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CORWIN SPRINGS KNOWN GEOTHERMAL RESOURCES AREA,

PARK COUNTY, MONTANA

By

H. C. Jim Taylor

and

J. S. Hinds

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CORWIN SPRINGS KNOWN GEOTHERMAL RESOURCES AREA,
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By H. C. Jim Taylor and J. S. Hinds

Abstract

The Corwin Springs Known Geothermal Resources Area (KGRA) is contiguous to Yellowstone National Park along a part of the northern boundary of the park near Gardiner, Park County, Mont. The area contains two known sites of hot-spring activity--LaDuke Spring, 2.8 km southeast of the small resort community of Corwin Springs, and Bear Creek Spring, 2.6 km east of Gardiner. LaDuke Spring issues from brecciated quartzite and has a flow rate of 380 l/min, a surface water temperature of 65°C, a silica-geothermometer temperature of 68.7°C, and a Na-K-Ca geothermometer temperature of 76.8°C. Bear Creek Spring issues from limestone and has a flow rate of 4 l/min, a surface water temperature of 32°C, a silica temperature of 46.7°C, and a Na-K-Ca temperature of 87.2°C. The springs, which are actively depositing travertine, are on or near the trace of the Gardiner fault--a high-angle reverse fault which forms the southwestern boundary of the Beartooth uplift.

Features that make the Corwin Springs KGRA potentially significant include: (1) Proximity of the Corwin Springs area to significant Pliocene and Pleistocene volcanism in Yellowstone National Park and related geothermal activity, (2) existence of a large potential geothermal reservoir in the northern extension of the Sepulcher Mountain graben, (3) localization of thermal activity along the Gardiner fault in the Corwin Springs area, (4) occurrence of negative gravity anomaly centered over the northern end of the Sepulcher Mountain graben, (5) existence of negative magnetic anomaly in the Corwin Springs area, (6) location of the area within the Intermountain seismic belt, (7) evidence of recent tectonism in the area, as demonstrated by Pleistocene and Holocene faulting, and (8) observed surface temperatures and estimated geochemical temperatures of the two known hot springs (features which do not indicate high subsurface temperatures).

Introduction

The purpose of this report is to summarize the geological, geophysical, and geochemical data which contribute to the overall geologic delineation of the Corwin Springs Known Geothermal Resources Area (KGRA). The Corwin Springs KGRA is contiguous to Yellowstone National Park along a part of the northern boundary of the park near Gardiner, Park County, Mont. (fig. 1). The area contains two known sites of hot-spring activity--LaDuke Spring, 2.8 km southeast of the small resort community of Corwin Springs, and Bear Creek Spring, 2.6 km east of Gardiner. Available information indicates that Corwin Springs was the site of a health resort that utilized hot water piped from LaDuke Spring; no actual hot spring exists at the community of Corwin Springs. The

Figure 1.--Index map showing location of Corwin Springs area. Corwin Springs Known Geothermal Resources Area (KGRA) shown in cross-hatch.

largest hot spring, LaDuke Spring, has a flow rate of 380 l/min and a surface water temperature of 65°C (G. Mowat and H. Owen, written commun., 1974). Bear Creek Spring has a considerably lower flow rate of 4 l/min and lower surface water temperature of 32°C. Both are on or near the trace of the Gardiner fault, a major high-angle reverse fault that forms the southwestern boundary of the Beartooth uplift (fig. 2). The subsurface temperatures were computed by Marshall J. Reed, U.S. Geological Survey, in program CHEMTEMP.

Geology

Structure

The Corwin Springs KGRA is characterized by the junction of major structural elements which may control the spatial distribution of surface thermal manifestations. The major north-striking faults of the Corwin Springs area extend southward into the principal thermal areas of Yellowstone National Park (fig. 3) where they seem to play a major role in the localization of surface geothermal activity (Ruppel, 1972, p. A51). The Gardiner reverse fault transects the Corwin Springs area along a northwesterly strike and provides the conduit for the thermal waters of LaDuke and Bear Creek Springs (fig. 2).

The Gardiner fault is a major Laramide tectonic feature described by Fraser and others (1969, p. 63-69) as a steeply dipping, imbricate, reverse fault zone in which the net throw exceeds 3,050 m. They calculated the dip of the fault to be 75° NE near Gardiner. Northeast of the Gardiner fault lies the uplifted Beartooth block, from which the sedimentary cover has been stripped, exposing Precambrian rocks with a partial covering of Cenozoic volcanic rocks. In the downthrown block,

Figure 2.--Major geologic features of the Corwin Springs area. KGRA boundary is shown by heavy solid line. Normal faults are shown by solid lines with bar and ball on downthrown side; dashed where approximated. Reverse fault, dashed where approximated shown with teeth on overriding block. The isolated land area 8 km east of Corwin Springs is included within the KGRA by legal sanction only. Geology from Foose and others (1961), Fraser and others (1969), and Ruppel (1972).

Figure 3.--Major faults and lineaments in the Corwin Springs-Yellowstone region. KGRA is shown in heavy stipple. Thermal areas are shown in light stipple. Lineaments are shown by dashed lines. Normal faults are shown by solid lines with bar and ball on downthrown side. Reverse faults are shown by solid lines with block teeth on overriding block. Modified from Ruppel (1972, fig. 22).

southwest of the Gardiner fault, about 3,050 m of Paleozoic and Mesozoic strata are preserved. The strata in this block dip away from a structural high in Yellowstone National Park toward the Gardiner fault where they are locally overturned near the fault trace to form an asymmetric syncline (Fraser and others, 1969, p. 65).

Two of the major north-striking faults, the Mammoth and East Gallatin faults, bound the Sepulcher Mountain graben (fig. 2), a major geologic structure that extends from the Corwin Springs KGRA into Yellowstone National Park. The magnitude of displacement on each of these faults is more than 1,220 m (Ruppel, 1972, p. A53). The Mammoth and East Gallatin fault extensions may be traced far to the south into Yellowstone National Park (fig. 3). The Upper, Midway, and Lower Geyser basins, and Old Faithful lie along the inferred extension of the East Gallatin fault. This alignment of the springs implies that the thermal activity may be structurally controlled at depth by the East Gallatin fault system (Ruppel, 1972, p. A51). Similarly, the inferred southward projection of the Mammoth fault zone coincides with the area of intense thermal activity at Norris Geyser basin and this alignment led Ruppel (1972, p. A53) to suggest that the thermal activity there, too, is controlled at depth by the (Pliocene?) Mammoth fault.

Seismicity

The Corwin Springs area lies within the Intermountain seismic belt, a zone of pronounced earthquake activity that extends north from Arizona through Utah, eastern Idaho and western Wyoming, and ends in north-

western Montana (Smith and Sbar, 1974, p. 1205). In a study of hydrothermal and seismologic activity in southwestern Montana, Robertson and others (1975) reported that the hydrologic regime of the hot springs of the region are apparently controlled by fault zones rather than by lava flows or igneous intrusives. They observed structural alignments of hot-spring loci in southwestern Montana. One alignment of hot-spring activity lies along a curved 250-km line that trends N. 30° W. from Gardiner (through the Corwin Springs area) to Marysville, Mont. Earthquake activity is common along this northwest-trending lineament, and this relation led Robertson and others (1975) to suggest a positive correlation of seismic and hydrothermal activity.

Recent faulting

Surface expressions of recent faulting were noted by Fraser and others (1969, p. 74) in the basalt-covered benches above the Yellowstone River between Gardiner and Corwin Springs. Holocene fault activity in the form of fissures, normal faults, and tilted fault blocks is visible within and above the brittle Pliocene basalt, which was deposited on weak sedimentary beds in the drag zone of the downthrown block of the Gardiner fault. Fraser and others (1969, p. 74) noted the similarity of these minor structural features to those formed in the Hebgen Lake area, 40 km southwest of Gardiner (fig. 1), after the 1959 earthquake. Additional evidence for the reactivation of reverse motion along the Gardiner fault during Quaternary time exists between Gardiner and Corwin Springs where hot springs, evidently localized by the Gardiner fault, deposited large amounts of travertine in Pleistocene and Holocene time. Fractures within the Holocene travertine deposits verify recent

fault activity (Witkind, 1975). About 122 m of displacement along the Gardiner fault was measured near Gardiner by Fraser and others (1969, p. 68) where a small outcrop of Pliocene basalt north of the fault was found perched about 122 m higher than correlative remnants just south of the fault. In another example of recent activity, large landslides of Holocene age are prominent on the slopes of Sepulcher Mountain southwest of Gardiner. The movement of these materials into the Yellowstone River valley may have been aided by the many recorded earthquakes in the area (Fraser and others, 1969, p. 68).

The presence of recent faulting beneath Quaternary volcanics in Yellowstone National Park is suggested by lineaments (fig. 3) that reflect minor movements at depth which cause a shattering of the overlying rhyolite (Ruppel, 1972, p. A58). Ruppel suggests that these lineaments serve as the loci of many areas of thermal activity, with the pre-rhyolite faults providing the main channels through which solutions rise to the surface. The projection of north-south trending lineaments into the Gardiner-Corwin Springs area (fig. 3) from the central part of Yellowstone implies that related recent fault movements may have also occurred in the northern extensions of the fault zones since the latest major caldera collapse occurred in Yellowstone 600,000 years ago (Ruppel, 1972, p. A58).

The Gardiner, Mammoth, Reese Creek, and Mol Heron Creek faults (fig. 2) are all documented in a recent study of known and suspected active faults in western Montana (Witkind, 1975). These major faults, affecting the Corwin Springs area, are all considered to have a high susceptibility to earthquake activity (Witkind, 1975). Evidence thus

supports the existence of tectonic activity through Cenozoic time in the Gardiner-Corwin Springs area, although the major episodes probably occurred during Paleocene to Eocene time and in Pliocene time.

Distribution and age of young volcanic rocks

The Electric Peak stock, a granodiorite and quartz diorite body, 13 km south of Corwin Springs in Yellowstone Park (fig. 2), is the youngest (Eocene) exposed intrusive body of the area. Rhyodacite porphyry sills intrude Cretaceous rock from Electric Peak north to Cinnabar Mountain. These scattered intrusive bodies are too small to show at the scale of the geologic map shown in figure 2. In the Cinnabar Mountain area, the sills and their enclosing sedimentary rocks are deformed in a drag zone beneath the Gardiner fault, and on Electric Peak they have been strongly altered by the Electric Peak stock. The sills were evidently emplaced after deposition of the Upper Cretaceous Eagle Sandstone and Everts Formation, but before major movements on the Gardiner fault in late Paleocene or early Eocene time (Foote and others, 1961, p. 1165; Ruppel, 1972, p. 43).

Eocene volcanic rocks (fig. 2) occur only as scattered erosional remnants in the Corwin Springs-Gardiner area. They include dacitic breccia, trachyandesite flows, and andesitic breccia, all correlative with the Absaroka Volcanic Supergroup (Smedes and Prostka, 1972), of Yellowstone National Park. One of the local source areas for these volcanics was probably from a topographically higher region a few kilometres east of the Corwin Springs-Gardiner area. The Electric Peak area was another local source of Eocene volcanics. At Sepulcher Mountain, southwest of Gardiner (fig. 2), extrusive andesitic breccias

of the Absaroka Volcanic Supergroup are exposed in the Sepulcher Mountain graben and are temporally equivalent to the intrusive Electric Peak stock.

Younger volcanics are represented by remnants of Pliocene basalt flows which spread down the Yellowstone valley from Yellowstone National Park. These basalts occur in discontinuous exposures along the bench northeast of the Yellowstone River. Five separate flows were mapped by Fraser and others (1969, p. 49), with each flow measuring 12-18 m thick. The downstream limit of the basalt remnants may be approximately 4.4 km southeast of Corwin Springs, although probable correlatives have been mapped 14.5 km northwest of Corwin Springs on a bench above the Yellowstone River.

The most recent volcanic activity in the area is represented by remnants of a Pleistocene rhyolitic ashflow sheet known as the Yellowstone Tuff (Fraser and others, 1969, pl. 1) that originated to the south in Yellowstone National Park. Remnants of the ashflow are exposed near Jardine, but they are too small to be shown at the scale of the geologic map in figure 2.

Gravity Anomalies

A pronounced Bouguer gravity low with at least 45 mGals of amplitude (Blank and Gettings, 1974) coincides approximately with distribution of the Pleistocene rhyolite of the Yellowstone Plateau. This major anomaly could represent (1) a thick disc-shaped accumulation of rhyolite, (2) a thickening of the silicic crust, (3) a cool, silicic intrusive body, or (4) a hot magma chamber (Pakiser and Baldwin, 1961, p. B247). The widespread thermal manifestations in the area of the Yellowstone caldera support Pakiser and Baldwin's model, or a combination of the

above ideas, which includes the presence of hot rock. The top of the steep gravity gradient associated with this anomaly lies within the -210 mGal Bouguer contour shown in figure 4. The -210 mGal contour not only encloses the large negative gravity anomaly of the Yellowstone caldera, but has a striking extension well into the northern part of the park, away from the caldera rim (fig. 4). This anomalous extension extends from Norris to well north of Mammoth into the Corwin Springs KGRA (fig. 4). Eaton and others (1975, p. 789) refer to this north-trending zone as the Norris-Mammoth corridor. Almost all observed areas of young hydrothermal activity, plus all of the post-caldera Quaternary rhyolite vents (fig. 4), lie within or very near the -210 mGal contour. Eaton and others (1975, p. 789) suggest that while the -210 mGal contour in the Yellowstone caldera region delineates the intrusive source of the rhyolite and its related hydrothermal fluids, they believe the negative gravity anomaly of the Norris-Mammoth corridor to be (1) partly due to numerous small rhyolitic and basaltic intrusives, and (2) partly due to low-density rocks in a downdropped fault block.

The negative gravity anomaly over the northern end of the Norris-Mammoth corridor, in the Corwin Springs area (fig. 5), could conceivably reflect a small rhyolitic intrusion analogous to areas described in the Yellowstone caldera region. Geological evidence is more in favor of an anomaly produced by thick, low-density clastic and volcanic rocks filling the Sepulcher Mountain graben, with contrasting high-density, pre-Tertiary sedimentary and crystalline rocks bounding the downdropped fault block on the north, east, and west (fig. 2). The possibility of a significant hydrothermal reservoir within the thick sedimentary

Figure 4.--Boundaries of major geological and geophysical features in the Yellowstone plateau region. Hydrothermal areas are shown in stipple. Vents for rhyolite flows are shown as asterisks. The -210 mGal Bouguer gravity contour is shown by a heavy solid line. The top of the steep gravity gradient outlining the low-density mass of the Yellowstone region is shown by a dashed line. The outer limit of the ring fracture zone is represented by a light solid line. Data from Eaton and others (1975).

Figure 5.--Bouguer gravity map of part of the Corwin Springs-Yellowstone area. Contour interval, 2.5 mGal. Gravity stations shown as open circles. Abbreviations: L, closed gravity low; H, closed gravity high. Gravity data from Blank and Gettings (1974).

section of the Sepulcher Mountain graben awaits further study of the graben and its relation to the hydrothermal activity in the Corwin Springs KGRA. A factor that complicates the development of the potential geothermal resource is that much of the surface area, and thus much of its reservoir potential, lies within Yellowstone National Park.

Magnetic anomalies

Eaton and others (1975, fig. 4) illustrated areas of relatively low magnetic intensity (1) inside the Yellowstone caldera and (2) outside the caldera wherever thick Phanerozoic rocks are prominent. The scattered negative magnetic anomalies inside the caldera and within the Norris-Mammoth corridor are interpreted to be related to areas of past and present hydrothermal activity. Eaton and others (1975, p. 791) speculate that the negative anomalies originate from large volumes of rock at shallow depths in which ferrimagnetic minerals have been destroyed by hydrothermal activity. Within the caldera, however, they believe an additional component of the negative residual magnetic anomaly may be due to a large volume of hot rock and included magnetic minerals above their Curie temperature. They believe the location of hydrothermal areas to be controlled by a ring-fracture zone (fig. 4) and by a linear fault zone (fig. 3) related to rhyolitic intrusive and extrusive activity of Pleistocene age.

In the Corwin Springs KGRA, the areas of hydrothermal activity, as exemplified by hot springs and extensive travertine deposits, fall within the negative residual magnetic anomaly illustrated by Eaton and others (1975, fig. 4), which encompasses a large part of the Corwin

Springs KGRA as well as the Mammoth area inside Yellowstone National Park. The area of closure on this negative magnetic anomaly within the Corwin Springs KGRA coincides generally to the area of closure delineated by the gravity low within the same area (fig. 5). The interpretation of Eaton and others (1975, p. 791), which notes the association of the lowest magnetic intensities outside the Yellowstone caldera with Phanerozoic sedimentary rocks, supports the suggestion of thick sedimentary deposits within the Sepulcher Mountain graben. Thus, additional evidence favors the hypothesis of a thick sedimentary sequence coinciding with the northern end of the Norris-Mammoth corridor.

Thermal manifestations

Many areas along the Gardiner fault are veneered by hot-spring deposits of travertine that range in age from Pleistocene to the present (Fraser and others, 1969, p. 69). Although most of the travertine in the area was deposited before the Wisconsinan glaciation, some travertine is currently being deposited at LaDuke Spring and Bear Creek Spring.

One preglacial travertine deposit north of Gardiner occurs in layers up to 12 m thick. The deposit, occupying an area greater than 2 km², was deposited on a terrace of basalt, volcanic breccia, and Pleistocene gravels. The original deposit may have been as large as 6.4 km long and 0.8 km wide. Such a deposit would be comparable to the present travertine deposit at Mammoth Hot Springs in Yellowstone National Park, 6.4 km south of Gardiner. The hot-spring deposits near Gardiner formed from heated groundwater which rose along the Gardiner fault zone, dissolved Paleozoic and Mesozoic limestone at depth, and precipitated calcium carbonate at the surface during cooling. The

solubility of calcite has an inverse relationship to temperature, so the precipitation of travertine at the surface indicates only moderate temperatures at depth.

The hot springs at Mammoth have a similar origin. They issue from the Mammoth fault zone with heavy concentrations of calcium carbonate dissolved from limestone deep in the stratigraphic section (Keefer, 1971, p. 77). The chemical composition of the thermal waters from the Mammoth Hot Springs area (Rowe and others, 1973, p. 12-13) bears a marked resemblance to the chemistry of the hot springs in the Corwin Springs KGRA (table 1). Most other hot springs in Yellowstone Park are related to the ring-fracture zone of the Yellowstone caldera and, alternatively, issue from Cenozoic rhyolitic ashflow tuff or from Pleistocene rhyolite or glacial sediments derived mainly from rhyolite (Keefer, 1971, p. 77). These hot springs deposit siliceous sinter, whereas the hot springs of Mammoth and the Corwin Springs-Gardiner area are noted for their travertine deposits and rely on major fault systems not related to the Yellowstone caldera for their water circulatory systems.

Table 1.--Chemical analyses of thermal waters from LaDuke and Bear Creek hot springs (analyst, J. M. Thompson).

	pH	ppm SiO ₂	ppm Ca ⁺⁺	ppm Mg ⁺⁺	ppm Na ⁺	ppm K ⁺	ppm Li ⁺	ppm HCO ₃ ⁻	ppm SO ₄ ⁻⁻	ppm Cl ⁻	ppm F ⁻	ppm B
LaDuke	7.81	46.8	310	65	238	24	0.27	306	1210	47	0.8	0.5
Bear Creek	7.33	29	310	91	113	42	0.40	1107	688	10	0.35	0.93

Robertson and others (1975), in finding silica solubility temperatures of some southwestern Montana hot springs to be as high as 115°C, suggested an origin by circulation of surface waters to depths of 2-4 km through permeable breccia along major fault zones, taking into

account the normal geothermal gradient of 30°C/km characteristic of southwestern Montana. The surface waters, when heated by thermal conduction at depth, rose along the fault zones to be discharged as surface springs.

Chadwick and Kaczmarek (1975) suggest reliability is poor in applying the Na-K-Ca geothermometer to determine base temperature values of hot springs in Montana. This conclusion resulted from observations that (1) reaction of thermal waters with extra-reservoir rock and (2) mixing of thermal waters with near-surface, cold ground waters were major contributors affecting variations of Na, K, and Ca cation ratios from initial Na, K, and Ca equilibrium ratios established within the hydrothermal reservoir at depth. Those investigators placed more credence upon the silica geothermometer except in cases involving (1) severe ground-water dilution or (2) shallow geothermal systems in carbonate rocks. In many cases in southwestern Montana these conditions may, and probably do, coexist.

Corwin Springs is a small community located on the Yellowstone River about 11 km northwest of Gardiner, Mont. (fig. 2). The most prominent hot spring, named LaDuke Spring, is 2.8 km southeast of the Corwin Springs community on the east side of the Yellowstone River (fig. 2). The spring issues from brecciated quartzite and is currently depositing travertine. The discharge rate of LaDuke Spring is 380 l/min and the surface water temperature is 65°C. The Na-K-Ca geothermometer temperature is 76.8° and the silica-geothermometer temperature, based on equilibrium with chalcedony, is 68.7°C (table 2).

The only other hot spring in the KGRA is Bear Creek Spring, 2.6 km east of Gardiner, near the junction of Bear Creek and the Yellowstone

River (fig. 2). Outcrops near the spring are Precambrian metasediments and Mississippian (Madison) limestone. The spring is currently depositing travertine. The discharge rate of Bear Creek Spring is only about 4 l/min and the surface temperature is only 32°C (G. Mowat and H. Owen, written commun., 1974). The large amount of locally deposited travertine indicates that flow rates were probably greater in the past. This is supported by Waring's (1965, p. 32) report of a previously measured flow rate equivalent to 114 l/min. The Na-K-Ca geothermometer temperature of Bear Creek Spring is 87.2°C and the silica-geothermometer temperature, based on equilibrium with chalcedony, is 46.7°C (table 2).

Chalcedony probably controls the silica in solution and the chalcedony temperature should be the best estimate of subsurface temperature for LaDuke and Bear Creek Springs (M. J. Reed, written commun., 1976). An anomalously high Na-K-Ca temperature for each spring (table 2) is probably due to the precipitation of calcite at the surface.

Table 2.--Subsurface temperatures from chemical indicators as determined by program CHEMTEMP by M. J. Reed (written commun., 1976). All temperatures in degrees Celsius.

	LaDuke Spring (65°C) ¹	Bear Creek Spring (32°C) ¹
1. Quartz temp (conductive)-----	98.8	78.0
Quartz temp (adiabatic)-----	99.9	81.8
2. Chalcedony temp-----	68.7	46.7
3. Cristobalite temp-----	48.5	28.4
4. Amorphous silica temp-----	-16.6	-34.1
5. Log (Na/K) temp-----	184.7	414.2
6. Log (Na/K) + 1/3 log (Ca ²⁺ /Na) temp---	162.9	223.2
7. Log (Na/K) + 4/3 log (Ca ²⁺ /Na) temp---	76.8	87.2

Notes:

No. 1 (conductive) allows no steam loss; No. 1 (adiabatic) allows for increase in concentration from boiling.

Nos. 2, 3, and 4 may control the silica in solution if they are present.

No. 5 assumes equilibrium between the solution and alkali feldspars above 150°C.

No. 6 applies only if No. 7 is above 100°C.

No. 7 applies only below 100°C.

Abbreviations: temp (temperature)

¹Measured temperature of spring water at surface.

Conclusions

Geological, geophysical, and geochemical criteria which contributed to the delineation of the Corwin Springs Known Geothermal Resources Area are summarized in the following list:

1. The Corwin Springs KGRA lies just to the north of intense geothermal activity and significant Pliocene and Pleistocene volcanism in Yellowstone National Park.
2. The Sepulcher Mountain graben, a major geologic structure and potential geothermal reservoir, extends from the Corwin Springs KGRA into Yellowstone National Park. The north-trending normal faults of the graben are influential in localizing thermal activity in Yellowstone National Park and, together with the Gardiner fault, may influence geothermal activity along the northern perimeter of the graben in the Corwin Springs KGRA.
3. A negative gravity anomaly is centered over the northern end of the Sepulcher Mountain graben in the Corwin Springs KGRA. Such a feature is best explained by thick sedimentary fill within the downthrown block.
4. A negative residual magnetic anomaly encompasses a large part of the Corwin Springs area and coincides generally with the negative gravity anomaly in the area. This geophysical feature is compatible with a thick sedimentary section in the Sepulcher Mountain graben.
5. The Corwin Springs KGRA is located within the Intermountain seismic belt and is situated along a northwest-trending lineament characterized by associated hot-spring and earthquake activity. Recent tectonism within the area is demonstrated by geologic

evidence of Pleistocene and Holocene faulting.

6. Two known hot-spring localities, actively depositing travertine, exist within the KGRA. The precipitation of calcite at the surface indicates only a moderate temperature in the reservoir. The geological environment of the Corwin Springs KGRA is similar to that of the Mammoth area in Yellowstone National Park, but differs greatly from the geothermally more significant geyser areas farther to the south near the Yellowstone caldera.
7. Although the information available gives an indication of the nature of the hydrothermal system, deep drilling is necessary to assess the temperature, permeability, and available fluid for geothermal development.

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