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Black Rock Desert

(updated 2012)

Geologic setting: The Black Rock Desert extends 100 miles SW-NE between Gerlach and Quinn River Crossing, with areal coverage of ~400 square miles. The desert's black rock originated in an island arc chain, rather than basalt flows. The resulting mixture of volcanic rock and limestone is fossiliferous (Bureau of Land Management, 2011). The Double Hot Springs—Black Rock Hot Springs fault appears to join a north-northeast lineament at Soldier Meadows Hot Springs. The 6-million-year-old basalts along this lineament are the youngest in the Black Rock Desert (figure).

Geothermal features: Numerous geothermal features line the range-front regions of Black Rock Desert, particularly along the western margin of the Black Rock Range and eastern margins of the Granite Range. There are eight distinct geothermal zones within the desert travelling counter-clockwise: Gerlach, Trego, Sulphur, MacFarlanes, Pinto, Soldier Meadow, western Black Rock Range, and Hualapai Flat.

Two gradient holes drilled in the central Black Rock Desert (within 4.8 km of Black Rock), an area unaffected by thermal groundwater, indicate that heat flow in the Black Rock Desert area is no more than two heat flow units (HFU). This value is not unusually high for the northern Basin and Range province (Olmsted et al., 1975).

Gerlach

The Gerlach thermal area is located at the southern terminus of the Granite Range, in the southwestern Black Rock Desert (figure). It includes two major groups of springs: Great Boiling Springs in Secs. 10, 15, T32N, R23E ~1.3 km northwest of Gerlach, and Mud Springs in Sec. 16, T32N, R23E ~1.8 km west of Gerlach.

Gerlach lies along a deep-seated, north-south fault zone extending from Winnemucca Lake to High Rock Lake (Sperandio and Grose, 1976), and hot spring clusters emerge from northeast-striking range-front faults (figure). Springs issue from unconsolidated lacustrine and alluvial deposits, associated with hydrothermally-altered granodiorite (figure). Some alluvial faults represent rupture of incompetent materials in response to movement in the underlying granodiorite (Olmsted et al.,

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1975). An upfaulted block of altered granodiorite between Great Boiling Springs and the Granite Range may expose part of the ancestral Gerlach Hot Spring system. Additional geophysical studies, not detailed here (Grose and Keller, 1974a, 1975b; Christopherson et al., 1977; Long et al., 1977), may be useful in structural and geologic interpretations.

The southern Granite Range consists of relatively uniform medium-crystalline granodiorite with scattered, elongate inclusions of diorite or gabbro. Thermal water has probably been in contact with granodiorite and related plutonic rocks of the Granite Range throughout its path, from high-mountain recharge to spring upwelling (Olmsted et al., 1975).

Great Boiling Springs: The springs were first described by Fremont (1845) who described them as "the most extraordinary locality of hot springs we had met during the journey." He reported that one large, circular pool, presumably the Great Boiling Spring, was entirely filled with boiling water which “boiled at irregular intervals with great noise”. Fremont measured temperatures up to 97.7°C. The area is also known for its mud volcanoes and mud vent activity (Russell, 1885, p. 52; White, 1955b). According to White (1955b), mud volcanoes have erupted clots of mud to 30 m or higher. They are characterized by sporadic intervals of activity separated by longer intervals of quiescence.

Great Boiling Springs were used extensively for bathing (figure), though some pools are too hot for swimming: a 19-year-old woman was scalded to death in 1973, an indication of the danger inherent in geothermal areas. The Gerlach General Improvement District built a bath house using geothermal fluids in 1989. The facility was planned for tourists and local residents, but never received a health department permit due to plugged water filters (sediment from the well). No bathing facilities are available at present (2012).

Geothermal groundwater apparently extends under the town, and two Gerlach homes use geothermal wells for space heating. The water in one well is reported to be 35-36°C (unpub. data, Nevada Division of Minerals). Mud Springs (figure) have mainly been used for stock watering and irrigation.

Gerlach-area springs and pools range in temperature to 97.7°C (Grose and Keller, 1975b), and shallow subsurface measurements exceed 120°C (figure). Mariner et al. (1974) have estimated the reservoir temperature at 167°C (quartz geothermometer) and 175°C (Na-K geothermometer). Springs primarily deposit siliceous sinter, and total dissolved solids are high relative to hot springs in northern and central Nevada (Mariner et al., 1974). Active deposition of native sulfur is reported at Great Boiling Spring (Matlick and Ehni, 1995). Reports of a borax works at Gerlach Hot Springs are believed to be false (Papke, 1976), as there is little aqueous boron and no borate deposits in the vicinity.

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Temperature-gradient holes were drilled by Cordero/Sunoco Energy Development Co. in 1972 (183m), by the USGS in 1973 (shallow), and by ESI/San Emidio Resources, Inc. in 1993 (914m). Additionally, ESI/San Emidio Resources, Inc. drilled three temperature gradient holes to depths of 243 to 457 m and one observation/production well to 914 m, a continuation of exploration by Benoit and others (1995, p. 156). The maximum well temperature was 129.4ºC at 150-175 m depth, north of the Great Boiling Spring. Roughly 185 m southeast, a Sunoco gradient hole intercepted 124.4ºC temperatures at 38 m depth (Matlick and Ehni, 1995).

Leasing information: As of 2010, Sierra Geothermal holds 1662 acres of geothermal leases near Gerlach. No further information is available about this project (http://www.unr.edu/geothermal/explactivity.htm).

Trego

Trego Hot Springs: Trego Hot Springs, located ~15 miles NE of Gerlach (Sec. 31 T34N, R26E), were measured at 86°C (Mariner et al., 1974; Grose and Keller, 1975b). The springs have been called Butte Hot Springs or Trego Hot Springs, and are clearly visible on airborne thermal infrared images (Grose and Keller, 1975b). Various chemical geothermometers indicate a thermal reservoir between 120-128°C (Mariner and others, 1974; Grose and Keller, 1975b). Trego Hot Ditch, adjacent to the hot springs, has a reported temperature of 31.1ºC and is used for bathing (Williams, 1996, p. 20-21). Trego Hot Springs are associated with a fault extension from the western Black Rock Range fault zone (see figure; L. T. Grose, written commun., 1977). The geology of Trego Hot Springs is discussed in Davis (1983).

Garrett Ranch: Warm water wells are located at Garrett Ranch (Sec. 10, T33N, R25E), about 5 km southwest of Trego Hot Springs and 3 km southwest of the Trego railroad siding. These wells have temperatures of up to 52°C (Sinclair, 1963). Grose and Keller (1975b) report a 22°C measurement for Coyote Spring, 2 km north of the ranch, though Sinclair (1963) reported a 16°C temperature. Coyote Spring is dry according to the Trego 7.5-minute topographic map (1980).

Leasing information:

N/A

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Sulphur

The Sulphur district is an old sulfur-mining area with minor associated mercury. A ca. 4 Ma hot-springs type gold deposit (Hycroft Mine) has been mined in the district since 1987 (Ebert et al., 1996). White (1955a) reported a strong odor of H_2S in short adits of the Devil's Corral workings ~5 km northeast of Hycroft Mine (north edge of Sec. 17 (protracted), T35N, R30E). Willden (1964, p. 111) suggested that sulfur was deposited by hot springs during the Pleistocene, when Lake Lahontan reached full extent and groundwater levels were high. However, it seems more likely that sulfur was deposited during the ca. 4 Ma gold mineralization and steam-heated hydrothermal alteration.

Sulphur Springs: A mild thermal anomaly was identified near Sulphur by the U.S. Geological Survey NWIS database, termed "warm spring in Sulphur" (U.S. Geological Survey, 2005). Sulphur Springs, located ~2.2 km east of Sulphur, were measured at 14.9°C and 19.4°C during a UNR sampling trip (Penfield et al., 2011).

<u>Leasing information:</u> Sulphur, a former Sierra Geothermal Power property, reverted to RAM Power during SGP's acquisition by RAM in 2010. No information is available on this 3,457 acre project.

In 2010, Caldera Geothermal acquired a 2,560 acre property near Sulphur. No further information is available.

MacFarlanes

MacFarlanes Bath House Spring: MacFarlanes is a small group of springs and seeps that form a travertine mound 4 m high and 180 m long, north of Sulphur (Sec. 27, T37N, R29E). The springs are currently (2002) flowing from the west end of the east-west trending travertine mound. They appear to have been active over the last 15,000 to 60,000 years (Sibbett et al., 1982). MacFarlanes may be controlled by a split or bend in a northeast-trending normal fault with over 400 m of displacement (Sibbett et al., 1982; Swanberg and Bowers, 1982).

The highest recorded temperature was 76.6°C (Sinclair, 1963) until August 2002, when UNR staff measured springs from 69 - 78°C. The UNR analyses give chalcedony geothermometers of 108-109°C, which suggest (1) relatively cool source water or (2) loss of SiO_2 during fluid ascent by dilution or precipitation. Sibbett et al. (1982) estimated the reservoir temperatures to be ~140°C (Na-K-Ca geothermometer), though chemical data were not reported. Sibbett's Na-K, quartz, and chalcedony geothermometers give temperatures between 80 to 120°C, though, more in line with the 2002 chalcedony estimates.

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The maximum recorded temperature during gradient drilling was 81.1ºC at 610 m. Data from shallow and intermediate-depth drill holes was modeled to predict a maximum temperature in the 150ºC range (Swanberg and Bowers, 1982). The area of geothermal activity is confined to a structural block between (1) a northeast-striking fault through the hot springs and (2) the north-striking faults bounding the western Jackson Mountains ~4 km to the east. The proposed water flowpath travels downward along the Jackson Mountains faults, and emerges at the MacFarlanes-area normal fault (Swanberg and Bowers, 1982).

Leasing information:

N/A

Pinto

Pinto Hot Springs: The second highest spring temperatures in Humboldt County are found at Pinto Hot Springs 1.5 km north of Pinto Mountain. Reported temperatures are 93-94°C for the eastern and western springs, which are ~1.5 km apart. The water analyses are also quite similar, indicating a close hydrologic connection. These springs are located in Secs. 17 and 19, T40N, R28E on the Pinto Mountain 7.5-minute Quadrangle map. Location data in older references are confused owing to the irregular nature of the local land grid.

The springs are surrounded by a small quartz monzonite outcrop (Willden, 1964, plate 1) in the Pinto Mountains, a low-lying range of mafic Tertiary volcanics. The reservoir is estimated at 162-165°C based on quartz geothermometry (Mariner et al., 1974), consistent with later Na-K-Ca geothermometers of 173-176ºC (Mariner et al., 1983, p. 105; White and Heropolous, 1983, p. 50). Travertine and siliceous sinter are interlayered in the spring deposits (Hose and Taylor, 1974), and cinnabar has been reported (George Berry, in unpubl. report to Sun Oil Co., 1963). The BLM also reports anomalous barium, molybdenum, zinc, and tungsten in the area (Olson, 1985). Batzle et al. (1976) give telluric profiles for Pinto Hot Springs.

Leasing information:

N/A

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Soldier Meadows

Soldier Meadows Hot Springs**:** The hot springs in Soldier Meadows are generally in and near Sec. 23, T40N, R24E. The area is named for the soldiers stationed at Camp McGarry, a U.S. Army field camp from the 1860s. Hose and Taylor (1974) describe a N30-35°E lineament that extends 105 km from Soldier Meadows northeast to Oregon. The lineament may have been a fault through early Tertiary terrain (figure; Hose and Taylor, 1974). Any tectonism that occurred after the Oligocene and Miocene volcanic rocks were deposited resulted in modest displacement.

Grose and Keller (1975b) found 49 thermal features at Soldier Meadows, each thought to be a distinct spring, using infrared imagery. Some warm springs were noted where no thermal springs had been reported in the literature. Grose and Keller found a bimodal temperature distribution for Soldier Meadows springs at ~21°C and ~52°C. Spring discharge was estimated to be 1890 L/min. The hottest measured spring is a 55°C gaseous spring in Sec. 19, T40N, R25E, sampled in August 2002.

Mariner et al. (1974) found a considerable number of 43.3-48.9°C springs along a flowing creek, which averaged 37.8°C in spring 1973. The Na-K-Ca geothermometer (65°C) is near measured spring temperatures, though chalcedony geothermometry is slightly higher at 87°C based on 2002 UNR sampling.

Leasing information:

N/A

Western Black Rock Range

Double Hot Springs, Casey Springs, Black Rock Hot Springs: A number of hot springs are located in alluvium along the west side of the Black Rock Range (figure). These springs are normally 1.6 km or less from bedrock outcrops, and align north-south over 11 km from Black Rock Point to Double Hot Springs (Hose and Taylor, 1974). A hot spring and warm well are also present in Sec. 10, T37N, R26E, 8-9 km north of Double Hot Springs (Waring, 1965; Olmsted et al., 1975). The known extent of the thermal anomaly is about 19 km.

The springs lie along a major range-front fault 56 km long, from Black Rock Point to Soldier Meadows. No data are available for the northern portion of the boundary fault. South of Black Rock Point, the fault crosses Black Rock Desert playa (figure) and joins with the Trego Hot Springs-area

fault (L.T. Grose, written commun., 1977). Holocene displacement on this fault may be related to a 1936 earthquake of magnitude 4.1 (Hose and Taylor, 1974).

Quartz geothermometry gives consistent values for springs at both ends of the fault. The estimated aquifer temperature at Double Hot Springs is 140°C, and trace amounts of travertine and siliceous sinter are reported (Hose and Taylor, 1974). Water temperatures along the range-front fault are usually 54.4 to 76.7°C, though temperatures have been reported up to 94.4°C (boiling for this elevation) at the southernmost spring.

Higher concentrations of dissolved solids are reported in springs near the south end of the fault. This is believed due to contamination of the waters by more saline brines that collect in low areas of the Black Rock Desert (Hose and Taylor, 1974). The hot springs along this zone were used for drinking, bathing, and stock watering by wagon-train emigrants (Paden, 1949) on the Applegate-Lassen Trail. Today they are used for stock watering and irrigation.

Jackson Reservoir: Water wells on the west side of the Black Rock Desert, 6-12 km northeast of Double Hot Springs, are also reported to be warm. The wells are in Secs. 10, 11, and 26, T37N, R25E (Sinclair, 1963; Grose and Keller, 1975b), and range from 36.1ºC and 39.4ºC for the northerly wells to 25.6ºC and 22.2ºC for the southerly ones. Wagner Spring (SE¼ NW¼ Sec. 4, T37N, R25E), located about 2.5 km north of the Sec. 11 wells, is also reported to be warm (Williams, 1996, p. 16).

Leasing information:

N/A

Hualapai Flat

Hualapai Flat is situated 10 miles north of Gerlach, in the westernmost arm of the Black Rock Desert. The faults at Hualapai Flat may join a regional, deep-seated fault zone that extends northward 64-72 km from the western Selenite Range to High Rock Lake, via Gerlach Hot Springs and western Hualapai Flat. North- and north-northeast-trending normal faults cut all lithologic units, and late Quaternary fault scarps and tectonic cracks transect the floor of Hualapai Flat, which is a small structural-topographic basin (Sperandio and Grose, 1976). Many of the normal faults occur along western Hualapai Flat, with their eastern sides downthrown. Displacements appear to be dip slip, amounting to meters to tens-of-meters on any one fault, but totaling thousands of meters

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between the Tertiary volcanic rocks and Cretaceous granodiorite along the southwest margin of Hualapai Flat (Grose and Keller, 1975b).

The oldest rocks in the Hualapai Flat area are Permian and Triassic metavolcanic and metasedimentary rocks (figure), tentatively correlated by Bonham (1969) with the Happy Creek volcanic series in Humboldt County. Cretaceous granodiorite intrudes the sequence in the Granite Range south of Hualapai Flat. The Tertiary is represented by a sedimentary unit of tuffaceous sands and air-fall tuffs, overlain by finely crystalline basalt. Elsewhere, andesitic to rhyolitic flows and tuffs underlie the basalt. Grose and Keller (1975b) also described a number of different Quaternary units.

Hualapai Flat underwent rifting, normal faulting, and subsidence in the late Quaternary (Grose and Keller, 1975a). These features indicate extension of Hualapai Flat, generally along a northwest-southeast axis. The Fly Ranch thermal system developed under this extensional tectonic regime: the major spring area is on the upthrown side of a 4.4-km-long fault scarp with maximum relief of 10 m. Sperandio and Grose (1976) believe the Fly Ranch anomaly is due to deep hydro-circulation along fractures where the north-south fault zone intersects a major northwest-trending fracture system. These fractures terminate at the northern Granite Range west of Hualapai Flat.

Cane Springs: Cane Springs are located on Donnelly Peak's southern flank, 10 km north of Hualapai Flat. A fault-bounded granodiorite covers western Donnelly Peak, and an unnamed phyllitic schist and quartzite unit covers the southern peak. High-grade gold ore was found as lenses within the granodiorite intrusive (Vanderburg, 1938).

Cane Springs were reported warm, but UNR sampling found 18°C maximum temperatures in July 2008. Samples taken in 1961 suggest reservoir temperatures of 57°C Ca-Na-K (Fournier, 1981) and 94°C chalcedony (Fournier, 1981).

Fly Ranch: Fly Ranch (or Ward's) Hot Springs are located in Hualapai Flat about 24 km north of Gerlach (mainly in Secs. 1, 2, T34N, R23E). The springs are the largest in northwestern Nevada, discharging into 30 to 40 pools over 30 hectares. The surface flow is used for irrigation (Sinclair, 1962). Spring deposits at Fly Ranch reportedly consist of siliceous sinter and calcareous travertine (Sinclair, 1962).

A shallow well (the "Geyser Well") has been discharging steam and boiling water since 1916, when it was drilled. The water is highly mineralized and precipitated a travertine tower 5 meters high. Nearby Fly Ranch Geyser is not a natural phenomenon either, but results from a leaking geothermal

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well drilled in 1964. The red and green colors of the travertine represent two species of thermophillic algae (Flynn et al., 1979).

Water temperatures in wells and springs range from cold to over 104.4°C. Mariner and others (1974) reported a 125°C minimum reservoir temperature using the silica geothermometer. In 1964, Western Geothermal, Inc. drilled a 300m deep well (Fly Ranch No. 1), and in 1979 Sunoco Energy drilled a 1589-m large-diameter geothermal well (Holland Livestock Ranch No. 1-2-FR in NE¼ NE¼ Sec. 2, T34N, R23E). The Holland Ranch well reached temperatures of 94ºC at 365 m (GeothermEx, 2004, Fig. FLY00-2).

Granite Creek Ranch: A thermal area of unknown extent is present in southern Hualapai Flat ~1.5 km south of Granite Creek Ranch (Sec. 35, T34N, R23E and Sec. 2, T33N, R23E) and ~9 km south of the Fly Ranch geothermal area. A well reportedly hit hot water in this area ca. 1917, and a tall steam plume was visible for miles (Trexler and Stewart, 2003). In 1964, Western Geothermal, Inc. drilled a 244-m geothermal test well and abandoned it due to shallow high temperatures and blow out issues (Grose and Keller, 1978; GeothermEx, 2004). In 1972, a 140.8 m well was drilled by Cordero Exploration near the abandoned hot well. A temperature of 105ºC was reported at 40 m depth in alluvium, with a temperature reversal below 46 m, to 93.6ºC at 140 m depth (Dennis Trexler, written commun., 2003, from George Berry files). This reversal suggests lateral flow of thermal water above 46 m depth. Well temperatures are constant (93.5ºC) within a granodiorite layer 116 m deep; thermal waters may have migrated there along a concealed conduit, probably a fault (Olmsted et al., 1975, p. 128). Hot water was also reported from a U.S. Geological Survey test hole in NW¼ Sec. 2.

Leasing information: In December 2009, U.S. Geothermal, Inc. announced that it had acquired assets from two locations, San Emidio Desert and Granite Creek Ranch. The Granite Creek assets are 5,414 acres of BLM leases about 10 km north of Gerlach (Shevenell et al., 2010).

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