8	5.8	0.4	2.8	0.4	0.4	0.6	.66
HCO_3	198	151	78	115	116	65	32	115	53	144	114	188	113	360	76
CO_3	0	0	62	15	41	34	32	0	0	0	0	0	0	0	0
SO_4	110	120	110	110	140	120	100	210	160	54	130	400	130	900	15
SiO_2	196	120	130	128	105	106	96	36	29	68	35	78	53	50	38
Na	218	320	120	170	160	120	110	340	270	36	530	290	90	450	20
K	17	15	3.0	3.2	3.8	1.8	1.1	4.4	1.0	9.8	7.0	43	2.4	14	1.6
Ca	6	19	3	2	2	4	2	44	8	29	15	27	19	135	24
Mg	0.3	0.5	<0.1	<0.1	<0.1	0.1	0.1	0.6	<0.1	10	1	10	1	42	4
Li	0.3	0.3	<0.1	0.1	<0.1	0.1	<0.1	0.2	0.2	0.03	0.34	0.43	0.05	0.03	.1
B	4.3	9.0	0.4	5.2	1.8	1.0	1.2	6.3	6.8	<1.0	18	<1.0	<1.0	1.3	<1.0
Cu	<0.1	<0.1	<0.1	<0.1	ND	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	< 0.1	< .1
Mo (µg/l)	9	10	30	60	20	60	30	50	10	2	8	20	6	40	3
Zn	0.1	0.1	<0.1	0.1	ND	0.1	<0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	.1
Fe	<0.1	<0.1	0.1	<0.1	ND	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	.5
NH_3	1.3	1.9	0.6	1.2	3.8	0.6	0.7	ND	ND	ND	ND	ND	ND	ND	ND
H_2S	0.5	1.3	ND	ND	4.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TDS	901	982	533	628	638	473	415	1093	536	366	1513	1060	425	1994	188
R (ohm-M)	12	6.5	22	16	16	19	21	ND	ND	ND	ND	ND	ND	ND	ND
$T^{o}C$	96	91	84	72	65	61	58	38	38	26	23	22.5	21.5	13	14
Flow (gpm)	100	50?	10	300	100?	60	60	50	50	20	3	50	50	300	10
$TSiO_2{}^{o}C$	177	148	152	151	139	140	135	87	78	124	86	124	114	102	89
$TNa/K^{o}C$	148	109	64	47*	61	37*	14*	27	-25*	341*	28*	239*	68	84	159
$TNa\text{-}K\text{-}Ca^{o}C$	183	153	124	120	129	80	78	69	56	79	108	211	54	87	27
Cl/SO_4	3.4	7.7	0.4	1.8	1.1	0.6	0.2	4.3	0.0	0.1	14	0.0	0.1	0.1	1.4
Cl/HCO_3	0.8	3.9	0.2	0.9	0.8	0.4	0.4	5.0	0.0	0.0	1.0	0.0	0.1	0.1	.2
Cl/F	8.1	29	0.6	5.4	8.0	1.3	0.6	47	0.2	3.3	130	1.3	5.3	27	6.3

*Does not reflect true subsurface temperature conditions.

N.D.= not determined

Table 3. Principle anions and cations of the Vale thermal and non-thermal waters

Sample Number	Sample Name	Anions	Cations	Inferred Water Age
X89844	Vale Hot Spring	$Cl > HCO_3 > SO_4$	Na > Ca > K > Mg	oldest
X89845	Hysell Warm Well	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg	oldest ?
X89831	Alkali Spring	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg	oldest ?
W10059	Weiser Hot Well	$SO_4 > HCO_3 > Cl$	Na > K > Ca > Mg	moderate
X89851	Mitchell Butte Hot Spring	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg	moderate
X89855	Snively Hot Spring	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg	moderate
X89854	Rattlesnake Hot Spring	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg	moderate
X89843	Dentinger Warm Well	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg	moderate
X89833	Carpenter Well	$SO_4 > HCO_3 > Cl$	Na > K > Ca > Mg	moderate
X89824	McDowell Spring	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg	moderate
X89826	Barlow Well #1	$SO_4 > HCO_3 > Cl$	Na > Ca > Mg > K	moderate
X89828	Jordan Hot Spring	$HCO_3 > Cl > SO_4$	Na > K > Ca > Mg	young
X89839	Bashon Hot Spring	$HCO_3 > SO_4 > Cl$	Na > K > Ca > Mg	young
X89822	Warm Mud Spring	$HCO_3 > SO_4 > Cl$	Na > Ca > Mg > K	young
X89853	Rattlesnake Cold Spring	$HCO_3 > SO_4 > Cl$	Ca > Na > Mg > K	young

Spring (X89839) produce the youngest thermal waters inferred from the relative abundance of anions and cations. The young waters have the shallowest origin whereas the oldest waters have the deepest origin or longest circulation path. Other warm springs and wells are also listed in Table 3.

The TDS/SiO_2 ratio for thermal springs and wells may correlate with the associated age and/or rock type. TDS/SiO_2 ratios (Table 4) for thermal and non-thermal water ranges from 151.4 to 4.3. Carpenter (X89833), Dentinger (X89843), Hysell [X89845) and Barlow (X89826) Warm Wells are all associated with recent sediments and exhibit high TDS/SiO_2 ratios. The recent sediments readily donate highly soluble ions such as Cl, Na, Ca, etc., thus giving waters high dissolved solids contents. The last thermal features mentioned (X89833, X89843, X89845, and X89826) derive the bulk of their chemical composition in a very shallow regime, and should therefore not be considered purely geothermal. Their fluid temperatures are however above ambient. Alkali Spring (X89831) issues out of a major fault. The chemistry of Alkali Spring is partially geothermal with some near surface contribution.

Figure 3 is a plot of boron versus sodium for the geothermal features of the Vale area. Waters with a constant B/Na slope are thought to have a common source; i.e. the variation in the values of B and Na is related to the progressive dilution of a single hot water source with cold B and Na-free meteoric water. The following relationships should be noted:

1. Meteoric water is located near the origin,

Table 4. A comparison of spring silica, total dissolved solids and rock types associated with springs

Spring Name	T°C	SiO_2	TDS	TDS/SiO_2	Associated Rock Type
Jordan Hot Spring	96	196	901	4.6	Owyhee Basalt
Vale Hot Spring	88	84	912	10.9	Chalk Butte & Qal
Rattlesnake Hot Spring	84	71	533	7.5	Owyhee Basalt
Bashon Hot Spring	70.5	128	628	4.9	Owyhee Basalt
Weiser Hot Well	65	105	638	6.1	Chalk Butte
Mitchell Butte Hot Spg.	61	106	473	4.5	Deer Butte
Snively Hot Spring	58	96	415	4.3	Owyhee Basalt
Hysell Warm Well	38	36	1093	30.4	Qal
Dentinger Warm Well	38	29	536	18.5	Qal
Warm Mud Spring	26	68	366	5.4	Deer Butte
Alkali Spring	23	35	1513	43.2	Qal Chalk Butte
Carpenter Well	22.5	78	1060	151.4	Qal
McDowell Spring	21.5	53	425	8.0	Qal
Barlow Well #1	13	50	1994	39.9	Qal
Rattlesnake Cold Spring	14	38	188	4.9	Owyhee Basalt

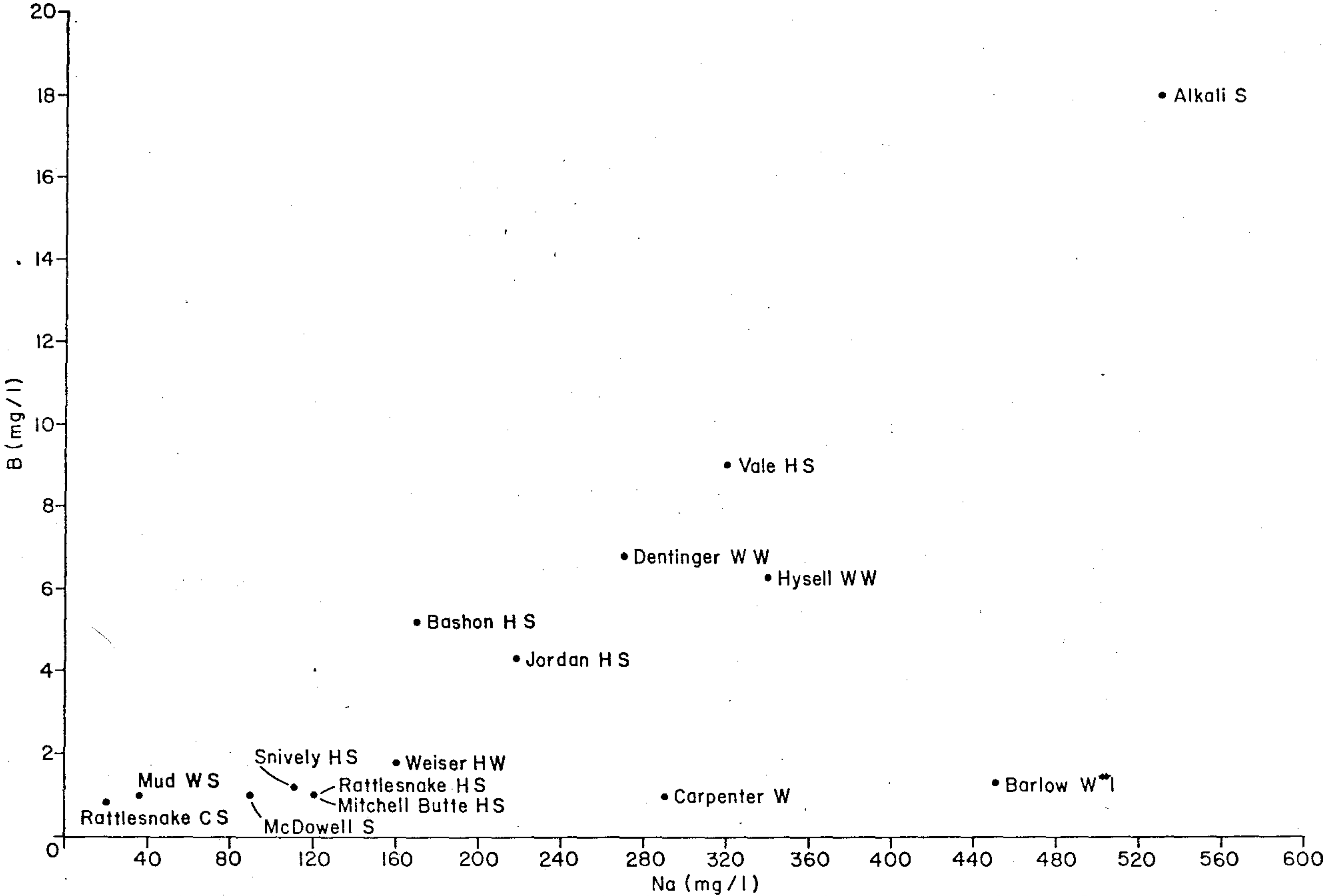

FIGURE 3. The relationship between B and Na for the thermal and non-thermal waters of the Vale area.

2. A dilution trend exists from Vale Hot Spring (X89844) to the origin of the diagram.
3. Points are artificially clustered at 1.0 mg/l of B because that is the lower limit of detection for rapid B analysis.

Figure 4 is a plot of Na versus Ca and may also be used to determine progressive dilution, i.e. thermal water having high Na and low Ca concentrations mix with meteoric water having low Na and high Ca concentrations. This diagram illustrates a dilution trend from Vale Hot Spring to meteoric water (Rattlesnake Cold Spring) which is plotted near the abscissa.

The relationship between SiO_2 and the $Cl/HCO_3 + CO_3$ ratio is useful in distinguishing families of waters. Figure 5 distinguishes Alkali Spring from the remaining waters that plot near the ordinate. Waters closest to the origin contain the largest fraction of bicarbonate rich meteoric water.

The relative proportions of $HCO_3 + CO_3$, SO_4 and Cl for thermal and non-thermal waters are plotted on Figure 6. In general, shallow groundwater and surface waters are bicarbonated, thermal waters of intermediate depth may be sulfate enriched, while deep thermal waters are generally enriched in chloride. Figure 6 shows the following relationships:

1. Meteoric water represented by Rattlesnake Cold Spring (X89853) is bicarbonated,
2. The waters of Rattlesnake (X89854), Snively (X89855), Mitchell Butte (X89851), Bashon (X89839), Jordan (X89828) and Weiser (W10059) Hot Springs last equilibrated at an intermediate depth,
3. The water of Vale Hot Spring (X89844) is enriched in chloride and has equilibrated at the greatest depth.

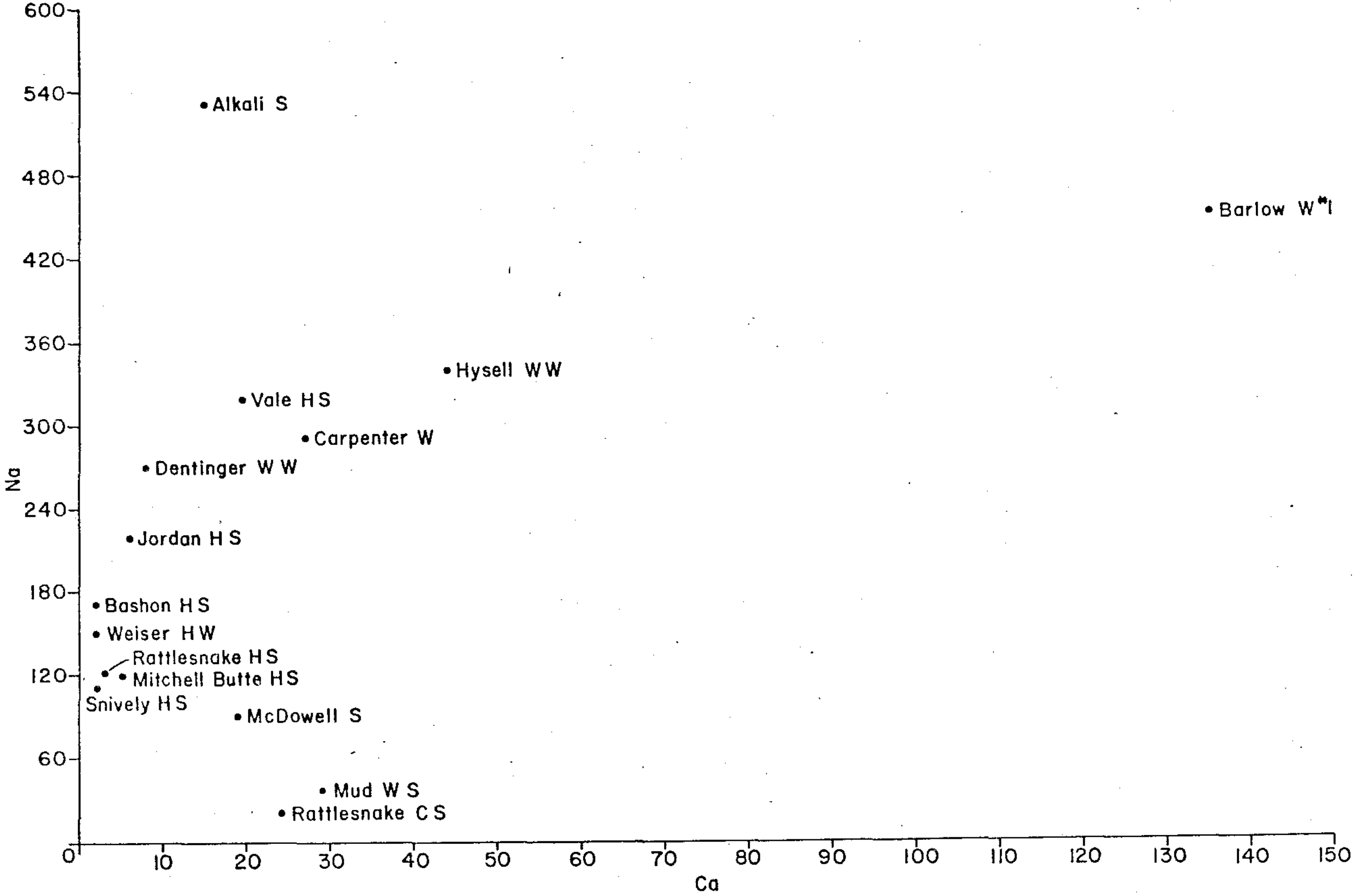

FIGURE 4. The relationship between Na and Ca for the thermal and non-thermal waters of the Vale area.

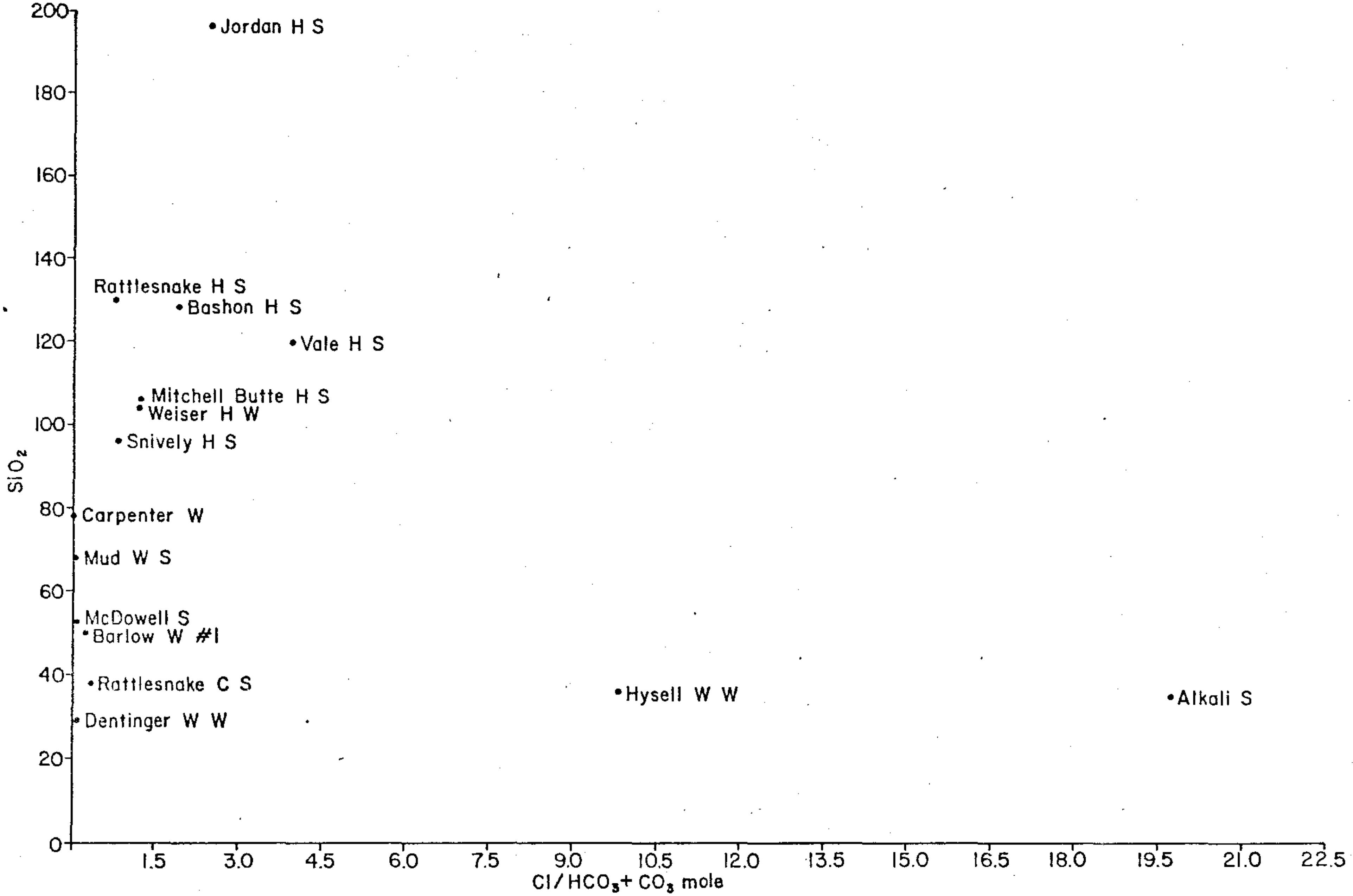

FIGURE 5. The relationship between SiO_2 and the Cl/HCO_3+CO_3 mole ratio for the thermal and non-thermal waters of the Vale area.

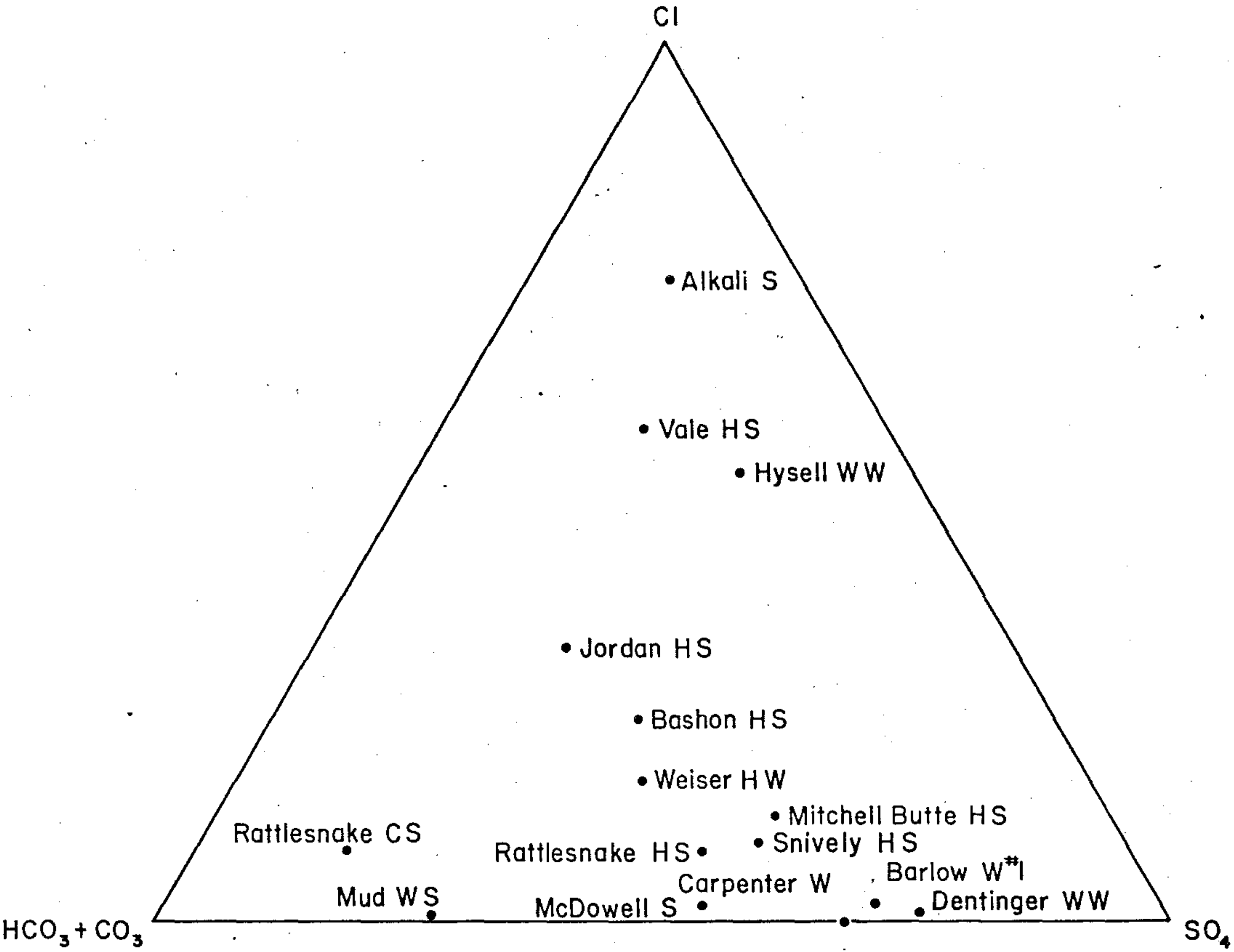

FIGURE 6. The relationship between HCO_3+CO_3, Cl and SO4 for the thermal and non-thermal waters of the Vale area.

MINERAL EQUILIBRIA

Computer program Solmneq was employed to compute the degree of saturation or undersaturation of various hypothetical minerals. Gibbs free energies (kcal/mole) are interpreted as follows:

negative values = undersaturation
0 = equilibrium
positive values = saturation

The saturated silicate minerals listed in Table 5 are very similar for most waters. The waters last equilibrated with a combined metamorphic and igneous mineral suite. The strong metamorphic showing may indicate a highly altered igneous reservoir rock at depth. Vale Hot Spring is saturated with carbonate minerals and indeed, steel piping at the old Vale spa are nearly plugged with calcite. Quartz is in all cases more saturated than the other silica minerals indicating that quartz subsurface temperatures are valid.

SUBSURFACE TEMPERATURES

Subsurface temperatures in the Vale area range from 183°C to 25°C. Jordan and Vale Hot Springs are most interesting with silica temperatures of 177°C and 148°C and Na-K-Ca temperatures of 183°C and 153°C, respectively. Correlation of silica and alkali thermometers for these hot springs is excellent. Rattlesnake, Snively, Mitchell Butte and Bashon Hot Springs and the Weiser Hot Well have equilibrated below 155°C and exhibit poor correlation between thermometers (see Table 2).

Table 5. Gibbs free energies in kcal/mole for selected water samples from the Vale, Oregon, area.
Positive values imply saturation, 0 values imply equilibrium, while negative values imply undersaturation.

	Jordan Hot Spring X89839	Vale Hot Spring X89844	Bashon Hot Spring X89828	Mitchell Butte Hot Spring X89851	Snively Hot Spring X89855	Rattlesnake Hot Spring X89854	Hysell Hot Well X89845	Dentinger Hot Well X89843	Mud Warm Spring X89822	Alkali Spring X89831	McDowell Warm Spring X89824
T°C	96	88	70	61	58	51	38	38	26	23	22
TDS	901	912	629	474	415	533	1093	536	366	1513	425
Carbonates		Dolomite 2.2				Calcite 0.3	Calcite 0.2		Dolomite 0.1		
		Huntite 1.7				Aragonite 0.2	Aragonite 0.2		Calcite 0.0		
		Calcite 1.1									
		Aragonite 1.0									
Silicates	Tremolite 5.4	Tremolite 27.7	Tremolite 22.0	Tremolite 19.5	Tremolite 31.0	Tremolite 16.9	Talc 3.4	Tremolite 12.5	Tremolite 10.2	Quartz 1.0	Tremolite 6.7
	Talc 5.2	Talc 15.7	Talc 12.5	Talc 11.1	Talc 16.0	Talc 10.6	Tremolite 2.1	Talc 7.3	Talc 9.0	Chalcedony 0.5	Talc 6.4
	Kenyaite 4.7	Crysotile 7.1	Fayalite 3.4	Fayalite 3.7	Crysotile 8.1	Fayalite 2.2	Quartz 0.8	Fayalite 2.5	Quartz 1.5	Cristobalite 0.2	Greenalite 2.1
	Magadite 3.6	Diopside 4.5	Crysotile 3.3	Diopside 2.7	Diopside 6.0	Diopside 1.6	Chalcedony 0.2	Diopside 1.1	Chalcedony 0.9	Talc 0.1	Quartz 1.4
	Fayalite 2.3	Fayalite 2.8	Diopside 3.2	Crysotile 1.8	Fayalite 3.0	Crysotile 1.4	Fayalite 0.2	Quartz 0.2	Cristobalite 0.6		Chalcedony 0.8
	Quartz 1.0	Quartz 0.5	Magadite 1.8	Quartz 0.9	Sepiolite 0.4	Quartz 1.0			Silicaam 0.2		Cristobalite 0.6
	Chalcedony 0.6	Clinenst 0.3	Quartz 0.9	Magadite 0.8	Clinenst 0.3	Chalcedony 0.5					Fayalite 0.5
	Cristobalite 0.3	Magadite 0.1	Kenyaite 0.8	Chalcedony 0.5	Quartz 0.3	Cristobalite 0.2					Silicaam 0.1
		Chalcedony 0.1	Chalcedony 0.4	Cristobalite 0.2							
		Sepiolite 0.0	Cristobalite 0.1								

STABLE ISOTOPE STUDIES

Figure 7 shows the variation between δD and δO^{18} relative to SMOW (standard mean ocean water). The straight line represents the almost world wide slope for meteoric waters plotted in this way. The pattern of isotopic variation is seen at once. The deuterium concentration is constant and equal to local meteoric water while O^{18} concentrations show the characteristic enrichment or shift. The most simple explanation for the oxygen shift is an isotopic exchange with carbonates and silicates in the rocks which the waters move.

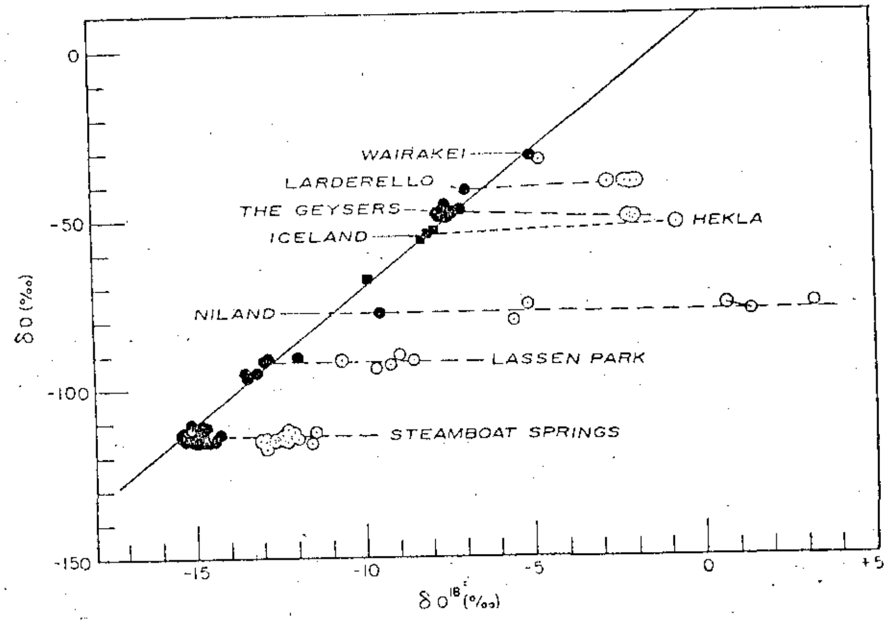

Figure 7. Observed isotopic variations in near-neutral chloride type geothermal waters and in geothermal steam. Solid points are local meteoric waters, or slightly heated near-surface groundwaters. Open circles are hot springs or geothermal water, crinkled circles are high temperature, high pressure, geothermal steam.

Silicate and carbonate rocks range from +6 to +30 $\delta 0^{18}$. δD generally does not vary from the meteoric concentration because rocks contain almost no H or D (heavy hydrogen). Note that the Niland Waters which have mingled with Colorado River sediments, rich in carbonates, shows the greatest shift. On the other end of the scale, Wairakei shows almost no shift. This lack of shift implies that waters descend quickly, stay in storage for a short time and then ascend.

To summarize, a strong shift in $\delta 0^{18}$ implies a long storage time and/or a large reservoir capacity. A very small shift implies one of the two situations: first, temperature-pressure conditions are to low to allow waters to exchange 0^{18} with rocks almost regardless of storage time, and second, the heat source or the region where waters are heated is so close to the surface that meteoric waters descend and rise quickly, so that the all important time element is unavailable for 0^{18} exchange to occur.

Figure 8 is a D - 0^{18} plot for the waters of eastern Oregon. Notice that Vale Hot Spring shows the greatest 0^{18} shift while Jordan Hot Spring shows about half as much 0^{18} shift. Rattlesnake Hot Spring, located south of Mitchell Butte, shows almost no shift. Both Vale and Jordan Hot Spring are attractive in light of this diagram. Jordan Hot Spring is however most attractive because it exhibits compelling chemistry, subsurface temperatures and the minimal 0^{18} shift.

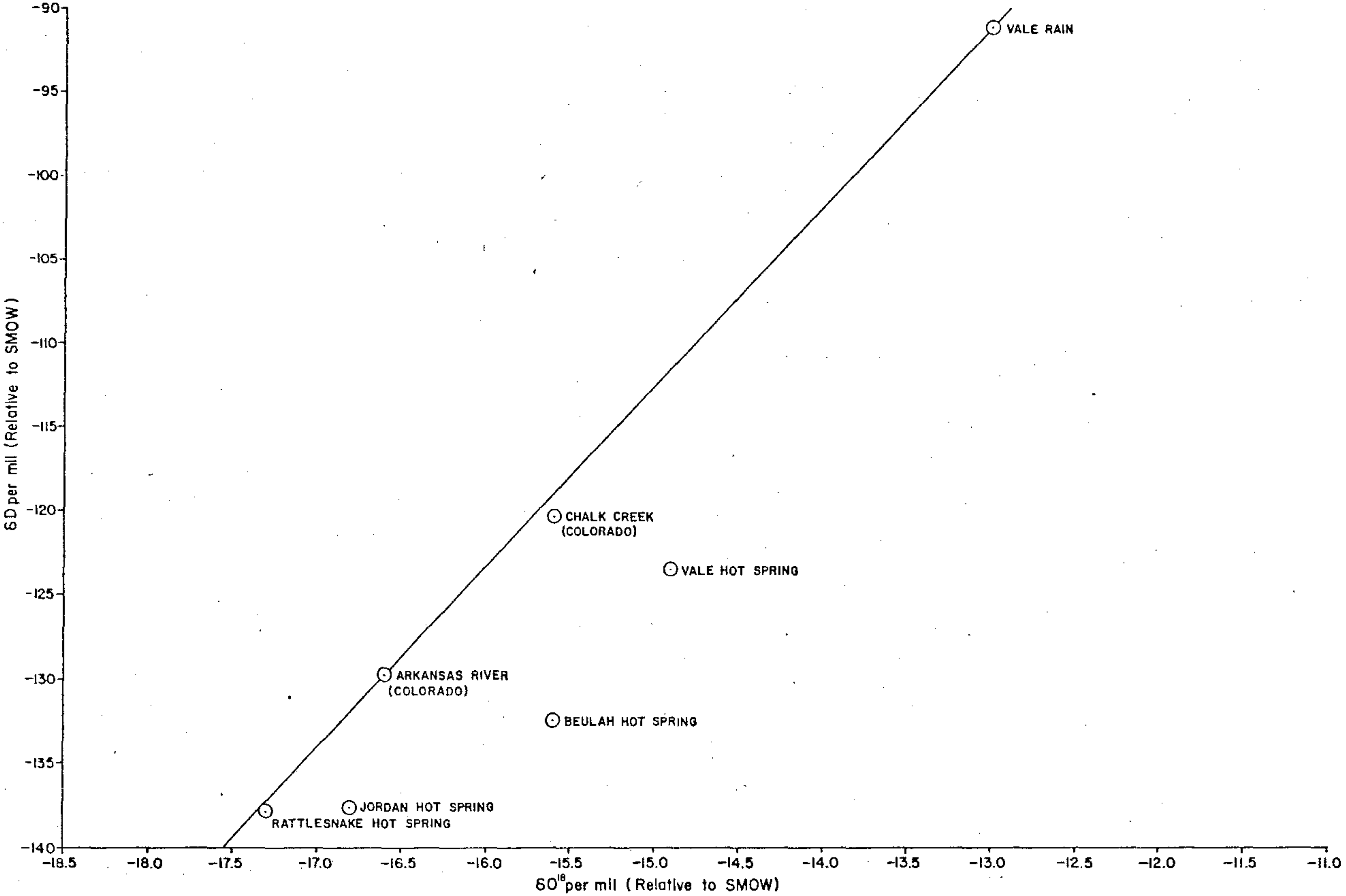

FIGURE 8. Stable isotope variations in the Vale thermal and non-thermal waters.

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GEOCHEMICAL
SAMPLE FORMS

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR209 Sample No. X 89828 Date 6/28/74 Time

Name: Jordan Hot Spring Location: Co. Malheur State OR

NW L/4 Sec. 9 T18S R: 43E ; Km/mi. of

Lat.: Long.: Sampler: JED & GAS

Elevation: 2640 Quad. Jamieson 15' Quad

Sample Type: Spring (p), well (p), creek, river, soil, salt, sinter, travertine, ~~gas,~~ rock, snow.

Description:

Water Temp. °C 96 Discharge: 15 [✓ gpm]/Lpm

Ground Temp. °C 91.5 Well Data: Depth

Air Temp. Bore

Odor H2S Pump Type

Fluid Color Level of water in bore

Fluid Taste Type of piping

Bubbling moderate Artesian Head

Boiling Rock Data:

Vegetation gray filament algae Type (surface) basalt

Fluid issues from basaltic soil Color

Grain size aphanitic

Megascopic Minerals

Salt: Type $CaCO_3$ & sulfur

Quantity moderate

Color white Alteration:

Form amorphous Rx Type (at depth)

Sinter: Type Water used for ranching

Quantity Immediate area used for: ranching

Color

Form Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation

Property owned by Jordan

Previous and/or Current Leases

Comments:

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR225 Sample No. X 89844 Date 6-28-74 Time 1645

Name: Vale Hot Spring Location: Co. Malheur State OR

SW1/4 SE1/4 Sec. 20 T 18S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: Deymonaz-Suemnicht

Elevation: 2240 Quad. Vale East

Sample Type: [✓ Spring (p)], well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C by river 91 at spa in pipes 88

Discharge: 50 g/min at river gpm/Lpm

Ground Temp. °C 79

Air Temp.

Odor sulfurous

Fluid Color murky

Fluid Taste sulfur

Bubbling little if any

Boiling --

Vegetation some algae

Fluid issues from soil along river bank (pipes at spa closed off need to be excavated for further study

Salt: Type

Quantity

Color

Form

Sinter: Type travertine

Quantity 6" thick around pipes

Color white

Form massive

Well Data: Depth

Bore

Pump Type

Level of water in bore

Type of piping

Artesian Head

Rock Data:

Type (surface) conglomerate

Color red (siliceous matric)

Grain size microscopic

Megascopic Minerals Qtzite, volcanic (basaltic pebbles)

Alteration: some green surface

Rx Type (at depth)

Water used for former spa

Immediate area used for: nothing old spa

Quality of sample: Exc., Good, [✓ Poor]

Malheur River high and overlapping spring

Probable cause of manifestation fault? distinct changes in lithology observed in Ridge behind area

Property owned by

Previous and/or Current Leases

Comments: some bubbling heard in one pipe at spa. May deserve further study after excavation.

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR220 Sample No. X89839 Date 6/29/74 Time 1800

Name: Bashon Hot Spring Location: Co. Malheur State OR

NW1/4 Sec. 30 T 19S R: 43E ; Km/mi. of

Lat.: Long.: Sampler: JED

Elevation: 2480 Quad. Harper Quad

Sample Type: [✓ Spring] (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 70.5

Ground Temp. °C 62

Air Temp.

Odor H2S

Fluid Color

Fluid Taste

Bubbling minor

Boiling

Vegetation reddish brown, green & gray algae

Fluid issues from fractures in basalt

Salt: Type sulfates

Quantity moderate

Color white

Form amorphous

Sinter: Type

Quantity

Color

Form

Discharge: 120 [✓ gpm]/Lpm

Well Data: Depth

Bore

Pump Type

Level of water in bore

Type of piping

Artesian Head

Rock Data:

Type (surface) basalt

Color dark gray fresh-white-green altered

Grain size aphanitic

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for 0

Immediate area used for: farming

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation

Property owned by Reinie Bashon, Rt 1, Box 22, Harper OR 97906

Previous and/or Current Leases

Comments: Has been excavated to channel flow. Pics Roll 3 Fm 18-19. Well drilled to south issued volatile gas before it was sealed. Gas issues along river.

SKETCHES

Owner stated temperatures of 90°C in winter. Mixing with irrigation runoff cools it in summer.

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. ______ Sample No. X ______ Date 9/1/75 Time 12:00

Name: WEISER HOT WELL Location: Co. Wash State Id

SW¼ SW¼ Sec. 10 T 11N R: 6W ; ______ Km/mi. ____ of ______

Lat.: ______ Long.: ______ Sampler: F. Dellechaie

Elevation: 2192 Quad. Weiser

Sample Type: Spring (p), [✓ well (p)] creek, river, soil, salt, sinter, travertine, gas, rock, snow.

send analysis

Description:

Water Temp. °C 65

Ground Temp. °C ______

Air Temp. ______

Odor H2S

Fluid Color clear

Fluid Taste S=

Bubbling yes

Boiling no

Vegetation no

Fluid issues from faucet on pump

Salt: Type 0

Quantity ______

Color ______

Form ______

Sinter: Type S

Quantity major

Color yellow

Form amorp

Discharge: 25 [✓ gpm] / Lpm

Well Data: Depth 150'

Bore 6"

Pump Type sub

Level of water in bore ?

Type of piping steel

Artesian Head no

Rock Data:

Type (surface) Chalk Butte

Color ______

Grain size ______

Megascopic Minerals ______

Alteration: ______

Rx Type (at depth) ______

Water used for greenhouse

Immediate area used for: recreation

Quality of sample: [✓ Exc.] Good, Poor

Probable cause of manifestation ______

Property owned by Virgil Harter 1816 1st Ave. S., Payette, Id.

Previous and/or Current Leases ______

Comments: ______

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR232 Sample No. X 89851 Date 6/28/74 Time 8:30

Name: Mitchell Butte Hot Spring Location: Co. Malheur State OR

NE1/4 NE1/4 Sec. 12 T 21S 5N R: 45E ; Km/mi. of

Lat.: Long.: Sampler: John Wood

Elevation: 2270 Quad. Mitchell Butte

Sample Type: Spring (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 61°	Discharge: 15 [✓ gpm]/Lpm
Ground Temp. °C 34°	Well Data: Depth
Air Temp.	Bore
Odor sulfurous	Pump Type
Fluid Color clear	Level of water in bore
Fluid Taste ---	Type of piping
Bubbling none	Artesian Head
Boiling none	Rock Data:
Vegetation green(bluish) algae	Type (surface) conglomerate
Fluid issues from joints	Color reddish
in conglomerate	Grain size coarse - fine
	Megascopic Minerals Qtz rock fragments
Salt: Type chlorides	
Quantity minor - moderate	
Color white & brown	Alteration: has chalky coating
Form amorphous	Rx Type (at depth)
Sinter: Type none	Water used for bathing & livestock
Quantity	Immediate area used for: ranching, farming
Color	
Form	Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation fault or joint controlled

Property owned by Mrs. Carl Quakenbush, N34 25 Autubon Ave., Spokane, Wash. 509-325-1921

Previous and/or Current Leases

Comments: Spring approx. 40 ft. higher than shown on map

SKETCHES

F-1, 2, R-5

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR236 Sample No. X 89855 Date 6/28/74 Time 10:00

Name: Snively Hot Spring Location: Co. Malheur State OR

SW1/4 NE1/4 Sec. 22 T21S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: John Wood

Elevation: 2260 Quad. Owyhee Dam

Sample Type: [✓ Spring (p)], well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 58°

Ground Temp. °C 39°

Air Temp.

Odor sulfurous

Fluid Color clear

Fluid Taste --

Bubbling moderate

Boiling none

Vegetation green & rusty brown algae

Fluid issues from gravels below roadbed

Salt: Type none visible

Quantity

Color

Form

Sinter: Type none

Quantity

Color

Form

Discharge: 60 [✓ gpm]/Lpm

Well Data: Depth

Bore

Pump Type

Level of water in bore

Type of piping

Artesian Head

Rock Data:

Type (surface)

Color

Grain size

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for once used for bathing

Immediate area used for: cattle, ranching

Quality of sample: Exc., Good, Poor

Probable cause of manifestation natural hydrologic flow

Property owned by State of Oregon - in Owyhee St. Park

Previous and/or Current Leases

Comments: area once used as resort

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. QR235 Sample No. X 89854 Date 6/28/74 Time 14:44

Name: Rattlesnake Hot Spring Location: Co. Malheur State OR

SE1/4 SE1/4 Sec. 14 T 21S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: John Wood

Elevation: 2280 Quad. Owyhee Dam

Sample Type: [✓ Spring] (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 51° Discharge: < 2 [✓ gpm]/Lpm

Ground Temp. °C 38° Well Data: Depth

Air Temp. Bore

Odor sulfurous Pump Type

Fluid Color clear - green tint Level of water in bore

Fluid Taste Type of piping

Bubbling none Artesian Head

Boiling none Rock Data:

Vegetation bright green algae Type (surface)

Fluid issues from crevice in Rx Color

Grain size

Megascopic Minerals

Salt: Type chloride

Quantity plentiful

Color dark green - white Alteration:

Form amorphous Rx Type (at depth)

Sinter: Type Water used for no use

Quantity Immediate area used for: ranching, farming

Color

Form Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation

Property owned by

Previous and/or Current Leases

Comments:

SKETCHES

F-14=R-5

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR224 Sample No. X 89843 Date 7/2/74 Time 19:30

Name: DENTINGER WELL Location: Co. Malheur State OR

S 1/2 Sec. 21 T 18S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: Jed

Elevation: 2240 Quad. Vale East

Sample Type: Spring (p), [✓ well (p)], creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 38

Discharge: ≃ 50 [✓ gpm]/Lpm

Ground Temp. °C

Well Data: Depth 550'

Air Temp.

Bore 6"

Odor H_2S

Pump Type Sub.

Fluid Color

Level of water in bore 40'

Fluid Taste sulfide & sweet metallic

Type of piping Steel

Bubbling

Artesian Head

Boiling

Rock Data:

Vegetation

Type (surface) Chalk Butte FM

Fluid issues from valley alluvium

Color

Grain size

Megascopic Minerals

Salt: Type

Quantity

Color

Alteration:

Form

Rx Type (at depth)

Sinter: Type

Water used for home & livestock

Quantity

Immediate area used for: farming

Color

Form

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation Contamination of ground water with heated water along flt.

Property owned by Dentinger

Previous and/or Current Leases

Comments: Pumps dry after 1 hr. Roll 4 #4 Aquifer struck at ~540' present water level ~40' small acreage - not leased.

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR226 Sample No. X 89845 Date 7/1/74 Time 1900

Name: Hysell Warm Well Location: Co. Malheur State OR

NW1/4 Sec. 29 T 18S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: JED

Elevation: 2360 Quad. Vale East

Sample Type: Spring (p), [✓ well (p)], creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 38

Ground Temp. °C

Air Temp.

Odor

Fluid Color

Fluid Taste sweet metallic

Bubbling

Boiling

Vegetation

Fluid issues from tuffaceous sed rocks

Salt: Type none

Quantity

Color

Form

Sinter: Type none

Quantity

Color

Form

Discharge: 50 gpm/Lpm

Well Data: Depth 147

Bore 6"

Pump Type sub

Level of water in bore

Type of piping steel

Artesian Head

Rock Data:

Type (surface) tuff/volcanic wep.

Color pink

Grain size

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for household

Immediate area used for:

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation flow along fault

Property owned by

Previous and/or Current Leases

Comments: pH

Original well to 775' with temp of 74°C, filled in to 147'.

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. ____ Sample No. X W10080 Date 10/8/75 Time 15:15

Name: SEC 9 WARM W. (HARPER WELL) Location: Co. Malheur State OR

Center 9 Sec. 1 T 19S R: 45 E ; ____ Km/mi. ____ of ____

Lat.: ____ Long.: ____ Sampler: F. Dellechaie

Elevation: 2840 Quad. Vale East

Sample Type: Spring (p), [✓ well (p)], creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 36	Discharge: 8 [✓ gpm]/Lpm
Ground Temp. °C	Well Data: Depth 696
Air Temp.	Bore
Odor	Pump Type
Fluid Color	Level of water in bore
Fluid Taste	Type of piping
Bubbling	Artesian Head
Boiling	Rock Data:
Vegetation	Type (surface) Chalk Butte
Fluid issues from steel pipe	Color
	Grain size
	Megascopic Minerals
Salt: Type	
Quantity	
Color	Alteration:
Form	Rx Type (at depth)
Sinter: Type	Water used for cattle
Quantity	Immediate area used for: cattle
Color	
Form	Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation well

Property owned by Blm

Previous and/or Current Leases

Comments: R1 F10

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. ____ Sample No. X W10079 Date 10/8/75 Time 16:00

Name: SEC 28 WW (Page well) Location: Co. Malheur State OR

SW 1/4 NE 1/4 Sec. 28 T 19S R: 45E ; ____ Km/mi. ____ of ____

Lat.: ____ Long.: ____ Sampler: F. Dellechaie

Elevation: 2800 Quad. Vale East

Sample Type: Spring (p), [✓ well (p)], creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 27

Ground Temp. °C ____

Air Temp. ____

Odor ____

Fluid Color ____

Fluid Taste ____

Bubbling ____

Boiling ____

Vegetation ____

Fluid issues from steel pipe

Salt: Type ____

Quantity ____

Color ____

Form ____

Sinter: Type ____

Quantity ____

Color ____

Form ____

Discharge: 12 [✓ gpm]/Lpm

Well Data: Depth 622 500-620

Bore ____

Pump Type ____

Level of water in bore ____

Type of piping ____

Artesian Head ____

Rock Data:

Type (surface) Chalk Butte

Color ____

Grain size ____

Megascopic Minerals ____

Alteration: ____

Rx Type (at depth) ____

Water used for cattle

Immediate area used for: cattle

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation well

Property owned by Blm

Previous and/or Current Leases ____

Comments: Rl Fll

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. ____ Sample No. X W10076 Date 10/8/75 Time 18:00

Name: SEC. 22 WELL Location: Co. Malheur State OR

SE 1/4 SE 1/4 Sec. 22 T 19S R: 43E ; ____ Km/mi. ____ of ____

Lat.: ____ Long.: ____ Sampler: F. Dellechaie

Elevation: 2968 Quad. Vines Hill

Sample Type: Spring (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 27

Discharge: 100 [✓ gpm]/Lpm

Ground Temp. °C ____

Well Data: Depth (718 total) 678

Air Temp. ____

Bore ____

Odor ____

Pump Type ____

Fluid Color ____

Level of water in bore ____

Fluid Taste ____

Type of piping ____

Bubbling ____

Artesian Head ____

Boiling ____

Rock Data:

Vegetation ____

Type (surface) Chalk Butte

Fluid issues from steel pipe

Color ____

Grain size ____

Megascopic Minerals ____

Salt: Type ____

Quantity ____

Color ____

Alteration: ____

Form ____

Rx Type (at depth) ____

Sinter: Type ____

Water used for cattle

Quantity ____

Immediate area used for: cattle

Color ____

Form ____

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation well

Property owned by Blm

Previous and/or Current Leases ____

Comments: not numering RIF12

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR203 Sample No. X 89822 Date 7/1/74 Time 19:40

Name: Warm Mud Spring Location: Co. Malheur State OR

NW1/4 NW1/4 Sec. 29 T 15S R: 44E ; Km/mi. ___ of ___

Lat.: ___ Long.: ___ Sampler: Wood, Dellechaie

Elevation: 2870 Quad. Jamieson

Sample Type: [✓ Spring] (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 26

Ground Temp. °C

Air Temp.

Odor none

Fluid Color clear

Fluid Taste hard (calcium)

Bubbling none

Boiling none

Vegetation large amount algae

Fluid issues from pipes into 3 watering troughs

Salt: Type none

Quantity

Color

Form

Sinter: Type none

Quantity

Color

Form

Discharge: 20 [✓ gpm]/Lpm

Well Data: Depth

Bore

Pump Type

Level of water in bore

Type of piping

Artesian Head

Rock Data: none

Type (surface)

Color

Grain size

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for livestock

Immediate area used for: cattle, ranching

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation natural hydrologic flow

Property owned by

Previous and/or Current Leases

Comments:

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR212 Sample No. X 89831 Date 6-28-74 Time 1100

Name: Alkali Spring Location: Co. Malheur State OR

SW 1/4 Sec. 5 T17S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: JED

Elevation: 2356 Quad. Moores Hollow

Sample Type: Spring (p), well (p), creek, river, soil, salt, sinter, travertine, ~~gas,~~ rock, snow.

Description:

Water Temp. °C 23

Ground Temp. °C

Air Temp.

Odor

Fluid Color

Fluid Taste

Bubbling

Boiling

Vegetation gray, green & reddish filament algae

Fluid issues from basaltic soil under pond

Salt: Type

Quantity

Color

Form

Sinter: Type

Quantity

Color

Form

Discharge: 3 gpm/Lpm

Well Data: Depth

Bore

Pump Type

Level of water in bore

Type of piping

Artesian Head

Rock Data:

Type (surface) BsH

Color lt. gray

Grain size aphanitic

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for livestock

Immediate area used for: rangeland

Quality of sample: Exc., [✓ Good], Poor

Probable cause of manifestation normal hydro flow

Property owned by

Previous and/or Current Leases

Comments: pic roll 3 Fm 10 sample collected at issuance from pond. Pond covered with dark green algae.

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR214 Sample No. X 89833 Date 7-2-74 Time 1800

Name: Carpenter Well Location: Co. Malheur State OR

SE1/4 Sec. 16 T 18S R: 45E ; Km/mi. of

Lat.: Long.: Sampler: JED

Elevation: 2350 Quad. Moores Hollow

Sample Type: Spring (p), [✓ well (p)], creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description: just west (on hill) of foothill drive

Water Temp. °C 22.5

Ground Temp. °C

Air Temp.

Odor

Fluid Color

Fluid Taste sweet metallic

Bubbling

Boiling

Vegetation

Fluid issues from

Salt: Type

Quantity

Color

Form

Sinter: Type

Quantity

Color

Form

Discharge: ~50 [✓ gpm]/Lpm

Well Data: Depth 490'

Bore 6"

Pump Type sub

Level of water in bore 135'

Type of piping steel casing

Artesian Head

Rock Data:

Type (surface) well indurated gravel

Color

Grain size

Megascopic Minerals

Alteration:

Rx Type (at depth)

Water used for home

Immediate area used for: farming

Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation

Property owned by Rex Carpenter

Previous and/or Current Leases

Comments: shale down to ~450' aquifer gravel. 160 acres, leased Gulf roll 4 fm 4 & 5

SKETCHES

AMAX GEOTHERMAL GEOCHEMICAL SAMPLE FORM

Spring No. OR205 Sample No. X 89824 Date 7/1/74 Time 20:10

Name: McDowell Springs Location: Co. Malheur State OR

NE1/4 SE1/4 Sec. 33 T 15S R: 44E ; Km/mi. of

Lat.: Long.: Sampler: Wood, Dellechaie

Elevation: 2667 Quad. Jamieson

Sample Type: [✓ Spring] (p), well (p), creek, river, soil, salt, sinter, travertine, gas, rock, snow.

Description:

Water Temp. °C 21.5 Discharge: 30 [✓ gpm]/Lpm

Ground Temp. °C Well Data: Depth

Air Temp. Bore

Odor none Pump Type

Fluid Color clear Level of water in bore

Fluid Taste ltttle hard Type of piping

Bubbling none Artesian Head

Boiling none Rock Data:

Vegetation some green algae Type (surface) float

Fluid issues from galvanized iron pipe

Color

Grain size

Megascopic Minerals

Salt: Type none

Quantity

Color Alteration:

Form Rx Type (at depth)

Sinter: Type none Water used for livestock

Quantity Immediate area used for: ranching farming

Color

Form Quality of sample: [✓ Exc.], Good, Poor

Probable cause of manifestation natural hydrologic flow

Property owned by

Previous and/or Current Leases

Comments: water slightly above background temperature

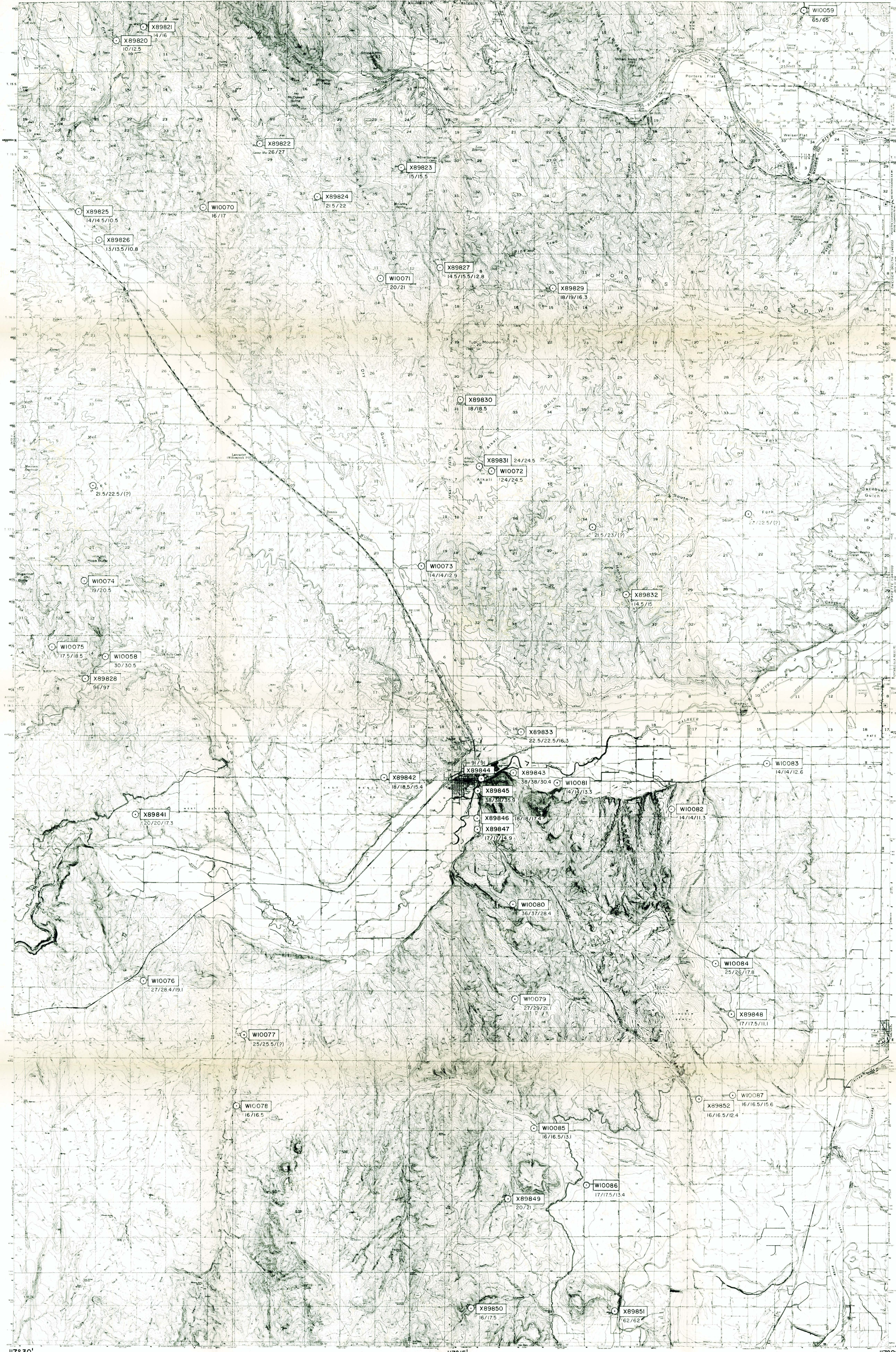
SKETCHES

AMAX EXPLORATION, INC.

DENVER, COLORADO

VALE
OREGON
GEOLOGY MAP

SOURCE : AMAX , 8/75
12/27/75



WI0085
16/16.5/13.1
- WELL CORRECTION REMOVING REGIONAL THERMAL GRADIENT (FOR WELLS OF KNOWN DEPTH ONLY)
- SURFACE WATER TEMPERATURE CORRECTED FOR ELEVATION
- SURFACE WATER TEMPERATURE

AMAX EXPLORATION, INC.
DENVER, COLORADO

VALE
OREGON
HYDROGEOCHEMICAL SAMPLE SITES

VALE GEOLOGY EXPLANATION

HOLOCENE

Qal	Alluvium
Qls	Landslides

PLEISTOCENE

Qtg	Terrace Gravels
Qtbc	Volcanic centers

PLIOCENE

TQb	Tertiary Quaternary basalt
Ta	Tub Mountain andesite
Tr	Sugar Loaf Butte pumicestone
Tba	Basalt vitrophyre
Tda	Dacite vitrophyre
Tri	Tertiary rhyolite
Tpf	Tertiary pitchstone
Tb	Coarse grained basalt
Tic	Chalk Butte sediments
Ticb	Chalk Butte basalt
Tig	Grassy Mountain basalt
Tigs	Grassy Mountain sediments
Tik	Kern Basin formation

MIOCENE

Tcr	Columbia River basalt
Td	Deer Butte formation
Tob	Owyhee basalt

TRIASSIC

ŦRu	Meta-sediments

—— - - -	contact, dashed where approximately located
—●— - -	fault, ball on downthrown side, dashed where approximately located
⋎20	measured strike and dip
⊕	horizontal attitude
⁘	altered areas -- silicification and/or hydrothermal alteration
A——A'	line of cross-section

GENERALIZED GEOLOGIC SECTIONS