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The South Cañon Number 1 Coal Mine fire: Glenwood Springs, Colorado

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ABSTRACT

The South Cañon Number 1 Coal Mine fire, in South Canyon west of Glenwood Springs, Colorado, is a subsurface fire of unknown origin, burning since 1910. Subsidence features, gas vents, ash, condensates, and red oxidized shales are surface manifestations of the fire. The likely success of conventional fire-containment methodologies in South Canyon is questionable, although drilling data may eventually suggest a useful control procedure. Drill casings in voids in the D coal seam on the western slope trail are useful for collecting gas samples, monitoring the temperature of subsurface burning, and measuring the concentration of gases such as carbon monoxide and carbon dioxide in the field. Coal fire gas and mineral condensates may contribute to the destruction of floral and faunal habitats and be responsible for a variety of human diseases; hence, the study of coal gas and its condensation products may prove useful in understanding environmental pollution created by coal mine fires. The 2002 Coal Seam Fire, which burned over 12,000 acres and destroyed numerous buildings in and around Glenwood Springs, exemplifies the potential danger an underground coal fire poses for igniting a surface fire.

Keywords: South Cañon Number 1 Coal Mine, coal fires, coal fire gas, mineral condensates, coal pollution.

INTRODUCTION

The South Cañon Number 1 mine is located ~6.4 km (4 mi) west of Glenwood Springs, in Garfield County, Colorado (Fig. 1). The room and pillar bituminous mine, burning since 1910, was ignited by an undetermined source.

On May 18, 2004, the authors visited the South Cañon mine fire in preparation for Geological Society of America Field Trip No. 412, scheduled for November 6, 2004. This report presents a synopsis of coal mining and fire in the canyon. In addition, recent subsidence features associated with the burning D coal seam are illustrated as are coal gas condensates and the instrumentation

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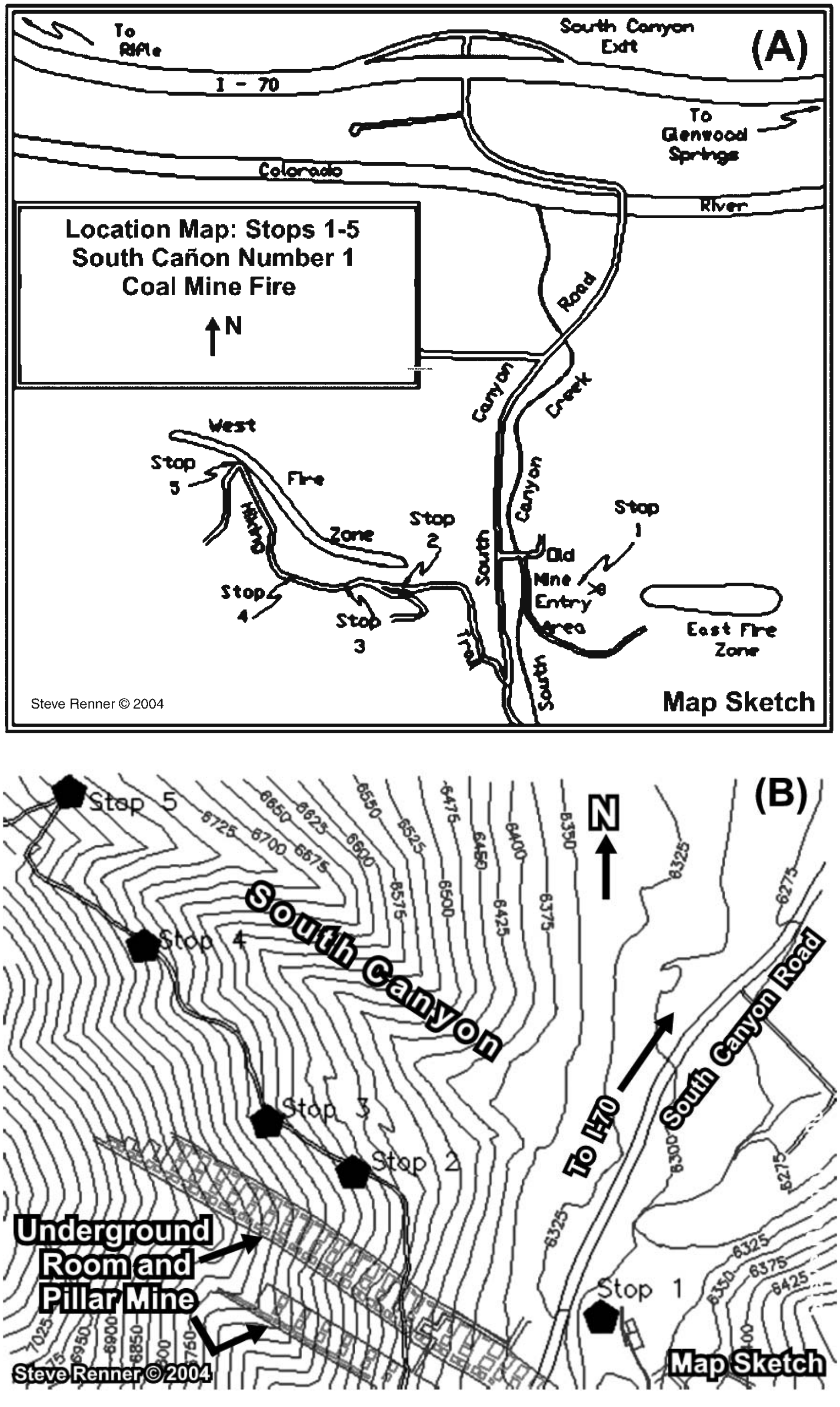


Figure 1. (A) Location map of the South Cañon Number 1 underground coal mine fire (west and east fire zones) and stops 1–5, relative to South Canyon Road and I-70, west of Glenwood Springs, Colorado. (B) Map of South Canyon, stops 1–5, and surface projection of the room and pillar coal mine on fire beneath the western slope of the canyon.

used to collect coal fire gas and thermocouple-temperature data. Techniques for using the instrumentation, a part of the field trip agenda, will provide participants with the skills necessary for collecting valuable data for laboratory analysis.

GEOLOGIC SETTING

The Upper Cretaceous sedimentary rocks in South Canyon are exposed in the Grand Hogback monocline. The monocline, formed during the later part of the Laramide orogeny (Middle to Late Eocene), extends northward from McClure Pass in Pitkin County to the town of Meeker in Rio Blanco County. It separates the Colorado Plateau to the west from the southern Rocky Mountains to the east (Rushworth et al., 1989; Kirkham and Matthews, 2000). Bedding plane attitudes in South Canyon consistently cluster around N35°W, 55°SW.

The Williams Fork Formation, an important coal-bearing unit in western Colorado, consists of alternating coal, sandstone, and shale beds of variable thickness. Numerous surface mines in the Williams Fork Formation are present in northwest Colorado. In South Canyon, and along the Grand Hogback in Garfield County, there are five coal seams that were mined in the Williams Fork Formation. These are, from the stratigraphically lowest to highest, the U, E, Wheeler, D, and Allen seams. The Wheeler, D, and Allen seams were the most important commercially; the Allen is reported to be up to 4.3 m (14 ft) thick near New Castle, west of South Canyon (Colorado Geological Survey, 2004). Drilling data indicate that in South Canyon, the D seam is 1.8–2.4 m (~6–8 ft) thick and the Wheeler seam is 6.1 m (20 ft) thick.

MINING METHODOLOGY

The South Cañon Number 1 mine, one of eleven burning coal mines in Garfield County, lies beneath the western and eastern slopes of South Canyon. Because of steeply dipping beds there, the mining techniques employed were analogous to those used in the anthracite fields of eastern Pennsylvania. Main entries were driven into a coal seam parallel to strike, near canyon-bottom (creek) level. Stope-like raises, or rooms, were then developed as much as 91 m (300 ft) up dip and parallel to strike, above the mains. Coal pillars, 12–18 m (~40–60 ft) thick, separated the rooms. Man-ways, or small passages, in the pillars were excavated between rooms, providing access to various levels of the active mine at different elevations above the mains. Typically, the coal was drilled and shot to bring it down dip. Doors were affixed immediately above coal passes in the mains so that the coal could be easily loaded into carts that traveled on rails within the main entries. In this manner, coal extraction proceeded along strike and up dip within the outcrop in a steep hillside.

In South Canyon, the D seam was mined more aggressively than others. It was initially mined at near-creek elevation, and subsequently, at below-creek elevation. Maps indicate that the same mining method was employed down dip of the initial workings, with 23-m-thick (75 ft) coal pillars separating adjacent stopes (Colorado Geological Survey, 2004).

MINING HISTORY

Published reports about the history of mining in South Canyon are essentially non-existent. Anecdotal information and early mine maps indicate that two stratigraphically lower seams, the E and U, were mined in the late 1880s. At some later date, mines in the Wheeler and D seams were developed. A small town was constructed at the site, and the area was inhabited until the mid-1950s. According to Rushworth et al. (1989), coal production totaled 925,000 tons during the life of the operation, from 1887 to 1953.

MINE FIRE

The U.S. Geological Survey first reported an underground mine fire in South Canyon in 1910. It was located in the Wheeler seam, on the west side of South Canyon (Rushworth et al., 1989). Anecdotal information, supplied by a retired miner, indicates that the fire spread from the west side of the South Cañon Number 1 mine to the east side in 1953, resulting in closure of the mine. Subsidence, red oxidized shales, gas vents, white ash, and condensates are surface manifestations of the fire today (Figs. 2, 6, 7, and 8).

The Colorado Division of Minerals and Geology has drilled into the east side of South Canyon and is in the process of drilling into the west side. The purpose of this exploratory drilling is to determine the locations of underground stopes and to determine which seams are burning at particular locations. The fire is currently thought to be burning in the upper stopes of the E, D, and Wheeler seams on the east side of the canyon and the Wheeler and D seams on the west side.

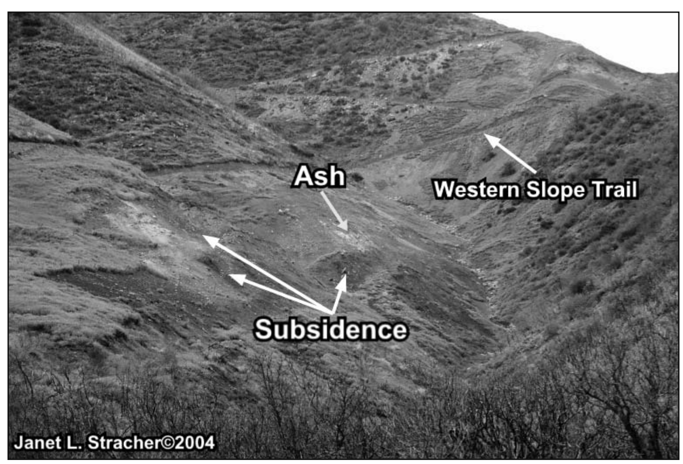


Figure 2. Western slope of South Canyon, where the 2002 Coal Seam Fire is thought to have started (see text). Red oxidized shale (area devoid of vegetation), subsidence, and white ash are present along strike.

It is likely that a second drilling program will be undertaken to more closely evaluate specific subsurface locations on fire. The drilling data will be reduced and evaluated, and will assist future decisions regarding actions necessary to slow the progress of fire on either side of South Canyon.

COAL SEAM SURFACE FIRE

On June 8, 2002, a brush and forest fire referred to as the "Coal Seam Fire" (Piper and Farer, 2002; Rocky Mountain News, 2004) erupted on the western slope of South Canyon. U.S. Forest Service investigators attributed the fire to a surficial gas vent from the underground coal fire in South Canyon. A spark or cinders from the vent is thought to have ignited foliage on the western slope (McKibbin, 2003). The fire spread down-canyon and into West Glenwood Springs after jumping the Colorado River and the Interstate 70 (I-70) highway, burning over 12,000 acres (Piper and Farer, 2002). In addition, 29 homes and 14 other buildings were destroyed, for an estimated loss of $7.3 million dollars (Rocky Mountain News, 2004). The surface fire was eventually extinguished, thanks to the work of nearly 700 fire fighters who created firebreaks and dropped slurry on the fire with air tankers (Piper and Farer, 2002).

ACCESS TO SOUTH CANYON

The base of the western and eastern slopes of South Canyon is readily accessible by automobile. A steep, winding dirt trail cut into the western slope, herein referred to as the "western slope trail," is accessible by foot or off-road vehicle. Surface manifestations of the underground fire in the D coal seam, in addition to burnt trees from the 2002 Coal Seam Fire, are visible from the canyon floor and along the trail. The trail provides a superb overview of the underground fire and the 2002 Coal Seam Fire, and from it, gas vents and drill casings used by the Colorado Division of Minerals and Geology to monitor the mine fire can be seen. Extreme caution must be used along the trail. Its maximum width is 3.4 m (11 ft), and an off road vehicle could easily tumble down slope. Because of subsidence along the slope, hiking off the trail is inadvisable.

GSA Field Trip Route

The trip departs from the Colorado Convention Center in Denver at 6:30 a.m. on November 6th, 2004. The route from Denver is as follows:

Cumulative		
mi	*km*	*Description*
160	~257	Follow I-70 west for ~257 km (160 mi) and get off at "South Canyon Exit 111," illustrated in Figure 1A.
160.2	~257.3	Turn left at the bottom of the off ramp and drive under I-70, ~0.3 km (0.2 mi) from the start of the exit.
160.5	~257.8	Drive ~0.5 km (0.3 mi) from the underpass along South Canyon Road (Fig. 1A) to a bridge crossing the Colorado River.
161.7	~259.7	After crossing the river, drive ~1.9 km (1.2 mi) along South Canyon Road (asphalt). At a fork in the road, there is a landfill on the right. Bear to the left where the asphalt ends and South Canyon Road becomes a dirt road.
163.3	~262.3	Drive ~2.6 km (1.6 mi) on this road to the base of South Canyon. This is stop 1, discussed below. From stop 1, it's about another 0.3 km (0.2 mi) to the western slope trail where stops 2–5 are located.

The Western Slope Trail

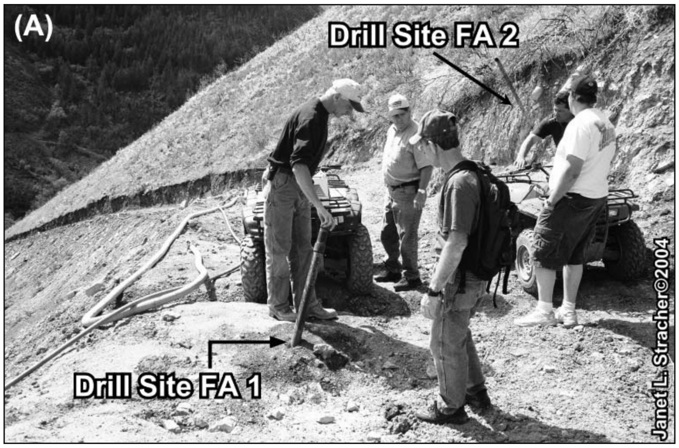
The hike along the steep western slope trail is strenuous, and sturdy walking shoes are mandatory. Several stops along the trail provide key locations where collection techniques may be readily demonstrated and spectacular views of surficial features associated with the underground mine fire and 2002 Coal Seam Fire are visible. In addition, Storm King Mountain, where 14 firefighters died in 1994, can be seen. The stops in South Canyon (Fig. 1), and related field trip events associated with them, are discussed below.

Stop 1. The first stop of the trip is at the collapsed and overgrown entrances to the South Cañon Number 1 Coal Mine, near the base of the eastern slope of the canyon. The elevation here is ~1928 m (6325 ft). Smoke billowing from these entrances forced closure of the mine in 1953.

Stop 2. Hiking up the western slope trail to the second stop, we can observe the location at which the 2002 Coal Seam Fire is thought to have begun. Surface manifestations of the fire consist of white ash in addition to subsidence and red oxidized shale along strike (Fig. 2).

Stop 3. Continuing up the trail, we see drill sites FA 1 and FA 2, which are used by the Colorado Division of Minerals and Geology to monitor subsurface combustion gas and temperatures (Fig. 3). The steel casings inserted into the drill holes have a nominal inside diameter of ~5.08 cm (2 inches), are ~3.2 m (10 ft) apart along dip, and penetrate a void in the bituminous D coal seam at 1.5 m (5 ft) below the surface, to a depth of ~33 m (108 ft). At this location, a gas collection technique using a LaMotte hand pump, Teflon intake and exhaust lines, and Tedlar gas collection bags is demonstrated. This technique is the same as that used by G.B. Stracher, T.P. Taylor, and J.T. Nolter in June of 2003 (Stracher, 2003) while filming for National Geographic at the Centralia mine fire in Pennsylvania (Fig. 4). A Pasco Scientific thermocouple probe for collecting temperature data and Drager tube field analysis of carbon monoxide and carbon dioxide are also demonstrated at Stop 3 (Fig. 5).

Approximately 30.5 m (100 ft) down slope from Stop 3 is a gas vent encrusted by minerals condensing from exhaled gas. Figure 6 illustrates samples collected for analysis on May 18, 2004, by G.B. Stracher and S. Renner. The temperature measured



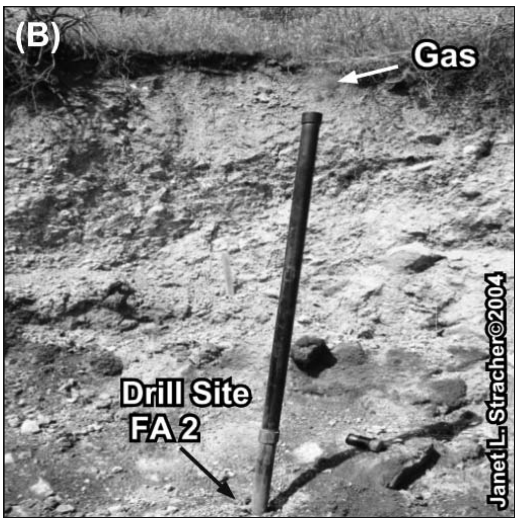


Figure 3. (A) Drill sites FA 1 and FA 2 (steel casings) used to monitor gas and temperatures associated with the burning D coal seam. Left to right: S. Renner, G. Colaizzi, G.B. Stracher, W. Duncan, and G. Griggs. (B) Exhaled coal fire gas from drill casing FA 2 (cap removed).

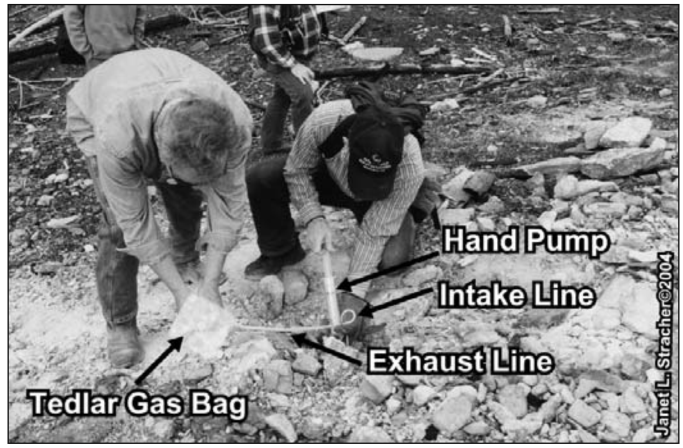


Figure 4. J.T. Nolter (left) and G.B. Stracher using a coal fire gas-collecting apparatus at the Centralia mine fire in Pennsylvania. This same apparatus is used to demonstrate the collection procedure to field trip participants at drill sites FA 1 and FA 2 in South Canyon. A LaMotte hand pump is used to pump gas from a coal fire vent through Teflon intake and exhaust lines into a Tedlar gas collection bag.

immediately inside the vent with the Pasco probe on May 18, 2004, was 89.4 °C (193 °F). Sample collecting techniques using plastic vials and metal spatulas are discussed at Stop 3, with an emphasis on avoiding sample contamination from soil or altered rock. If conditions permit, G.B. Stracher and one of the trip co-leaders will climb down slope and demonstrate the actual collection process. For safety and liability reasons, field trip participants will not be permitted to accompany them.

Stop 4. Drill site FE, for monitoring subsurface combustion gas and temperatures, is seen at stop 4, further up the western slope trail from stop 3. Those field trip participants who volunteer to do so will take a gas sample and thermocouple temperature measurement here. A section of iron rail from a track, adjacent to a closed depression ~61 m (200 ft) down slope, suggests the presence of a mine entrance on the western slope (Fig. 7).

Stop 5. The final stop on the trip along the western slope trail is a switchback at 2115 m (6939 ft). Here, field trip participants can observe (1) overgrown mine entrances at the base of the eastern slope of South Canyon; (2) subsidence features, gas vents, and white ash (at eye level) on the eastern slope, due to subsurface burning of the D coal seam (Fig. 8); (3) subsidence and red oxidized shale along strike of the D coal seam burning beneath the western slope; (4) the devastation in South Canyon caused by the 2002 Coal Seam Fire; and (5) Storm King Mountain, where 14 trapped firefighters died in the "South Canyon Fire" (unrelated to the coal mine fire) on July 6, 1994 (Butler et al., 1998). This fire began on July 2, 1994, when a lightning strike ignited piñon juniper and other foliage. It was contained by July 11, 1994, after burning more than 2,000 acres and triggering debris flows across I-70 as torrential rains poured down on the burn area (Cannon et al., 1995).

DISCUSSION

Subsidence at mine entries, subsequent to closure of the South Cañon Number 1 mine, has not impeded oxygen from reaching the underground fire that continues to burn there. Surface sealing and conventional fire control methods are not likely to work in South Canyon because of former mining practices that left numerous pillars of coal exposed to oxygen circulating through rock fissures. Fire containment is further complicated by the rugged terrain in South Canyon, steeply dipping coal beds there, and the questionable subsurface extent of the fire.

Methods for controlling and extinguishing underground coal mine fires in mountainous terrain include the use of liquid nitrogen and the injection of foamed grout into surface vents and fissures (Feiler and Colaizzi, 1996). However, such techniques

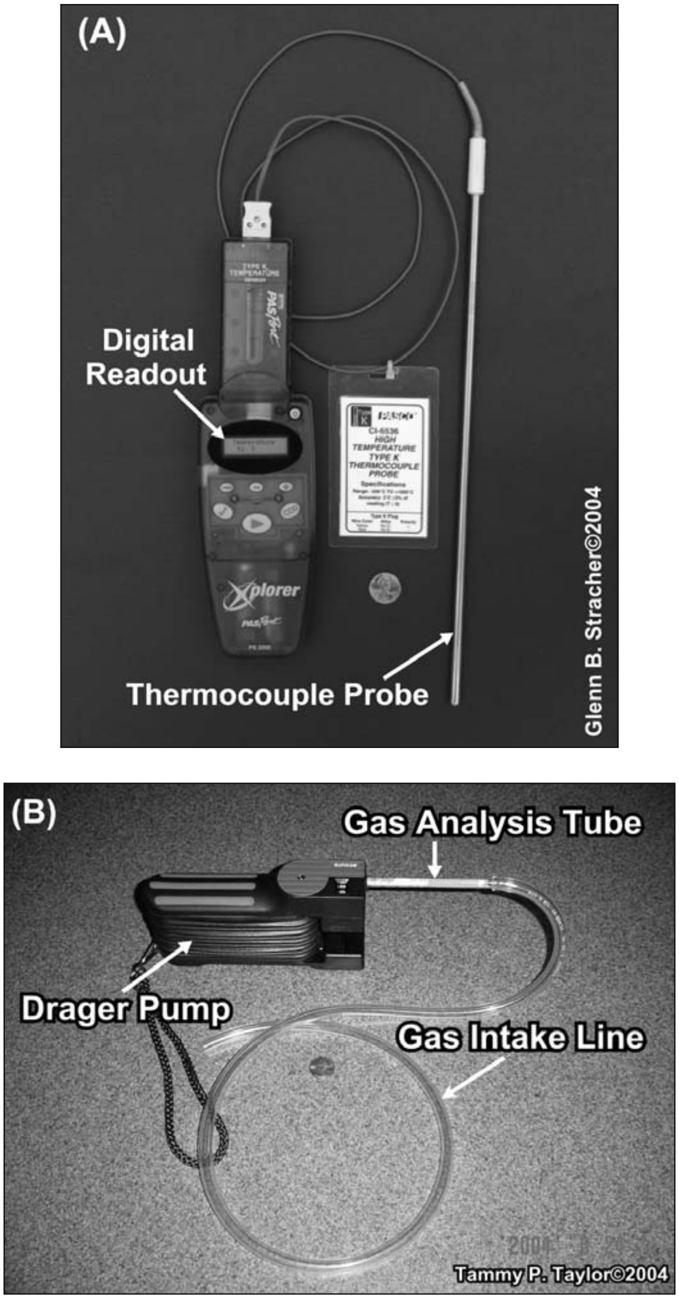


Figure 5. (A) Pasco Scientific thermocouple probe used to measure coal gas temperatures at drill sites FA 1, FA 2, and FE. The metal probe is inserted into the gas, and the temperature is digitally recorded. (B) Drager hand pump and tube apparatus used to extract coal fire gas and measure carbon monoxide and carbon dioxide concentrations in the field.

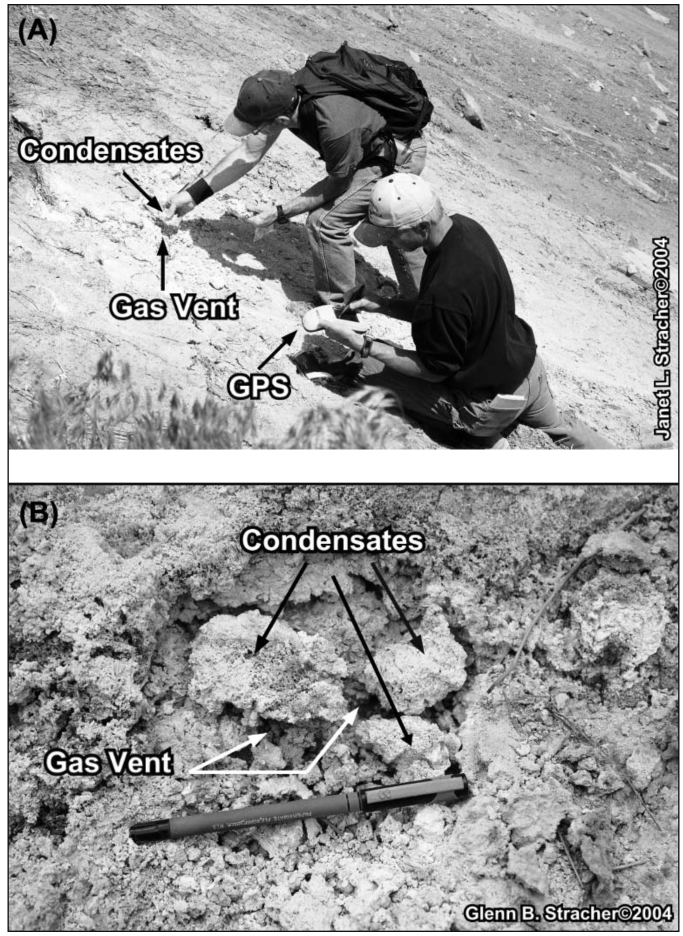


Figure 6. (A) G.B. Stracher (left) collecting condensates encrusting a coal fire gas vent, while S. Renner records GPS coordinates. The temperature ~5 cm (2 inches) inside the vent on May 18, 2004, was 89.4 °C (193 °F). Location is 39°32′09.737″ N, 107°25′14.803″ W, at an elevation of 2028 m (6654 ft) and ~35 m (115 ft) down slope from drill sites FA 1 and FA 2 (Fig. 3). (B) Close-up of condensates and gas vent.

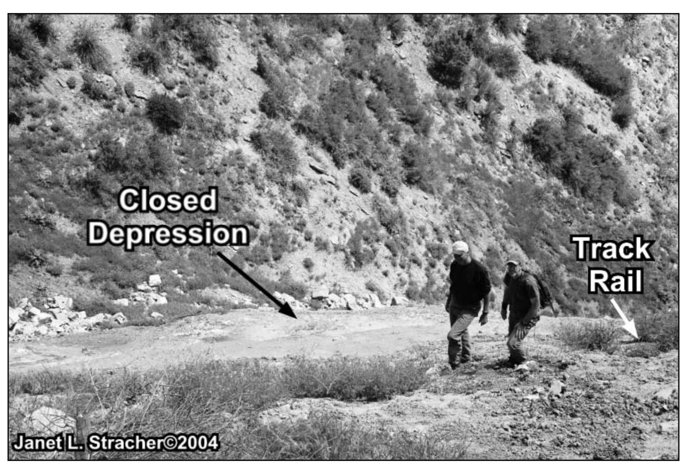


Figure 7. Iron track rail adjacent to a closed depression, ~61 m (200 ft) down slope from stop 4, suggesting the presence of a mine entrance on the western slope. Left to right: S. Renner, G.B. Stracher.

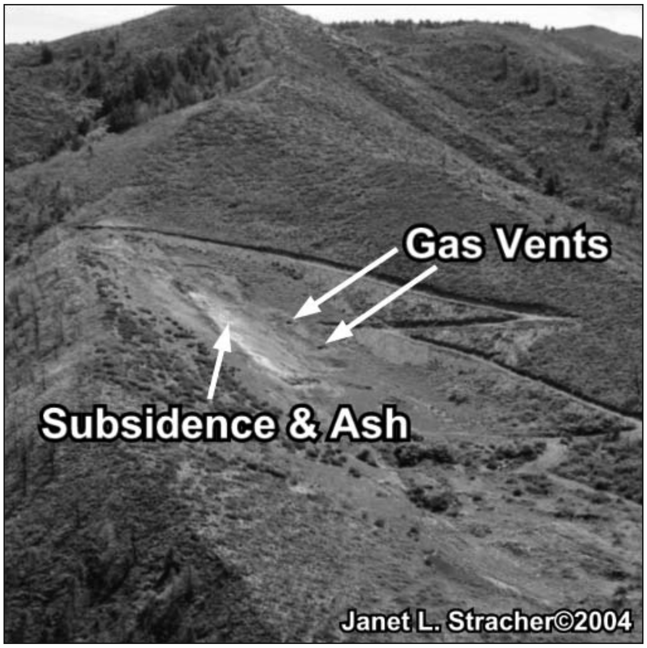


Figure 8. Subsidence, ash, and gas vents (small black spots) on the eastern slope of South Canyon due to subsurface burning of the D coal seam.

may be cost prohibitive in South Canyon, and the potential for these alternate methods to contain the underground fire there is questionable, for the same reasons conventional methods are problematic. Regardless, additional test-drilling data, acquired by the Colorado Division of Minerals and Geology, may suggest a method to contain the fire.

The study of coal fire gas and its condensation products can be critically useful in understanding the pollution caused by coal mine fires. The chemistry of exhaled gas and condensates is reflective of elements and compounds that may be released as pollutants into the atmosphere, soil, or the hydrosphere. Such pollutants may be responsible for a variety of environmental and human health problems, including the destruction of floral and faunal habitats, bronchitis, lung cancer, stroke, pulmonary heart disease, chronic obstructive pulmonary disease, arsenosis, and fluorosis (Finkelman et al., 1999, 2001, 2002; Johnson et al., 1997, p. 19; World Resources Institute, 1999, p. 63–67; Stracher and Taylor, 2004). Consequently, the study of coal mine fire gas and mineral condensates, such as those in South Canyon, can be critically useful in understanding environmental pollution.

The authors sincerely hope that some of their readers, including the field trip participants, will pursue research in the health-related and numerous additional areas of study associated with coal fires science.

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DEDICATION

This manuscript and the work contained herein are dedicated to Dr. Nancy Lindsley-Griffin and Dr. John R. Griffin of the University of Nebraska–Lincoln. Without their guidance and rigorous training of the senior author in the elegant techniques of complex field geology, this project and others undertaken by him, both in America and abroad, could not have been completed. They have and will always be for him a source of inspiration, two people to whom he can turn, even when they are not beside him, and who, with their "spiritual guidance" in his mind's eye, assist him in determining the most straightforward method by which to proceed while working in the field.

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