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ON THE OUTCROP

COAL CLINKER SITE IN THE LATE CRETACEOUS BLACKHAWK FORMATION, CASTLE GATE, UTAH, USA

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LOCATION

Traveling on U.S. Hwy 6, turn northeast onto U.S. Hwy 191 toward Duchesne, UT. Travel approximately 1.3 miles. There is a pull out on the left, just past the entrance to the Castle Gate Cemetery (on left). The clinker outcrop is located across the road at **39°43'59"N 110°51'02"W** (figs. 1 & 2). The road cut is approximately 18 m (56 ft) high and 50 m (164 ft) wide (fig. 3).

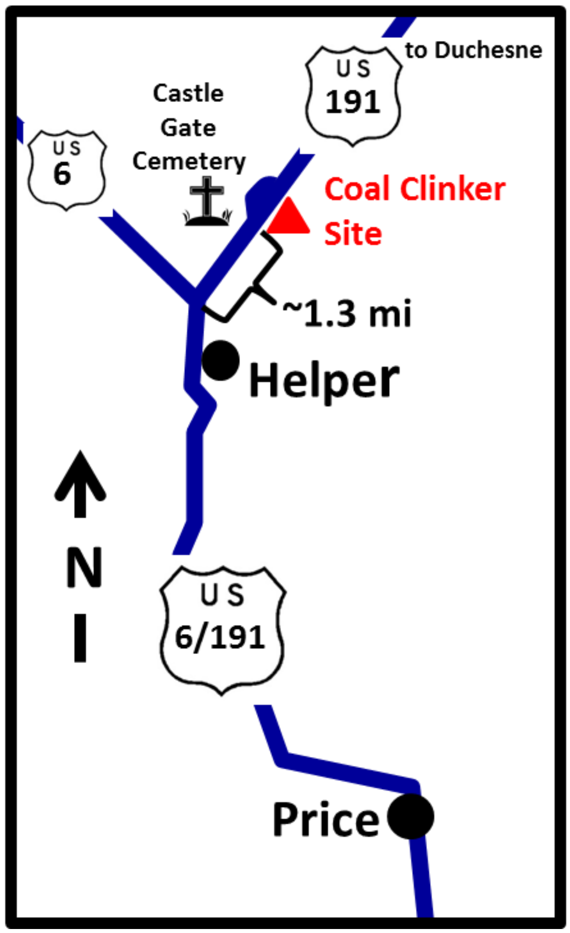

Figure 1. Location map of clinker site near Helper, UT along U.S. Hwy 191.

Figure 2. Google Earth image of clinker outcrop along U.S. Hwy 191.

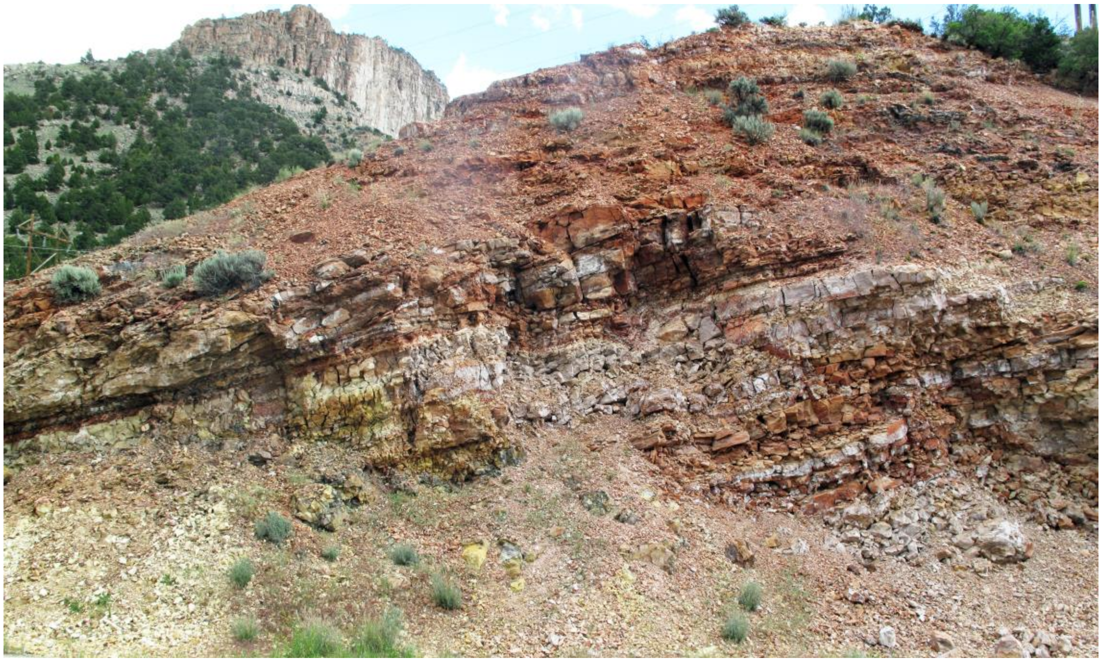

Figure 3. Looking southeast from U.S. Hwy 191 pullout toward clinker outcrop.

SIGNIFICANCE OF SITE

The buildup of heat from the interaction of coal and oxygen can result in the spontaneous combustion of coal. Erosion and mining exposes coal seams leaving them susceptible to the possibility of lightning strikes and human error (Masalehdani, *et al.*, 2007). The oxidation of coal results in the formation of gases, typically CO and CO_2 and combustion occurs when the ignition temperature of coal is reached (Gaweda, *et al.*, 2013). Ignition temperature of bituminous coal is approximately 455°C (850°F); anthracite - 600°C (1112°F); lignite - 526°C (979°F). Coal fires produce intense heat, reaching temperatures of more than 1000°C (1832°F) (fig. 4), which, in turn, can metamorphose the overlying and underlying host rock (fig. 5). For continued burning, coal fires require oxygen and an escape vent for the release of gases. Burning causes subsidence as the coal is consumed resulting in fissures, which serve as chimneys and provide a two-way exchange of oxygen and combustion gases (fig. 6). Coal seam fires may burn for decades, or even centuries (Stracher and Taylor, 2004).

Figure 4. For almost a century, hellish fires have been burning deep underground in Jharia, India. Beginning in 1916, as a result of coal mines that were improperly shut down, fires have burned through more than 41 million tons of coal. There are approximately 70 fires currently burning in the Jharia coalfield, the largest coal mine fire complex in the world. Photo from**:** Underground Coal Fires in India, *Mining Global*, **http://www.miningglobal.com/miningsites/1406/PHOTOS-Underground-Coal-Fires-in-India**

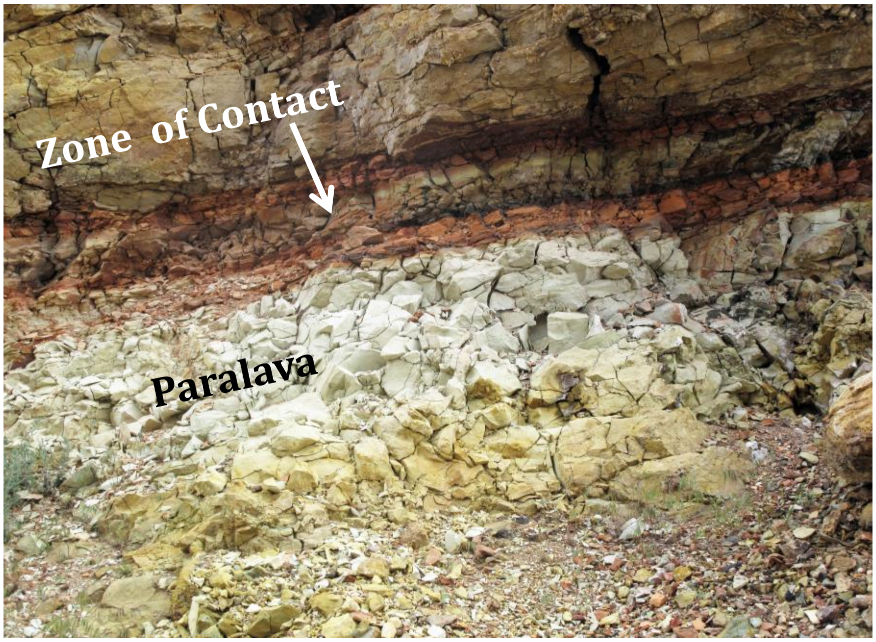

Figure 4. Upper zone of contact metamorphism.

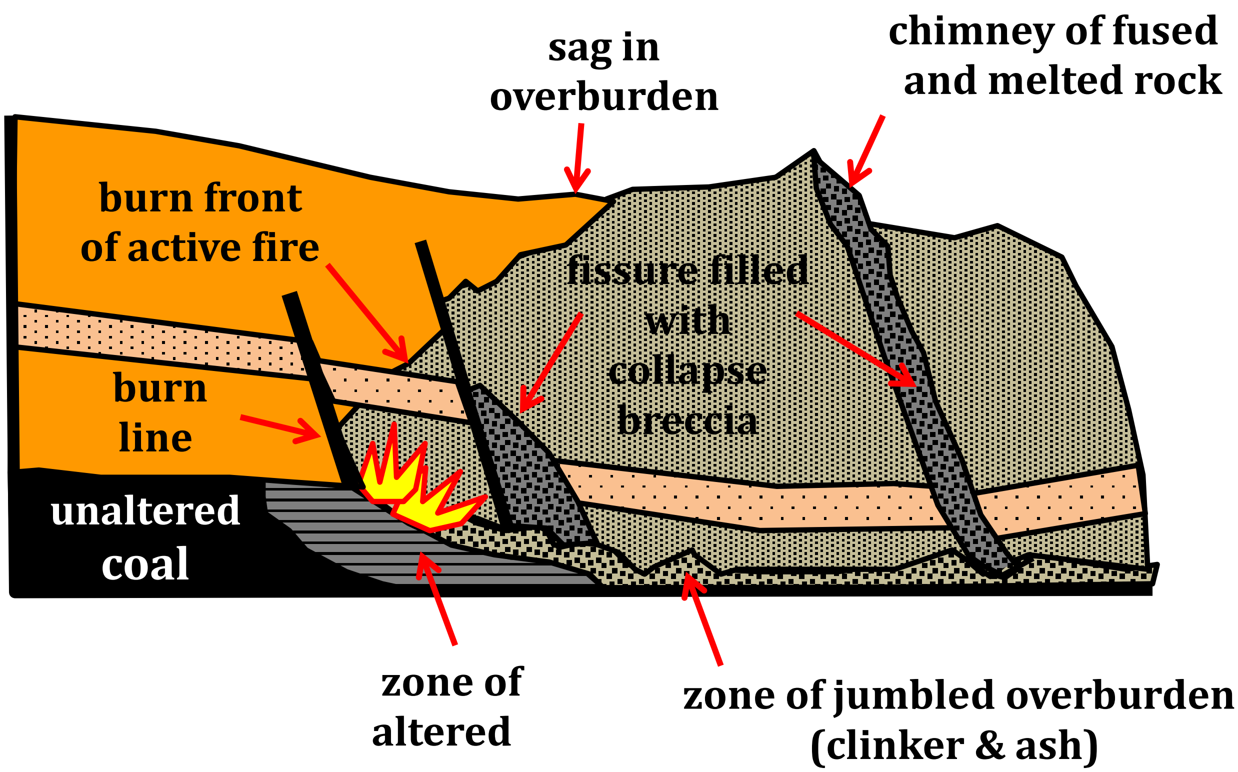

Figure 5. Cross section of typical coal fire. Transition from unburned coal to burn zone results in a downward collapse of overlying strata. Normal faulting (fissures) act as chimney structures allowing for two-way gas exchange between coal fire and the surface. Adapted from Zilberfarb (fig. 1, 2014).

When the sedimentary host rock is heated as a result of coal seam fires, the host rock is pyro-metamorphosed (high temperature/ low pressure) resulting in the formation of *paralava*, a low-grade metamorphic rock formed adjacent to coal seams (Masalehdani, *et al.,* 2007).

Coal fires are constructive in the sense that the paralava (coal clinker) is used for landscaping and construction. Additionally, coal fires do alter the local topography by creating sinkholes, valleys, and slump blocks (Stracher, 2007). However, most people consider coal fires to be destructive because a valuable resource is consumed; there is a potential loss of floral and faunal habitats; and pollution in the form of carbon dioxide (CO_2), benzene (C_6H_6), toluene (C_7H_8), and other toxic gases. The per-annum global emissions of the components in coal fire gases has never been quantified (Stracher, 2007). Metals such as lead, mercury and copper can be mobilized and leached into the groundwater, posing additional health risks (Zilberfarb, 2014).

SITE DESCRIPTION

The Castle Gate site is in the Upper Cretaceous Blackhawk Formation within the Book Cliffs coalfields. Coal burns of recent age are common in the coal outcrops of the Upper Cretaceous Blackhawk Formation throughout the Wasatch Plateau of east-central Utah. Zilberfarb (2014) describes several additional sites in the area. It is not uncommon to find burned coal extending 61 m (200 ft) into the subsurface from the outcrop. Coal mining has intersected clinker beds of burned coal in numerous mines in the area (Fry, 1991).

The average Blackhawk coal is characterized as high-volatile, relatively high BTU, coal containing low sulfur, ash, and moisture (Eves, 1991). Zilberfarb (2014) states that the Castle Gate site represents fire temperatures higher than at other sites in her study – exceeding 1475°C (2687°F). Temperatures were determined by comparison between phase diagrams and observed mineralogy in XRD spectra. High temperature minerals observed included tridymite and cristobalite (SiO_2) – both are high temperature polymorphs of silica.

Although the coal seam is not visible, it is likely a thick, which would allow for a longer, hotter, continued burning (Zilberfarb, 2014, p. 46). Zilberfarb (2014) also recognizes an uncollapsed antiform, which would result in a cavity in the area where the coal has burned away.

The coal fire resulted in the formation of colorful clinker (paralava) in a rainbow of colors: varying shades of yellows, reds, whites, black, greys, blue-green, and greens (fig. 6). Vesicular clinker occurs in the black and green shades.

Figure 6. Colorful paralava (coal clinker) in varying shades of yellows, reds, whites, black, greys, blue-green, and greens.

GENERAL STRATIGRAPHY

Significant coal resources are located in the southern Wasatch Plateau, which is located in central Utah to the west of the San Rafael Swell in parts of Emery, Sevier, and Sanpete Counties. The majority of thick, continuous coal beds occur within the Late Cretaceous Blackhawk Formation. The lower Blackhawk coal zone contains seven major coal beds, each of which can be traced to, and correlated with, distinct marine shoreface sandstone within the Star Point Sandstone Formation (fig. 7). The Blackhawk and Star Point Sandstone represent marine, marginal-marine, lagoonal, and continental depositional environments and were first studied by Spieker (1931). Spieker (1931) recognized the Star Point Sandstone as a beach and near-shore deposit that inter-fingered eastward with marine shales of the Mancos Shale, and described the Blackhawk as continental rocks deposited in a low-lying coastal plain with rivers, swamps, and lagoons. Additional studies include those of Ryer, 1981, 1982, 1984; Ryer and Langer, 1980; Methany and Picard, 1985; Bunnell and Hollberg, 1991.

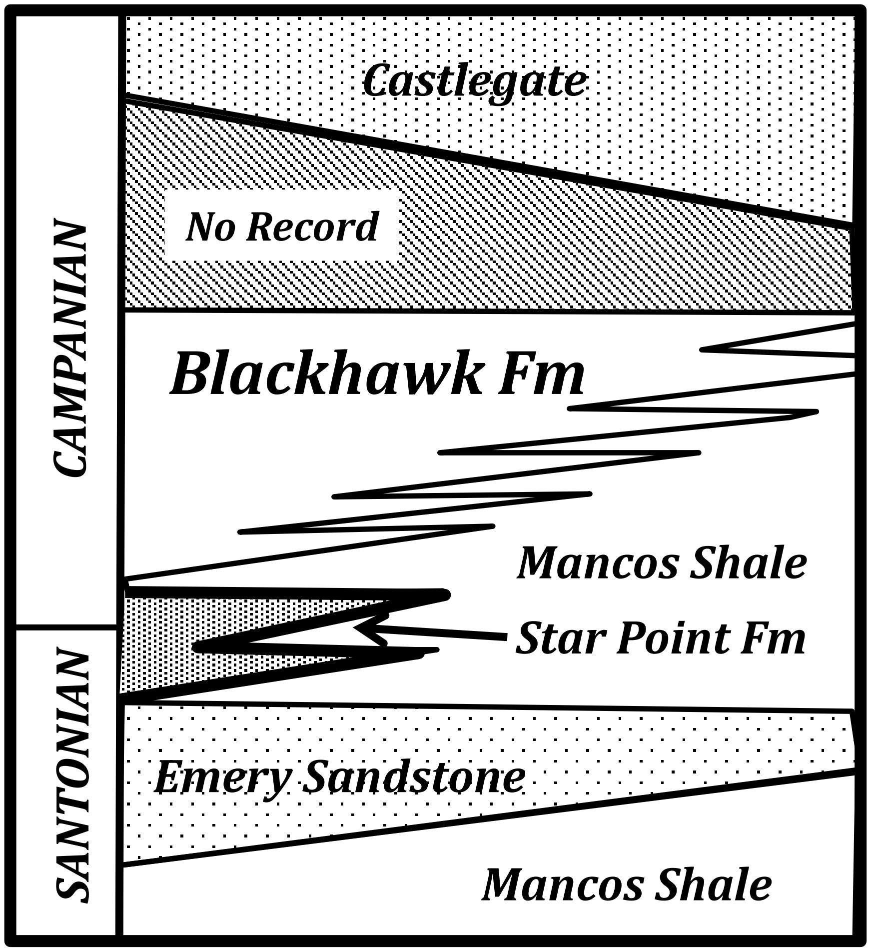

Figure 7. Time-stratigraphic chart of Santonian and Campanian sediments in east-central Utah, showing the relationship of the Blackhawk Formation with surrounding units. Adopted from North, *et al.,* 2005.

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