12TH ANNUAL ROCKY MOUNTAIN GROUNDWATER CONFERENCE
BOISE, IDAHO

FIELD TRIP
BOISE FRONT GEOTHERMAL
1983
ITINERARY

11:30 Leave Red Lion Downtowner Hotel by furnished transportation for Boise Warm Springs Water District well site on north side of Old State Penitentiary (State museum).

11:40 Assemble in parking area on north side of Old Penitentiary for introductory statement about site features.

12:00 Visit wells and historical building for discussion of history, geology and modern engineering at the site.

12:30 Return to parking area or Old Penitentiary building for LUNCH and continued discussion of geohydrology of the site and nearby development.

1:30 Drive through Foothills East Subdivision and up Cottonwood Creek toward Idaho batholith exposures above Rocky Canyon gorge.

1:45 Stop at intersection of Cottonwood and Picket Pin Creeks to observe rhyolite and basaltic tuff and discuss structured features.

2:15 Stop at upstream end of gorge to observe and discuss contact with granitic rocks.

2:40 Arrive at turn-around at junction of Fivemile Creek and Cottonwood Creek. Reverse direction and return through Rocky Canyon, Aldape Heights to Military Reserve Park.

3:00 Arrive on ridge overlooking juncture of Cottonwood and Fivemile Creeks in Military Reserve Park, near old radio facility. Observe upper part of basaltic section and overlying lower Idaho Group sediments.

3:20 Boise Geothermal Limited, Well #2. Discuss well construction, geohydrology, engineering and role of these four wells in the overall geothermal development.

3:50 Capitol Mall Well #2. Discuss the State of Idaho system, observe the production well installation and begin walking tour through State buildings to observe the distribution and heat-exchange engineering features.

4:30 Arrive at Capitol Mall Well #1. Finish the walking tour with discussions and observations of the injection well installation for the State of Idaho system.

5:00 Return to Red Lion Downtowner Hotel.
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BOISE, IDAHO

FIELD TRIP GUIDEBOOK AND ROAD LOG

prepared by

Will Burnham & Spencer Wood

Field Trip Leaders:

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The objectives of the field trip are two-fold. The first is to offer an opportunity to visit the principal sites of development of thermal groundwater for applications in the City of Boise as of early 1983. The second is to see in outcrop those rock units and geologic structural features that are controls on the thermal water system. There are other private developments within and near Boise which can be discussed by trip leaders, but they are not included in the itinerary. The road log is accompanied by a large amount of textual and illustration material which represents the general understanding of the geology and geohydrology by the authors as of this time. However, much of the field and laboratory work is preliminary and incomplete, and changes in interpretation seem to come all too frequently as new information develops. Nevertheless, the principal framework of lithologies, faulting, and thermal water distribution appear to be substantially correct.

Mileage

0.0 Parking area at North side of Old State Penitentiary Museum compound, behind the Bishops House. Looking north across the south boundary of Section 12, T. 3N, R. 2E (indistinct fence line) at the ridge slope and the newly re-furbished well house for BWSWD (Boise Warm Springs Water District) wells. The well house contains the original two wells drilled in 1890 for hot water at this site, which was a prominent hot spring, seep, and marsh area. (Wells, Merle W., 1971) Both wells were re-developed and partially reconstructed at various intervals, principally in about 1930. The wells are each about 400 to 410 feet deep, are 31 feet apart, and are cased with 12-inch steel pipe to a depth of 160 feet. Below 160 feet the wells are about 9 inches in diameter and are uncased. Information about the subsurface materials drilled is sketchy, but it is probable that 160 feet marks the base of potentially collapsible sediments and the top of more stable
volcanic rock. (See attached diagrams and cross-sections) Borehole television inspection of the wells in 1980 indicates hard, fractured rock of probable rhyolitic composition to about 370 feet, then coarse conglomerate to the bottom.

The wells are both artesian, and will flow at the well house floor (elev. 2,765 ft.) if not pumped. The distribution system pipeline taps the casings a few feet below the top to prevent overtopping. They have been in continuous use since 1891 and still yield water at the original temperature of 170-172°F (78°C). The best available information indicates that static water level has declined a few feet during the 90-year period—perhaps as much as 18 feet. (See Lindgren, Waldemar, 1898) Yield of each well is limited by depth of pump setting which is at the 160-foot casing base. The west well is slightly the better of the two, and will yield at least 1,200 gpm (gallons per minute) when pumped alone. Drawdown interference between wells is large, and maximum yield with both pumps operating is only slightly greater than 1,200 gpm. Average discharge during the peak of the winter heating season is about 800 gpm. Average for the season is nearer 500 gpm. Well tests in 1980 prior to installation of the present pumps gave indicated aquifer transmissivity and storativity values of about 15,000-25,000 gpd/ft. and 1.5 x 10^-4, respectively. The well house is on the National Register of Historic Buildings, and the current recon-struction has carefully retained unique features. Note the sloping corners which retain the basal parts of the wooden derricks constructed for the original wells. Other wells have been drilled near these from time to time, but none have proved adequate insofar as yield.

The latest is a cable-tool hole drilled to a depth of 595 feet (from elev. 2,785 ft.) about 650 feet northwest of these wells. This latest well penetrated a fault plane at about 315 feet, then was drilled in hard, dense rhyolitic or dacitic rock to 471 feet. A white clay occurs to 487 feet, then pinkish, quartz-rich rhyolite to the bottom at 595 feet. Insufficient yield for the planned use, and water temperature of about 145°F (63°C) make the well unusable. It is presently equipped with a water-level recorder to monitor annual trends and the effect of pumping at the producing wells. (See attached hydrograph)
Sketch and generalized cross-section across east end of ridge behind old State Penitentiary and BWSWD wells showing geologic units and fault displacement.
The attached sketch and cross-section of the ridgeslope, and stratigraphic chart identify the principal geologic features of this geothermal site. The wells are in or very near at least one of three distinct fault planes that strike along the ridge base and dip 65 to 80° south. The northernmost fault is immediately north of the recent "dry" well (BNSWD #3) to the west and is the one cut by the well at about 315 feet. The middle fault trace is sub-parallel and trends about through the production wells. The third, and apparently largest fault offset, is on a plane again sub-parallel and trending just behind the old penitentiary -- beneath the parking area. The tabular blocks between the faults are tilted to the northwest, about 12°, forming ramps on the down-dropped sandstone surfaces as seen to the right of the well house. The ridge face behind the well house is a moderately eroded fault scarp, exposing sandstone and siltstone along the crest resting on a thin greenish-gray claystone layer--all sediments of the lower Idaho Group. (See stratigraphic chart attached.) The claystone is unconformable on porphyritic basalt (Tbt) that, in turn, laps unconformably against the higher of the two rhyolitic rock outcrops to the west, or left (locally referred to as Castle Rock). Large (several centimeters) phenocrysts of feldspar occur in the basalt, as well as zeolite, calcite and opaline secondary deposits. The basalt occupies the same stratigraphic position as basalt flow units at the base of the basaltic tuff unit found in outcrop throughout the area and in the geothermal wells at Military Reserve and Capitol Mall. The remainder of the scarp face is composed of two distinctive rhyolitic to dacitic rock types (Tsv1 on stratigraphic chart), best seen in and around the two prominent outcrops of "Castle Rock". The higher and larger mass is a stoney rhyolite flow, or densely welded rhyolite tuff displaying well developed sheet jointing; the orientation of which suggests a tight asymmetric anticlinal fold whose axis plunges gently north. This is the outcrop described as a laccolith by Lindgren in his 1898 report, and argued over by geologists ever since. There is now good evidence to indicate that the exposure represents only the draping of the lower Idaho Group sandstone (Til) over the rhyolite, with a large erosional unconformity between.
Stratigraphic and lithologic sequence of the principal rock units seen in outcrop within the foothills, and in the geothermal wells near Boise.
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<tr>
<th>SERIES</th>
<th>South of Snake River</th>
<th>Boise Area</th>
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<tr>
<td>Recent</td>
<td>Recent lava flows</td>
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<td></td>
<td>Melon Gravel*</td>
<td>Terrace Gravel</td>
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<td>Upper</td>
<td>Bancroft Springs Basalt*</td>
<td>Boise River</td>
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<td>Sand Springs Basalt</td>
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<td>Crowsnest Gravel*</td>
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<td>Thousand Sprgs. Basalt**</td>
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<td></td>
<td>Madson Basalt</td>
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<tr>
<td>Middle</td>
<td>Black Mesa Gravel*</td>
<td>(Unconformity)</td>
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<td></td>
<td>Bruneau Formation*</td>
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<td>Glens Ferry Formation*</td>
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<td>Chalk Hills Formation*</td>
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<td>Poison Crook Formation</td>
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<td>Idavada Volcanics*</td>
<td>Upper Idaho Group</td>
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<td>Lower Idaho Group</td>
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<tr>
<td>Eocene - Cretaceous</td>
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<td>Idaho Batholith</td>
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*New stratigraphic names
**Old stratigraphic names, redefined

Figure 2. Upper Cenozoic stratigraphic units of the western Snake River Plain proposed by Malde and Powers (1962), and as adapted for the Boise geothermal area.
The core of the nearer, smaller outcrop is the same stoney rhyolite, although the jointing is oriented more to the northwest and the fold upside down. Surrounding this outcrop is a dark green or brown to nearly black, porphyritic rhyolitic vitrophyre with glassy groundmass. Plagioclase phenocrysts in the glassy matrix are about 1 to 1.5 mm in size. The rock displays large hexagonal joint columns oriented perpendicular to the plane of faulting.

Fragments that appear to be derived from the stoney rhyolite may be seen near the contact with that rhyolite as inclusions in the vitrophyre. An excellent exposure of hydrothermally altered and leached rhyolitic rock occurs along the northernmost fault plane immediately north of the "dry" well (BWSWD #3).

Finally, the fault group displayed here marks the southern boundary of a triangular horst block that underlies most of the Foothills East Subdivision area across the ridge to the north of this locality and extends northward beyond Military Reserve Park. Displacement of the rhyolitic rocks across this fault group is indicated to be at least 800 feet, down to the south. The latest well drilled in the down-thrown block (the Kanta well at the SE corner of the old prison compound) reached rhyolite at about 790 feet below elevation + 2,765 ft., which matches closely the log of a second well to the southeast (State Old Pen well).

0.25 Klotz St. and Penitentiary Rd. Idaho State Agricultural Laboratory on the right uses hot water from the BWSWD wells for laboratory and other purposes. Looking across the field on the left to the old penitentiary buildings, the Kanta and State Old Pen wells are on the flat just at the toe of the hill slope. We are still on the structural block faulted down at least 800 feet below "Castle Rock". Maximum temperature of water from the two known hot-water wells in this block is at least 10 degrees F less than that of the BWSWD wells. The reason may be both because of mixing with cold near-surface water, and because of lateral distance of the wells from major fault planes.

0.35 Stop sign. Intersection with Warm Springs Avenue (Hwy 21). Recent magnetic surveys in this vicinity by Dr. Wood and others at Boise State University show a major anomaly across a line paralleling Warm Springs Ave. to the left. This is believed
Distribution and service areas for the three separate geothermal systems in place in Boise. The Boise City and Boise Warm Springs Water District systems are inter-tied. The Capitol Mall system serves State of Idaho facilities, and is a separate closed system.
to mark the trace of the principal Boise Front Fault (Foothills Fault of Hollenbaugh) which further displaces the rhyolite down to the southwest several hundred feet. Turn right on Warm Springs Ave.

0.60 Trolley House restaurant and school on left. Immediately behind is a Boise City swimming pool. This is the site of the Natatorium which was a major user of BWSWD well water. Continue on Warm Springs Avenue.

1.1 Locust Street. Turn right toward foothills. Many of the homes along Warm Springs Ave. and the first two blocks here on the north side use the BWSWD well water for space heat and for domestic hot water. The water is delivered through either a meter or an adjustable orifice. Spent water is discharged to the sewer or to canals leading to the Boise River. (See map BWSWD distribution system).

1.35 Stop sign at Jefferson Street.

1.45 Rise in street grade, and higher ground to right and left. Locust Street crosses the principal faults of the Boise Front about here. Cross onto the horst block. Immediately ahead is thin alluvium on basaltic tuff. Immediately south of this point the basaltic tuff is believed to be at least 700 feet below land surface.

1.6 Turn right onto Shenandoah and enter Foothills East Subdivision.

1.8 The knob on the left is capped by lower Idaho Group sandstone (Ti1) overlying basaltic tuff. Sandstone overlies flow basalt under the ridge coming into view on the right leading up to "Castle Rock". The horst block is broken in this vicinity by internal normal faults with displacements of a few feet to tens of feet. The faults trend mainly NW, dip steeply SW, and are generally down to the northeast. Continue around Shenandoah St.

2.1 Intersection with Rimrock St. on left. The multiple dwelling units ahead on the right are about on one of the northeast boundary faults of the horst block. Several sub-parallel normal faults, down to the northeast are present in this vicinity and trend SE through the large depression on the right. The faults bring lower Idaho Group sediments down against basaltic tuff and flow basalts.
2.3 Turn right on Shaw Mtn. Road. Immediately after the turn Shaw Mtn. Road crosses the trace of the principal northeast boundary normal fault of the horst block. The fault trace is covered by unfaulted terrace gravel here, but strata of the block immediately ahead (NE) are down at least 250 feet relative to those of this block. The down-faulted, graben-like block, narrow at this southeast end, is tilted several degrees northwest.

2.5 Bear left on Shaw Mtn. Road.

2.6 Descending the south wall of Cottonwood Creek Canyon. A good view of the nearly flat-lying, brown, basaltic tuff unit overlain by light gray sand is ahead just beyond the ranch house in the canyon on the left. Just ahead the road crosses the second main normal fault of the Boise Front zone of faulting. Although not well exposed along the road here, this fault is clearly traced both to northwest and southeast, and marks the northeast boundary of the graben block just crossed. Trend of the fault is about N38°W with a steep SW dip. Throw is down to the SW such that the basaltic tuff exposed beyond the house is found in wells this side of the fault at depths of about 300 feet.

3.0 Cross cattleguard, then Cottonwood Creek. On ridge point at northeast side of tributary from the right, basaltic tuff is overlain by white sand (Tg), which in turn is unconformably overlain by Quaternary bouldery terrace alluvium (Qg). The white sand is Tertiary and everywhere in this vicinity marks the contact between basaltic tuff (Tbt) and the lower Idaho Group sediments. The Quaternary gravel above is a terrace deposit that is essentially unfaulted within the foothills, and marks an ancestral Cottonwood Creek drainage system. It is traceable from terraces at the present mouth of Cottonwood Creek to an elevation of about 3,500 feet in upper Picket Pin Creek, ahead.

3.3 Good view of basaltic tuff unit in canyon wall on south side of creek. Tuff on both sides of canyon and in the roadcuts on the left. Here the tuff is overlain by red-brown arkosic sand and silt.

3.7 Road crosses onto outcrop of purplish-gray, glassy, flow banded welded rhyolite tuff (Tsv₂). Basaltic tuff overlain by lower Idaho Group sandy sediments lap onto and over the rhyolite in the ridge on
the left. Across the creek the basaltic tuff appears to lap onto the rhyolite. The rhyolite here is a dark vitrophyre of the lower \( Tsv_2 \) unit shown on the stratigraphic chart.

3.8 **Stop 1.** Confluence of Cottonwood Creek and Picket Pin Creek. Stop in wide area where road branches to the right. Note the purplish-gray perlitic rhyolite on the point between the creeks, and the reddish-brown fluvial sand in the roadcuts on the ridge above. The west edge of the rhyolite outcrop here between the creeks is beveled to a uniform, flat, bench surface some 20 or 30 feet above the creeks, as can be seen nearby in either creek. The red-brown fluvial deposit is in the lower Idaho Group, thus this contact marks a large erosional unconformity at this locality. The top of the basaltic tuff unit is at or just above road level in the canyon wall on the north side of Cottonwood Creek, yet about 2,000 feet up Picket Pin Creek the top of basaltic tuff is more than 500 feet above this point. There, as here and just to the west, the tuff shows nearly horizontal bedding. The ridge to the left looking up Cottonwood Creek contains dark reddish-brown granitic sand mixed with abundant basaltic tuff near the base, grading upward toward the ridge crest to essentially pure granitic (arkosic) fluvial sand and gravelly sand. The rhyolite flow of Rocky Canyon, as seen directly ahead from this stop, is at least 200 feet thick, and is probably about 400 feet thick. The rock is complexly flow-banded and highly fractured, varying in color from dark and glassy gray-brown to a stoney lavender-gray. It contains euhedral quartz and phenocrysts of both plagioclase and alkali feldspar. Mafic minerals are not conspicuous, but careful examination is yet to be done. Flow features suggest it may be either a densely welded ash flow tuff or rhyolite flow. It is known to occur in the subsurface in Freestone Creek, 1.5 miles northwest. As one proceeds up the road from here through Rocky Canyon Gorge, it is noted that the top of the rhyolite exposure rises in sharp steps. Faults are not clearly evident in the gorge walls, but fracturing is intense and these may represent vertical displacement. Laterally, along the mountain front in both directions, there is evidence that the third principal fault trace of the Boise Frontal Fault zone lies through this locality.
Continue up Rocky Canyon Road

4.0 Note sudden offset in height of canyon walls, then immediately the near-vertical fracture patterns in the rhyolite on either wall.

4.3 Stop 2. At upstream margin of rhyolite. On the left, north of the road in thick brushy growth, the granite of the Idaho Batholith (ki) is in fault contact with basaltic tuff. These red-brown deposits give the color to the saddle-like swale in the contact zone between the granite and the rhyolite. South of the creek (to the right) the basaltic tuff is clearly evident in the lower part of the canyon wall, and appears to lap against the rhyolite. A few hundred feet upstream, an old mine adit follows the fault contact between granite and basaltic tuff. The contact zone here has not been studied sufficiently to determine just how the granite, rhyolite and basaltic tuff occur. It appears, however, that the basaltic tuff overlies or laps against the rhyolite, and that both are faulted against the granite on a contact that trends N52°W and dips toward the southwest about 72 degrees. (See geologic map and sections)

4.4 Note complex joint and fracture pattern in canyon walls.

4.45 The road bends sharply left, then back 90° right. The granitic rock here is biotite bearing, but much of the rock is hydrothermally altered so it contains no visible mafic minerals. Originally it was probably a biotite quartz monzonite porphyry, with alkali feldspar. In the tributary to the right there are hydrothermal quartz veins and alteration in the granitic rock. Note the consistent joint sets or extensive fracturing in the area. The offset in the canyon coincides with the trace in Picket Pin Creek (to the southeast) of the fault contact between granitic rock and basaltic tuff.

Continue up Rocky Canyon Road through the granitic rock exposures, noting the great variability in degree and orientation of jointing and fracturing. Flow basalt caps the south canyon wall ridge, lying unconformably on both the granitic rocks and basaltic tuff. Unconformably on this basalt, and on the granitic rocks of the north canyon wall is gravelly alluvial sediment of the lower Idaho Group.
6.0 Basalt dikes cutting granitic rocks in roadcuts.

6.25 **Stop number 3.** Turnaround at mouth of Fivemile Canyon. Numerous old workings for gold in quartz veins occur up this canyon. Large outcrops with prominent jointing are seen ahead in Cottonwood Creek and on east wall of Fivemile Canyon. Note contrast with outcrops downstream and to the west. This traverse deep into the granitic rock provides a view of the degree of development of secondary openings (joints, fractures, shear zones) that are believed to provide the permeability necessary for deep regional percolation of meteoric water that is heated at depth, then rises along traces of the Boise Frontal Fault zone.

Turn vehicles around and retrace the trip. The intent now is to use this as the beginning point for a trip upward in stratigraphic sequence (and time) across most of the rocks of importance to the geothermal system and the wells. The best conceptual model at present is that recharge to the thermal water flow system occurs here and to the northeast over the jointed, fractured granitic rocks, and through the intense fracturing of the rhyolitic rocks. Consider this concept as we now backtrack through Rocky Canyon and emerge on the basaltic tuff. The tuff is widespread throughout the Boise Front and into the valley. It has very small cross-bed permeability and does not accept recharge readily. It is broken only by the faults, and the basaltic composition tends to alter to clay wherever faulting has allowed contact with hydrothermal conditions. Thus, the basaltic tuff and the overlying Idaho Group sediments provide a hydraulic cap to the deep circulation system in the granitic and rhyolitic rocks. We climb back out of Cottonwood Creek onto Idaho Group sediments and Qg as we return to the intersection of Shaw Mtn. Road and Shenandoah Street.

0.0 Re-set odometer to 0.0 at junction of Shaw Mtn. Road and Shenandoah. Continue down Shaw Mtn. Road and recall that we are again on the horst block.

0.25 Note fault on right in roadcut bank of cross-bedded yellowish sand. This fault is one of the main internal structural features of the horst block. It strikes NW and dips 62°NE. A second, similar fault
is visible again on the right a few hundred feet further on around the curve. The faulted sand belongs near the base of the lower Idaho Group sediments. Basaltic tuff outcrops a short distance below the road, on the left.

0.6 Cross contact at base of the uppermost basalt flow units in the area (Tba), designated the basalt of Aldape Heights on the stratigraphic chart. Below the road, on the left, there are exposures of a light gray sand that separates this basalt from the basaltic tuff sequence. Continue around Shaw Mtn. Road on the Aldape Heights basalt (Tba), which dips about 15° southwest.

0.7 Looking northwest along the toe of the Boise Front and the trace of the principal faults of the Frontal Fault zone. Straight ahead are the four Boise Geothermal Limited wells, BGL-1 thru 4 and test hole BGH-1 (Beard). Three sub-parallel planes of normal faulting are known to occur along or near the break in slope, with a down-to-the southwest throw of rhyolitic rocks totaling about 900-1,000 feet. The fault planes here dip about 80-85°SW. This fault zone trace is the same one noted earlier beneath Warm Springs Avenue near the old penitentiary.

0.9 Continue left on Reserve Street.

1.1 Turn right at signal onto Mountain Cove Road. Berms on the right bound flood-control basins for Cottonwood Creek and Freestone Creek drainages. Controlled outflow is through the flume along the road, on left.

1.4 Cross headgate structure and turn right onto dirt track up the frontal slope. Exposure at base of slope on left and around the ridge into Cottonwood Creek is the uppermost of two distinct basalt flows of the Aldape Heights basalt (Tba). The dirt road climbs on a large slump mass, down to the right. Continue winding back and forth to the top of ridge and to a wide parking area on the left.

1.7 Stop number 4. Park in designated area for overlook into Cottonwood-Freestone Creeks. Walk about 200 feet north to picnic shelter and overlook.
At this point we are standing on the Quaternary terrace gravel noted earlier as we crossed Cottonwood Creek heading up to Rocky Canyon gorge. The gravel is in erosional contact here with the Tba unit that is seen in exposure across the canyon, and it caps the ridge between the creeks. This is the youngest deposit known in the area, except for the alluvium of the present stream terraces and channels. This terrace gravel (Qg) is not known to be offset by faulting anywhere from here to its head. It contains cobble layers as well as large blocks and boulders of distinctive basalt from the outcrops overlying granitic rock above the Rocky Canyon gorge, about 2.5 miles upstream. The gradient and elevation of these deposits project into the air and do not merge with the valley floor access the frontal faults. The deposit is at least 150 feet above the valley. The terrace deposit has not been found across the frontal fault traces. From these data it is inferred that the frontal faults are the traces of the youngest of the fault movements within the Frontal Fault Zone, and that the latest movements are at least as young as these terrace deposits. Only the relative age of the terrace deposits is known, however.

Looking north at the north canyon wall above Mountain Cove Road, the upper flow unit of Aldape Heights basalt (Tba) is exposed in the old quarry and dips about 12° SW. Base of Qg is seen at the top of the exposure unconformably on the basalt. Down and to the right near the road is a thin white sand which thickens southward under our vantage point, and separates the two flow units of Tba. Up and slightly right of the sand exposure is an outcrop of sandstone striking NW and dipping only about 3 to 5 degrees SW. The sandstone belong stratigraphically well above the basalt with which it appears here to be continuous. One of the main faults of the NE side of the horst block passes between the outcrops, trending N58°W and dipping steeply NE. The fault also cuts across the nose of the dividing ridge between the creeks before us and to the right, then can be found in a tributary draw along this side of the canyon about 1,200 feet upstream. Another, and the main NE boundary fault of the horst block crosses the dividing ridge a few hundred feet farther east, and trends N52°W with a steep NE dip. The two wells noted by Lindgren in his 1898 report as being in Cottonwood Creek about 2 miles above Boise were
Figure 3 Generalised location map of the Capitol Mall and Military Reserve Park area with wells, line of section, and general geology.
located near the south wall of the creek just upstream (East) of the trace of this NE boundary fault of the horst. The basalt reported in those wells is the down-faulted Tba. Return to the vehicles and retrace the route down the frontal slope.

1.9 On switch back above well BGL-3. (See map, figure 3 for well numbers and locations.) The Tba unit is under soil cover in the roadcut at the road junction. The top of basalt is found in well BGL-3, about 80 feet away, at a depth of 270 feet. This fault offset of nearly 300 feet is the middle of the three fault planes along the front, striking N38°W and dipping 85°SW. The first geothermal test hole drilled in 1975 and designated BEH-1 (BLM) is located beside the nearest metal sided building across the road and flume toward the west, about 400 feet away. All three fault traces of the frontal fault zone occur between here and well BEH-1 (the BLM well).

2.0 **Stop 5.** At Boise Geothermal Limited Well No. 2. Wells are numbered in the order drilled. Number 1 is at the SE without a shelter. The others are in concrete housings designed for partial burial to blend with park landscaping. Most of the pertinent information on locations, well construction, yield, water temperature and quality, instrumentation, distribution system and uses is given in accompanying maps, diagrams, and tables. A few additional facts on design, construction, testing, and completion follow:

1. Data from test holes BEH-1 (BLM) and BGH-1 (Beard) restricted location to near vicinity of interpreted faults striking NW along the toe of the break in slope of the Boise Front.

2. Right-of-way and access restricted locations to roadways and berm tops within Military Reserve Park between Mountain Cove Road and the south boundary.

3. Planned uses determined a desired peak season yield of 2,000 gpm or greater. Test data from the BLM-Beard holes indicated individual well yields of 500 gpm with economically feasible drawdown. Consequently, four wells were needed, to be fitted into available locations.
Section from SW to NW through Capitol Mall and Military Reserve to the granite NW of Cottonwood Creek.
Schematic correlation section from the State Capitol to Cottonwood Creek.
Typical well construction for Boise Geothermal Limited wells 1 thru 4 and Capital Mall well 2.
Temperature profiles for BGL #3, ELM (BEH-1), Beard (BH-1) after wells shut in for several months and temperature stabilized.
4. Spacing to minimize drawdown interference between wells had to be matched to access and right-of-way, and to pipeline costs for the gathering system.

5. State and local laws and regulations related to geothermal wells required pressure grouting of surface casing to protect shallow cold-water aquifers, and blow-out protection when drilling the thermal zone. Such requirements dictated size, type and capabilities of drilling equipment used. Design discharge and drawdown dictated size of pumps required. Size of pump dictated size of hole to be drilled to accept casing and the pressure-cemented annulus needed. Size of surface casing was further dictated by size of the production hole and casing needed, and by the possibility that at least two hole-size reductions might be needed below the surface casing. Such considerations further determined the size and type of drilling equipment.

6. Drilling deep, large diameter holes in or near fault zones anticipates hole-wall instability and loss-of-circulation problems. A carefully designed and controlled drilling mud is required. To minimize drilling mud effects on thermal water production, only bentonite clay mixed with fresh water was used where mud drilling was necessary. Conditioning additives were closely monitored and kept to a minimum. Wherever possible in the thermal water production zones, drilling was done with water only; with compressed air assistance in removing cuttings and maintaining circulation.

7. Only moderate thermal-water formation pressures were encountered, and as a rule the wells did not flow or make a significant amount of water during drilling. Each well was completed by circulating out the drilling fluid with clear water, then air-lifting to reduce the column density sufficiently to initiate artesian flow. Flow was continued until the discharge was clear and stable. Well BGL-3 is located such that the wellhead elevation is above artesian pressure head. That well was air-lift pumped for completion.
8. The wells were test flowed or pumped under a variety of procedures designed to determine both well and aquifer hydraulic characteristics under planned production schedules and use. Testing included long-term monitoring of water-level changes in the thermal water zones at the Koch well which is drilled in the fault blocks northeast of the Frontal Fault Zone. Also monitored was BWSWD well #3 which is in or near, the faults directly connected to the Frontal Fault zone and the BLM test hole which is on the valleyward side of the Frontal Fault zone. During flow tests, all wells in the vicinity completed in the thermal water zones were used as observation wells. Additionally, shallow cold-water wells nearby were monitored for possible drawdown effects.

9. Well and aquifer characteristics, as based on testing done to date, may be summarized as follows:

The wells in Military Reserve Park and valleyward in the Capitol Mall area display a seasonal static level fluctuation that matches closely both timing and magnitude of change in cold-water municipal, domestic and irrigation wells in and near Boise. The Koch well water level fluctuates in a manner completely out of phase with the other wells, and is more in harmony with industrial and municipal supply wells within the foothills toward the northwest. BWSWD well #3 water level follows very closely the pumping times and magnitude at the two production wells near the Old Penitentiary. (See attached hydrographs)

The thermal water aquifer system at the BGL wells is well confined, with indicated storage coefficients of $10^{-4}$ to $10^{-3}$. All wells have a barometric efficiency of about 80 to 90 percent. During the early, initial period of a test, the aquifer responds as a fault-fracture system with indicated transmissivity in the $10^6$ gpd/ft. range and a no-flow boundary across the faults to the northeast. Toward the southwest, the Capitol Mall and BLM observation wells indicate the aquifer responds more in the character of a granular material with transmissivity values of the order of $10^5$ gpd/ft. and storativity of $10^{-3}$. 

25
There is a regional gradient of the static water level (pressure head) toward the northwest from BGL-1 to BGL-3 within the Military Reserve area. Also, toward the west-northwest between wells in Military Reserve and those at Capitol Mall. The pressure head in the thermal groundwater system is everywhere greater than either artesian or watertable levels in the cold-water aquifers of the lower Idaho Group sediments. It is, therefore, interpreted that the gradient in the thermal water system reflects lateral migration valleyward from the frontal faults and discharge upward by cross-bed bleeding to Idaho Group deposits at lower head.

Continue southeast along the line of wells to Reserve Street.

3.15 Reserve Street. Turn right and proceed toward downtown Boise.

3.6 Turn right on Fort Street. Cold-water wells here in the Military Reserve Park area are 400-500 feet deep. Monitored water levels in these wells do not reflect drawdown caused when flow-testing the geothermal wells. Idaho Group sediments are more than 600 feet thick in this vicinity.

3.8 Turn left on Washington Street.

3.9 On the left, the structure in the parking lot houses the State of Idaho Capitol Mall well No. 1. The field trip will not stop here, as it will return to this site at the end of a walking tour through the State facilities.

Continue west on Washington Street.

4.15 State of Idaho parking lot on right. Enter lot and continue around to Capitol Mall well #2 well house near SE corner. This is the final stop. Vehicles will be taken to Capitol Mall well #1 lot to await completion of walking tour of the State facilities.

Capitol Mall well #2 was drilled by the same equipment and under essentially the same specifications as the four Boise Geothermal Limited wells in Military Reserve Park. The well is 3,030 feet deep and bottoms in quartz-rich rhyolite (Tsv2). Attached diagrams and
correlative sections give the essentials of well construction and stratigraphic relations. Pressure cementing of the 12-inch surface casing was done by Halliburton Oil Well Cementing, and the suite of borehole geophysical logs made by Schlumberger, both from Evanston, Wyoming. In addition to the geolograph record and cuttings logging, logs were run for Natural Gamma, Caliper, Induction Electrical Resistivity, Borehole Compensated Sonic, Compensated Neutron-Formation Density, and Temperature. These were used to guide production casing, perforation and completion programs. The drilling was done with freshwater mixed bentonite mud and/or with just fresh water and air. Artesian flow was controlled by mud until well-head valving was in place and disposal facilities were in order. Upon purging of mud from the column, flow of at least 950 gpm was obtained for initial cleanup and completion. Temperature of discharge water stabilized at 160°F (71°C), and shut-in pressure of the hot water column was about 18 psig. The water quality is similar to that from other wells and, following flow tests for data about aquifer constants, the well was equipped and placed into service for the 1982-83 heating season. Attached information sheets furnish the pertinent information about the well, the heat-exchange equipment in the State buildings and the equipment for injection of the spent water at Capitol Mall well #1.

After viewing the well facilities, proceed with walking tour through office buildings and to Capitol Mall well #1. This well is equipped for injection of the spent thermal groundwater from well #2. Drilled under a separate State contract with light-duty rotary drilling equipment, the well is 2,152 feet deep and bottoms in sandstone and conglomerate (Tssf1) below the upper silicious volcanic rock (Tsv1). The well was drilled primarily as an exploratory well, and was not designed sufficiently to meet flow needs for heating the Capitol Mall. It does serve well, though, as an injection well, the receiving aquifer being the upper part of the rhyolite at about 1,700-1,800 feet.

End trip at Capitol Mall #1. Re-board transportation for return.
## Representative Water Quality

(Geothermal & Shallow Cold Water)

<table>
<thead>
<tr>
<th></th>
<th>BNSWD  (Westwell)</th>
<th>DCL-2</th>
<th>Capitol Mall #2</th>
<th>Barnes (Foothills)</th>
<th>BMCO- Centennial (Valley)</th>
<th>Boise River (Barber)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific Conductance (micromhos/cm</strong></td>
<td>378</td>
<td>405</td>
<td>415</td>
<td>157</td>
<td>208</td>
<td>85</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>8.15</td>
<td>8.15</td>
<td>7.55</td>
<td>6.77</td>
<td>7.7</td>
<td>7.29</td>
</tr>
<tr>
<td><strong>Temperature, °C</strong></td>
<td>78</td>
<td>74</td>
<td>70.5</td>
<td>16</td>
<td>(Cold)</td>
<td>9</td>
</tr>
</tbody>
</table>

| **Cations**          |                   |       |                 |                    |                          |                      |
| Calcium              | 3.2               | 1.9   | 1.3             | 16                 | 21                       | 10.4                 |
| Magnesium            | <0.1              | <0.1  | 0.1             | 2.8                | 0.48                     | 1.26                 |
| Sodium               | 82.6              | 88    | 79.2            | 10.4               | 23                       | 4.4                  |
| Potassium            | 1.4               | 1.1   | 0.6             | 1.6                | 0.75                     | 0.9                  |
| Silica (SiO₂)        | 73.5              | 74    | 55.6            | 39.7               | 27                       | 13                   |

| **Anions**           |                   |       |                 |                    |                          |                      |
| Bicarbonate          | 137               | 138   | 142             | 33                 |                          | 46                   |
| Chloride             | 5.9               | 5.4   | 8               | 3.6                | 5                        | 0.3                  |
| Sulfate              | 21.5              | 20    | 19              | 10                 | 20                       | 2                    |
| Flouride             | 19.1              | 15.7  | 16              | 0.32               | 0.62                     | -                    |
I. Pump Data and Operation
   a) Production Pump P-5 - Peerless 5 stage vertical turbine, 70 foot setting, with 2 speed 40 hp motor, rated for 750 gpm at 165 ft. TDH on high speed and 500 gpm at 75 ft. TDH on low speed.
   b) Injection Pump P-6 - Peerless 4 stage horizontal centrifugal rated for 750 gpm at 360 ft. TDH.
   c) Injection Pump P-7 - Peerless end suction centrifugal rated for 300 gpm at 75 ft. TDH.
   d) Operation
      Pump P-7 - On at temperatures below 60°F
      Off at temperatures above 60°F
      Pump P-5 - On at low speed at 200 gpm
                  On at high speed at 375 gpm
      Pump P-6 - On at 500 gpm
      Pump P-5 - Discharge pressure controlled to 30 psig on low speed and 50 psig on high speed.
      Pump P-6 & P-7 - Suction pressure controlled to 10 psig

II. Pipeline
   a) Buried geothermal supply line is pre-insulated asbestos-cement, 8-inch size for the main line and 4-inch size to the Library.
   b) Buried geothermal return line is uninsulated asbestos-cement, 8-inch size for the main line and 4-inch size to the Library.
   c) Exposed geothermal piping is welded or screwed carbon steel with field applied 1-1/2 inch fiberglass insulation. Main supply and return lines are 8-inch size. Victaulic fittings were used in mechanical rooms and the pump stations.

III. Building Retrofits
   a) Len B. Jordan Building
      97,000 sq. ft., 115 gpm geothermal design flow, $1.71 \times 10^6$ Btuh design load. Geothermal water flows directly to stainless steel air coils which were installed upstream of the existing steam coils, which were left intact to provide back-up and peak heating. A 330,000 Btuh heat exchanger uses geothermal return water to heat domestic hot water.
b) Hall of Mirrors

145,000 sq. ft., 80 gpm geothermal design flow, \(1.12 \times 10^6\) Btu/h design load. Geothermal water flows to a plate heat exchanger to heat a new closed building hot water loop. The existing steam coils were removed and replaced by hot water coils. A steam converter was installed in series with the plate heat exchanger to provide back-up and peak heating.

c) Capitol Building

127,000 sq. ft., 160 gpm geothermal design flow, \(2.32 \times 10^6\) Btu/h design load. Geothermal water flows to a new plate exchanger which was installed in series with the existing steam converter in the existing closed building hot water loop. The steam converter was left intact to provide back-up and peak heating. There are several small, remote air handlers with steam coils that were not retrofitted because it was uneconomical to pipe hot water to them.

d) Central Services

43,000 sq. ft., 60 gpm geothermal design flow, \(0.81 \times 10^6\) Btu/h design load. Geothermal water flows to stainless steel air coils which were installed upstream of the existing steam coils, which were left intact to provide back-up and peak heating.

e) Tower

166,000 sq. ft., 110 gpm geothermal design flow, \(1.68 \times 10^6\) Btu/h design load. Geothermal water flows to a new plate heat exchanger which was installed in series with the existing steam converter in the existing closed building hot water loop. The steam converter was left intact to provide back-up and peak heating. The heat exchanger was actually sized for 220 gpm geothermal flow, and will be able to carry the second Tower when it is added to this structure. A 500,000 Btu/h plate heat exchanger heats domestic hot water with geothermal return water.

f) Supreme Court Building

66,000 sq. ft., 60 gpm geothermal design flow, \(0.83 \times 10^6\) Btu/h design load. Geothermal water flows to a plate heat exchanger which heats water in a new closed building hot water loop. The existing steam coils were removed and replaced with hot water coils. A new steam converter was installed in series with the plate heat exchanger to provide back-up and peak heating.
g) State Library

39,000 sq. ft., 40 gpm geothermal design flow, 0.52 x 10^6 Btuh design load. A new plate heat exchanger was installed to heat the closed building hot water loop. One air handler had hot water coils, and the steam coils in the other air handler was replaced with hot water coils. The existing steam converter was upgraded to increase its capacity to handle back-up and peak heating for both air handlers.

h) Controls

Water flow to the air coils is controlled by the leaving air temperature which is on a reset schedule of 75°F supply air at 60°F outside air temperature and 100°F supply at 20°F outside air temperature.

Geothermal water flow to the plate heat exchangers is controlled by the leaving closed building loop water temperature which is on a reset schedule of 85°F and 60°F outside air temperature and 120°F at a 20°F outside air temperature.

IV. Experience

The system was started up October 1, 1982. For the winter of 1982-1983 the system operated very well, although start-up problems kept the energy management system from recording as much data as was hoped for. Generally, flows were somewhat less than the design values, injection pump P-6 was not required to be used, and geothermal water return temperatures ranged from 120 to 130°F for buildings with plate heat exchangers and 100 to 110°F for buildings with direct use stainless steel coils.

Following is a table showing degree days and therm usage at the State of Idaho Capitol Mall gas meter.

<table>
<thead>
<tr>
<th></th>
<th>1981 - 1982</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
<td>Total</td>
</tr>
<tr>
<td>Degree Days</td>
<td>497</td>
<td>624</td>
<td>915</td>
<td>1,240</td>
<td>974</td>
<td>4,250</td>
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<tr>
<td>Therms</td>
<td>36,114</td>
<td>51,501</td>
<td>56,776</td>
<td>68,003</td>
<td>65,061</td>
<td>277,455</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>1982 - 1983</th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
<td>Total</td>
</tr>
<tr>
<td>Degree Days</td>
<td>432</td>
<td>863</td>
<td>1,031</td>
<td>897</td>
<td>653</td>
<td>3,876</td>
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<tr>
<td>Therms</td>
<td>14,858</td>
<td>15,722</td>
<td>21,487</td>
<td>31,447</td>
<td>20,259</td>
<td>103,773</td>
</tr>
</tbody>
</table>

Corrected 1982-1983 usage = $103,773 \times \frac{4250}{3876} = 113,786$

% gas usage in '82-'83 = $\frac{113,786}{277,455} = 41\%$ of '81 - 82'

The State of Idaho realized a savings of approximately $80,000 on its gas bill in 1982-1983 as compared to the same 6 months in 1981-1982.
PUMP OPERATION CONTROLLED BY FLOW SIGNAL

PRESSURE CONTROL LOOP
ARTESIAN BYPASS LINE
SAND SEPARATOR

PUMP P-5 2-SPEED

PRODUCTION PUMP STATION

BUILDING RETROFITS (TYPICAL)

INJECTION PUMP STATION

TEMPERATURE CONTROL LOOP
STAINLESS STEEL DIRECT USE AIR COIL

DOMESTIC HOT WATER HEATER

FLOWMETER
PLATE HEAT EXCHANGER
ALUMINUM COPPER AIR COIL

AIR FLOW

PUMP P-6
PRESSURE CONTROL LOOP

PUMP P-7
INJECTION WELL
References


