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MEMORANDUM FOR RICHARD A. GATES
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SUBJECT: Observations and Sample Collection Methodology at Wolf Run Coal Company, Sago Mine, MSHA I. D. No. 46-08791, on March 20-21, 2006

Observations

As requested by the Accident Investigation Team, several rock and water samples were collected from the Sago Mine. Several water samples were collected from the Buckhannon River, Trubie Run, and an un-named tributary off Trubie Run. Additionally, observations of features were conducted in the vicinity of spad 4064.

March 20, 2006 Sample Collection

Sample collection began on the track entry of the Main between crosscuts 32 and 33, where arches were installed through difficult ground conditions beneath Trubie Run. Dripping water was collected in a small glass vial, and labeled "Trubie" (Figure 1).

Figure 1. Collection of dripping water in the track entry of the Main, between Crosscuts 32-33.

Observations resumed inby the former 2nd Left Seals. The underground sample collection effort was prompted by an interest to document the cause of the "blue haze" that has been observed throughout portions of the 2nd Left Mains. Figure 2 represents a map of the 2nd Left Mains showing the locations of water and rock samples collected on March 20, 2006. Observations proceeded inby along the #7 Entry of the Main, where "blue haze" was observed on several broken rock faces. This entry had been benched, and these locations were not accessibie. "Blue haze" was observed in the vicinity of spad 3986, where the crosscut had not been benched. Two samples, one of rock that hosts the "blue haze" on its surface, as well as a water sample, were collected from the roof of the crosscut between spads 3986 and 3981. Water droplets were collected with a plastic eye dropper by drawing each individual droplet into the dropper, and then expelling the water into a glass vial (Figure 3). When all available water droplets that were in contact with the "blue haze" had been collected, the glass vial was approximately half full. The plastic eye dropper was used only at this collection site, and was labeled with the sample number "BH3986-28" before being separately stored to avoid cross contamination with other eye droppers, which were carried in a sealed plastic freezer bag. Mine personnel assisted in the collection of a slab of immediate roof rock that hosted "blue haze" on a fracture surface. When the slab was retrieved, it was broken in half, with one half retained by MSHA personnel and the other half provided to mine personnel, who were present. The MSHA sample was stored in a freezer bag and labeled "BH3986-28" whereas the sample provided to the mine was stored in a freezer bag labeled "BH3986-28 duplicate". Photos were taken of the sample in place in the roof, after it had been split in half, and of each half in its respective bag (Figure 4).

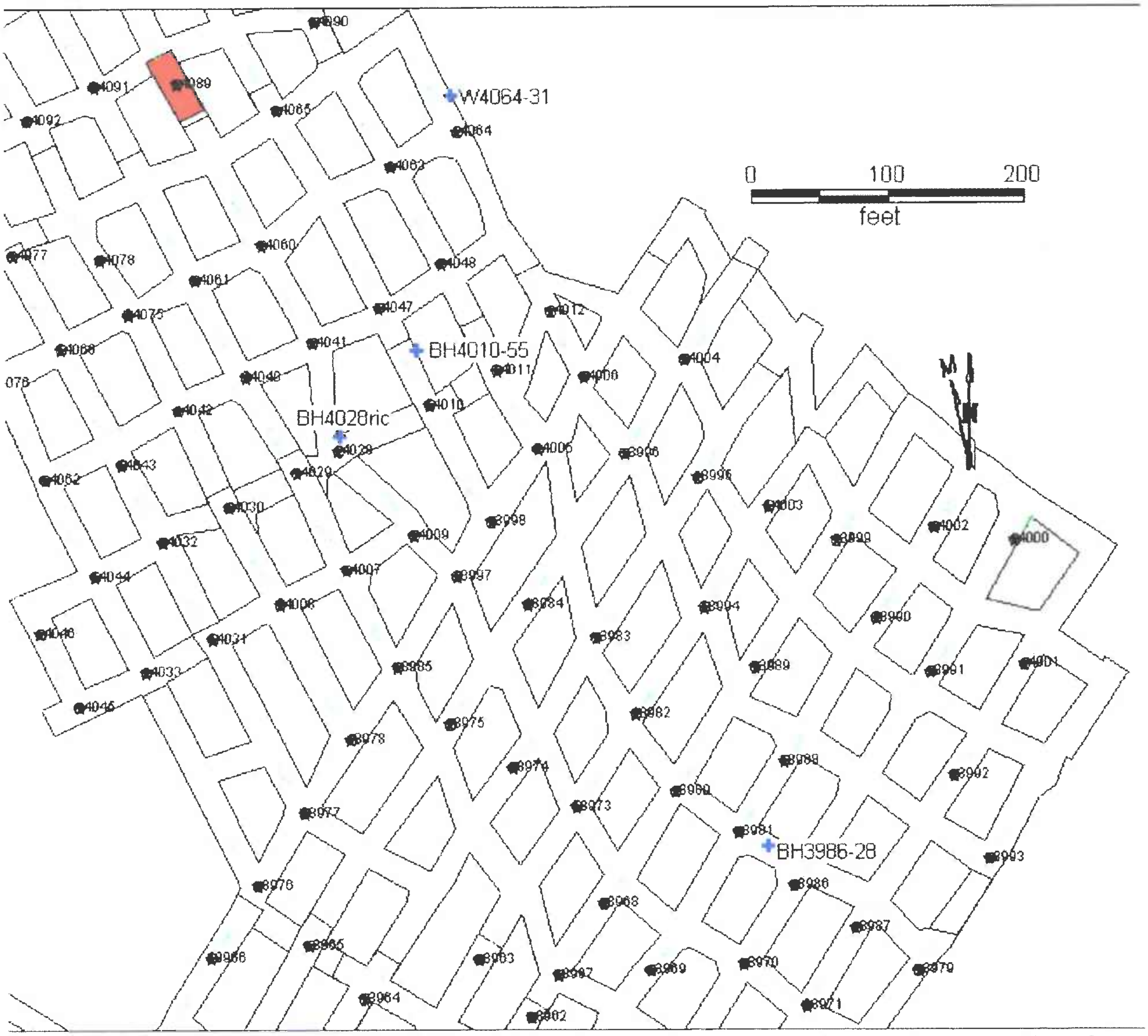

Figure 2. Map of the observed area of 2nd Left Mains in which rock and water samples were collected on March 20, 2006.

Figure 3. Collection of water droplets on the roof and fracture faces where "blue haze" was observed between spads 3986 and 3981.

Figure 4. Photo of Sample BH3986-28, with the mine's duplicate sample. The sample was collected from the roof approximately 28 feet into the left-hand crosscut from spad 3986. The distance was measured with a laser range finder.

Observations then proceeded along the #2 Entry of 2nd Left Mains, and across to the vicinity of spad 4028. "Blue haze" was observed on the rib of the right inby crosscut in the spad 4028 intersection. No water was present at this site, and so no water sample could be collected. However, a slab of rib that hosted the "blue haze" on the exposed face was collected, and split in half, with each half provided to the mine and MSHA personnel present (Figure 5). As the MSHA sample was being further split to obtain a suitably sized sample to place in a bag, the rock separated along a prominent bedding plane, exposing a fossil of a fern leaf attached to a very well developed central stalk, preserving the diamond-shaped, nearly serrated texture of the bark.

Figure 5. Samples collected from the right inby crosscut in the spad 4028 intersection. Half of the sample was retained by MSHA in a bag labeled "BH4028ric" and the other half was retained by mine personnel in a bag labeled "BH4028ric duplicate."

Observations continued across to the spad 4010 intersection, which had to be accessed by proceeding inby from spad 4028 to a more accessible crosscut due to benching. No water was observed in this sample collection locality, so no water sample was collected. A slab of "blue haze" coated rock was obtained from the right rib of the #6 Entry, where the floor ramped down to the beginning of the benched area (Figure 6).

Figure 6. Slab of "blue haze" coated rock retrieved from the right rib approximately 55 feet inby spad 4010. This slab was subsequently split in half, with each half retained by mine and MSHA personnel present.

Observations continued inby along #7 Entry, from the adjacent crosscut from spad 4010 to the crosscut inby spad 4063. This crosscut connects with terminated #8 Entry, where a barrier was left for a gas well. Observations were made of the intersection of the crosscut and the #8 Entry, the segment of the #8 Entry inby spad 4064, and the segment of the crosscut. A sample of water seeping from the right rib of the #8 Entry was collected with a plastic eye dropper, which was labeled with the sample number "W4064-31" to mark it distinctly from the eye dropper used previously for sample collection at the BH3986-28 site (Figure 7). The labeled eye dropper was photographed.

Figure 7. Water sample in glass vial collected from right rib of solid coal block in #8 Entry, 31 feet inby spad 4064. Plastic eye dropper is labeled with sample number to distinguish it from the separate dropper used in collection of sample BH3986-28.

The intersection is characterized by a series of wavy brown streaks, which extend into the adjacent #8 Entry and crosscut. Each wavy brown streak has a linear, although undulatory trend that was measured with a Brunton compass. The streaks in the outby side of the #8 Entry exhibit a trend of approximately N 13-15°E, such that they project into the right inby corner of the intersection (Figure 8 and 9). Traversing from the #8 Entry inby to the left-hand crosscut, the brown wavy streaks change their orientation, and continue to trend toward the right inby corner of the intersection. Thus, the brown wavy streaks define a radiating pattern with a center point about the right inby corner of the intersection. These long, roughly linear, but wavy brown streaks are developed in flat, planar portions of the exposed roof. Several brown wavy streaks were observed that are approximately perpendicular to those developed on the planar roof horizon. These perpendicular streaks were developed along protrusions or small brows from the roof, and represented the exposed ridges of bedding asperities, and are generally less than 4 feet long. Comparatively, the longer linear, but wavy streaks are generally 7-12 feet long. The brown wavy streaks do not represent surficial dust, and instead represent actual linear exposures of rock. The brown shale is masked by a very thin bedding parting of black, carboniferous shale, except where it has been removed to expose the brown wavy streaks. The removal mechanism gave the appearance of sand blasting or scouring, rather than gouging. There were no depressions associated with the streaks that would suggest a geologic origin such as scour marks or trace fossil imprints. Despite the straight rib profiles observed even in the benched portions of this area, characterized by an absence of sloughing, several large (1 x 2 feet) blocks of coal had been removed from the face of the discontinued #8 Entry. This intersection, and the short segment of the crosscut and entry, had not been benched. While in the intersection, gas could be heard seeping from the right rib, and the sound of gurgling water was also apparent from the right rib. The sound was similar to that of water running down a drain, rather than pouring into a standing body. The intersection was characterized by standing water that ranged in depth from nominally 3 inches to at least 7 inches. Underground observations concluded in this intersection and the mine was exited.

Figure 8. Photo of linear, wavy brown streaks in the terminated #8 Entry, viewed looking inby along #8 Entry. Streaks are actually the exposed based of the brown shale that overlies the thin black carbonaceous shale bedding parting.

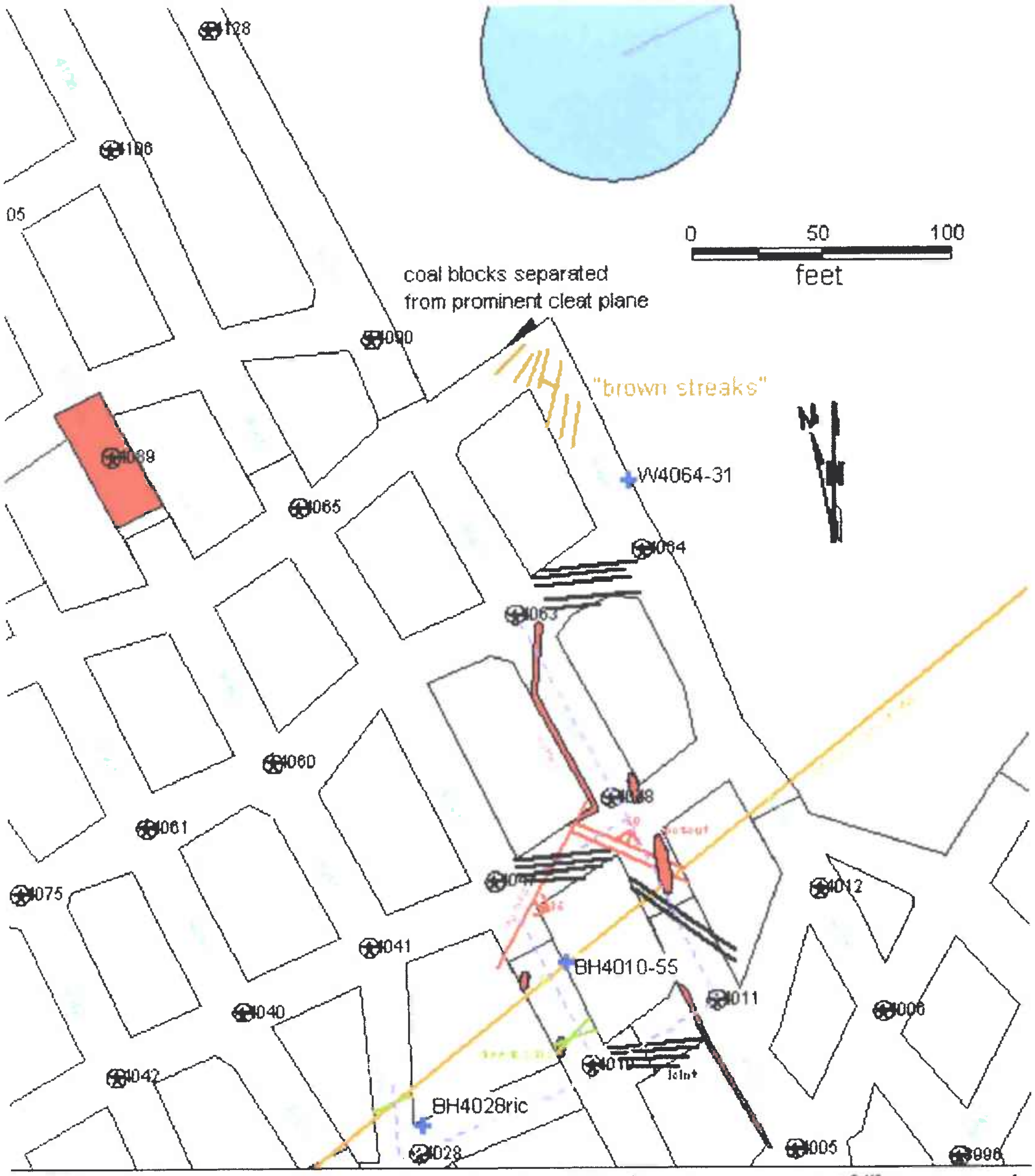

Figure 9. Detailed map of observations in the 2nd Left Mains, showing positions of "brown streaks" and sample collection sites with detailed geological observations from February 21, 2006.

March 21, 2006, Observations

Observations and sample collection continued on the surface the following day. Water samples were collected from a segment of the Buckhannon River, a segment of Trubie Run, a small tributary that drains into Trubie Run, and from Trubie Run at a position directly over the Main where sample "Trubie" was collected on the previous day (Figure 10).

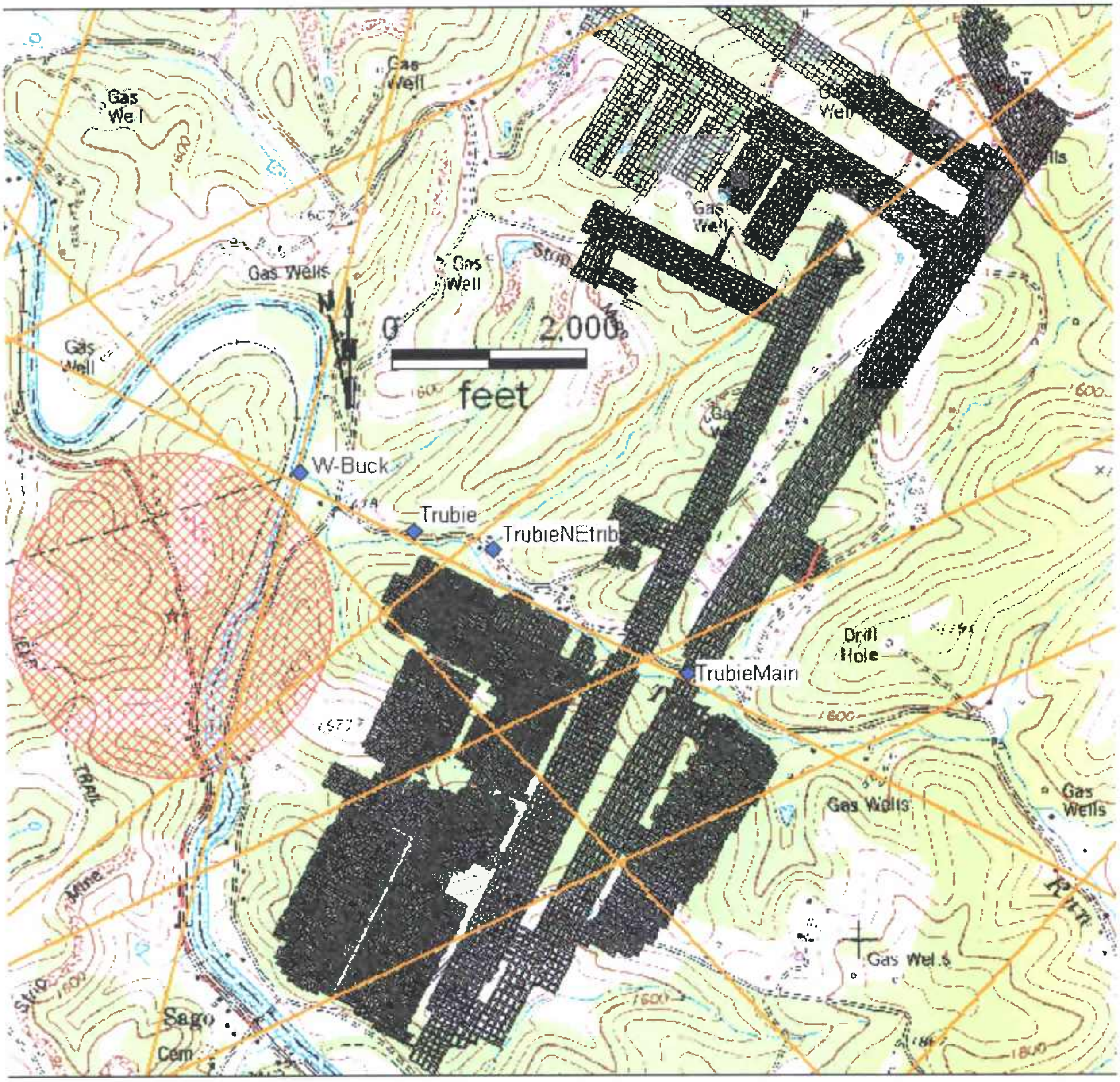

Figure 10. Map of surface water sample locations in relation to Sago Mine workings, RCD lineaments, and location of lightning strike.

The first sample was collected from the Buckhannon River along a segment north of the position of a reported lightning strike, and the point where Trubie Run enters the river. The sample, labeled "W-Buck," was collected from the edge of the stream bank, in slow moving water, with no visible organic material present. The location of the sample site was determined with a hand-held GPS unit, and recorded for display in the GIS from which Figure 10 was produced. The next sample was collected from Trubie Run between the Buckhannon River and the un-named, northeast trending tributary, and labeled "Trubie" (Figure 11). A sample with the same name was collected on March 20, 2006, from the underground workings on the track entry in the Main beneath Trubie Run. However, the two samples have different exhibit numbers. Sample

"TrubieNEtrib" was collected from the un-named tributary that trends northeast from Trubie Run. No other access could be found for this small stream, although the valley was paralleled by a county road to the head of the valley. Sample "TrubieMain" was collected from Trubie Run above the point where the Main passes beneath Trubie Run. This location was determined with a hand-held GPS based on coordinates provided by the mine. All locations were confirmed by MSHA personnel using their own hand-held GPS unit.

Figure 11. Photo of surface water sample collection at location "Trubie." Not to be confused with the sample named "Trubie" collected from the track entry of the Main, underground.

Upon completion of the surface water sample collection, a prominent tree that was reportedly struck by lightning on the day of the Sago Mine explosion was visited. The position of the tree was determined using a hand-held GPS unit, and plotted on the RCD GIS maps (Figure 12). Using a powerful hand-held magnet, a small piece of magnetic material was found at the base of the tree. The material is interpreted to be magnetite, and exhibits surface oxidation. The genesis of the magnetite is not known. The magnetite could represent detrital material that was originally incorporated in eroded sedimentary rock, or if evidence of lightning striking the ground, would have to represent a change from original hematite (Fe_2O_3) to magnetite (Fe_3O_4).

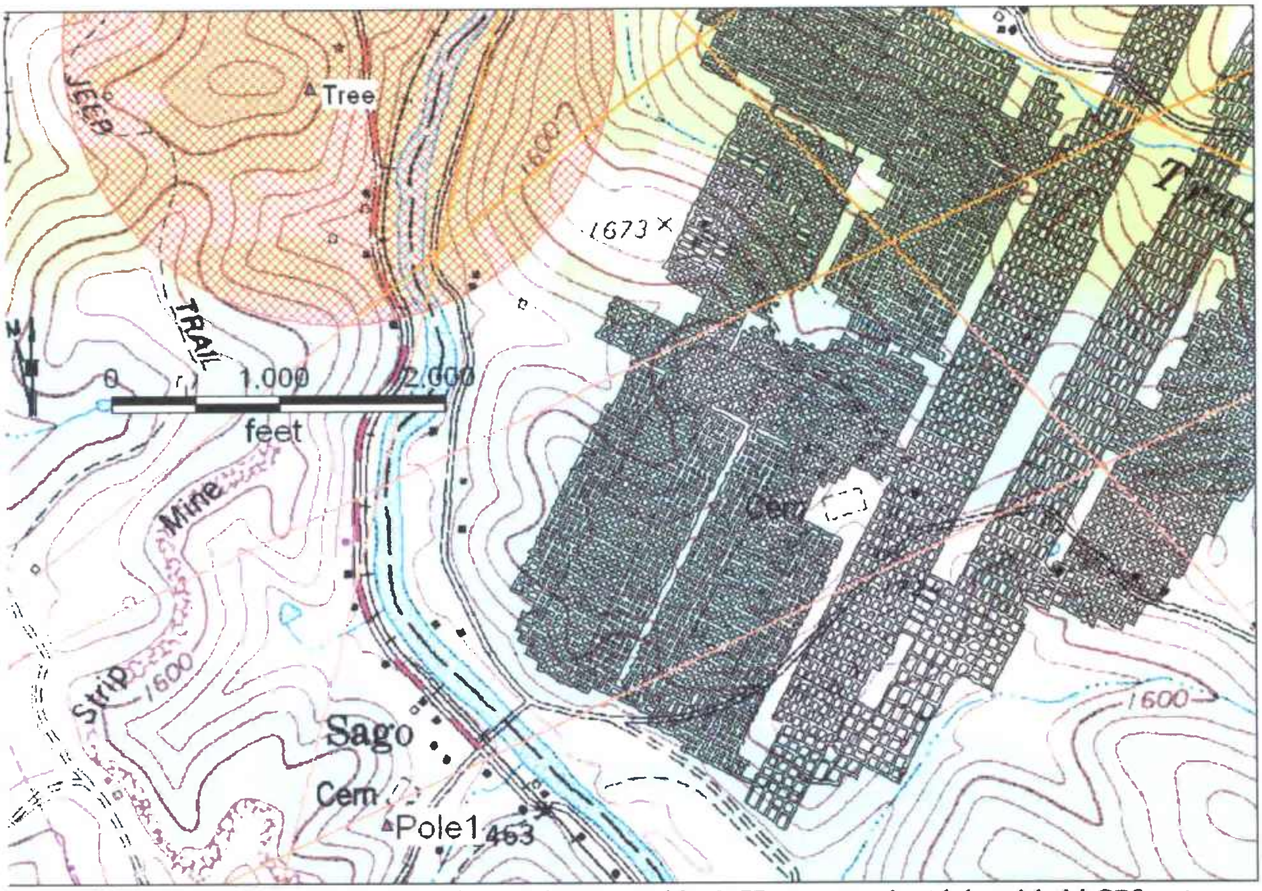

Figure 12. Location of lightning-struck tree, determined by RCD personnel with hand-held GPS unit. Location is 300 feet from plotted location of lightning strike, indicated by small red star in center of cross-hatched area. Locality "Pole 1" represents a twin-pole power line support that reportedly exhibited lightning damage, although the timing of the damage is unknown.

Discussion and Analysis Results

The purpose of the samples collected on March 20, 2006, was to document the "blue haze" and determine its composition. The rock samples and water sample, collected at "BH3986-28," "BH4028ric," and "BH4010-55," were submitted for X-ray diffraction and Inductively Coupled Plasma-Mass Spectrometry to determine the composition of the blue film that coats the rocks. Due to the inability to obtain sufficient sample material for analysis, only the iridescent coating from sample "BH4028ric" could be analyzed by X-ray diffraction. The iridescent "blue haze" scraped from sample "BH4028ric" was determined to be calcite, based on the X-ray spectrum of diffraction peaks. Due to the lack of limestone in the mining horizon and the absence of water precipitates and "drippers," it seems most likely that the source of the calcite diffraction peaks is from lime rock dust applied to the coal ribs.

Whole-rock geochemical analysis was also conducted of the "brown streaks," and the samples collected at each "blue haze" location to determine if there were differences in the rock. The results of analysis by Inductively Coupled Plasma, reported as major oxides, are summarized in Table 1. The analysis results appear to be representative of sedimentary rocks, and even highlight the differences between roof shale (BH3986-28 and #8 brown streaks) with a higher percentage of silica and lower alumina in keeping with the abundant quartz grains distributed throughout the shale. In contrast, samples collected from the rib (BH4010-55 and BH4028ric) host significantly lower silica values and much higher alumina values, reflecting domination by clay with a lack of clastic sedimentary input. These differences are also reflected in marked differences in the magnesium, potassium, and phosphate contents in which MgO and K_2O are lowest in the paleo-soil horizon binder collected from the rib of BH4010-55, while phosphate is higher. Differences between the rib samples from BH4028ric and BH4010-55 may reflect that sample BH4028ric was collected from a fossiliferous portion of the coal seam, whereas samples from BH4010-55 were collected from a paleo-soil horizon that separates the upper and lower splits of the coal seam.

Element:	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total
Units:	%	%	%	%	%	%	%	%	%	%	%	%
Detection Limit:	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01	0.01	0.01
Reference Method:	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP
# 8 brown streaks; Exhibit 7	55.85	24.33	3.52	0.02	1.42	0.25	0.37	3.98	1.141	0.1	9.27	100.2
BH3986-28; Exhibit 3	55.3	22.07	5.34	0.059	1.41	0.23	0.3	3.54	1.079	0.11	9.32	98.78
BH4010-55; Exhibit 5	46.52	31.04	2.28	0.003	0.18	0.46	0.36	1.75	1.259	0.87	13.51	98.22
BH4010-55B; Exhibit 5b	48.47	30.34	2.03	0.003	0.22	0.38	0.39	2	1.491	0.6	12.5	98.43
BH4028ric; Exhibit 4	48.87	26.13	3	0.012	1.04	0.14	0.35	2.62	1.269	0.09	16.97	100.5

Table 1. Results of Inductively Coupled Plasma analysis, reported as major oxides, for rock samples collected in 2nd Left Mains.

A sample of the "brown streaks" in the dropped #8 Entry was determined by X-ray diffraction to contain quartz, muscovite, kaolinite, siderite, and rutile. The presence of quartz, muscovite, and kaolinite are expected components of shale, and the results are supported by microscopic analysis conducted on other samples of the immediate roof that documented the presence of abundant quartz grains scattered throughout a matrix of muscovite mica. Siderite, an iron carbonate, is a sedimentary mineral found in clays, shales, and coal beds. Rutile, a titanium oxide, is a common accessory mineral in sedimentary rocks due to its resistance to weathering. The "brown streaks" are actually scour marks, exposing the overlying brown shale where the thin, black carbonaceous bedding parting of the immediate roof was scoured away. It is interesting to note that the "brown streak" scour marks form a radial pattern with respect to the northeast corner of the #8 Entry face, beyond which is located the cased gas well.

The purpose of the water samples collected from surface streams on March 21, 2006, and from the right rib of the #8 Entry on 2nd Left Main (W4064-31) and from the track entry of the Main ("Trubie") was to assess the pH and electrical conductivity of water in the vicinity of the mine. A photo-lineament, referred to as "RCD Lineament 9NE" projects directly over the inby side of spad 4010, and appears to represent a steep, narrow drainage that trends northeast from Trubie Run. The water samples were collected in segments that run from the area of the prominent lightning-damaged tree to the spad 4010 area to assess the potential that electrolytic solutions might occur in fracture zones between these two points. Results of pH and electrical conductivity tests are summarized in Table 2. The pH values of all samples, both surface and underground, are nearly neutral, ranging from 6.8 to 7.5. The pH of water samples collected from the surface, from the Buckhannon River and Trubie Run, are consistently 6.8. The pH of water samples collected underground is slightly more alkaline, at 7.1-7.5. Electrical conductivity values are reported in units of micro-Siemens per centimeter. A micro-Siemens is the same as a micro-mho, denoting that conductivity reported in "mho" units is the inverse of resistivity reported in "ohms." Samples collected from Trubie Run and the northeast-trending tributary of Trubie Run is very similar, ranging from 42.3-47.9 micro-Siemens/cm. These conductivity values are within a range comparable to that for "good city drinking water." Upon entering the Buckhannon River, the electrical conductivity values exhibit a marked increase and nearly double to 83.5 micro-Siemens/cm. This value is comparable to a range greater than that of ocean water. Water samples collected underground exhibit a much higher conductivity, with a sample collected from the fire tap at the junction with the new 2nd Left Main characterized by a value of 196 micro-Siemens/cm and the sample of dripping water collected from the track entry Main directly beneath Trubie Run (Figure 1), characterized by a value of 295 micro-Siemens/cm. The sample of dripping water collected from the right rib of the #8 Entry (W4064-31) is characterized by a much higher electrical conductivity of 708 micro-Siemens/cm. For example, this value is comparable to the electrical conductivity given by one reference as a 30% solution of nitric acid. It should be noted that Sample W4064-31 was collected from the rib of the #8 Entry near where the cased gas well is located.

		Conductivity	pH
Units:		μS/cm	pH
Detection Limit:		0.01	0.1
Reference Method:		ISE	pH
Fire tap - 2nd Left; Exhibit 1		196	7.1
Trubie; Exhibit 1		295	7.2
W4064-31, Exhibit 6		708	7.5
W-Buck; Exhibit 1		83.5	6.8
Trubie; Exhibit 2		47.9	6.8
Trubie NE trib; Exhibit 3		44.8	6.8
Trubie Main; Exhibit 4		42.3	6.8

Table 2. Electrical conductivity values (in micro-Siemens per centimeter) and pH values for water samples collected underground and from surface streams.

Chemical analyses were also conducted on samples W4064-31 and BH3986-28 by the Inductively Coupled Plasma-Mass Spectrometry method, to identify approximately 3-dozen trace elements. The most abundant material in both samples was sodium, which occurred in the water droplets collected at locality BH3986-28 at a concentration of 447 ppm, and at locality W4064-31 at a concentration of 135 ppm. The next most respectively; silica at 12 and 9 ppm, respectively; potassium at 10.4 and 1.9 ppm, respectively; magnesium at 2.2 and 0.6 ppm, respectively; aluminum at 2.2 and 0.2 ppm, respectively; and less than 1 ppm of cobalt, zinc, arsenic, and bromine with even lower concentrations of remaining trace elements.

Based on the neutral pH values for the water samples, it would be difficult to consider water in the vicinity of the mine as "acid mine water." Based on the electrical conductivity values for the water samples, surface water appears to have little likelihood for representing a good conductor, although the sample from the Buckhannon River exhibited greater conductivity than that of ocean water. The water samples collected underground exhibit much greater values for electrical conductivity, with water dripping from the roof and rib exhibiting the highest conductivity values. The sample with the highest electrical conductivity value (W4064-31) was collected from the rib adjacent to the cased gas well (Figure 9). Based on a review of available literature, the value of 708 micro-Siemens/cm is comparable to the conductivity of a 30% solution of nitric acid. Because the pH of the sample is shown to be neutral, the high conductivity value suggests that some other ionic substance is present and has dissociated. Strong acids are considered good electrical conductors because they easily dissociate into charged ions in solution. The presence of high concentrations of sodium may be an indication of a strong ionic solution in this vicinity. That the sample with the very highest value of electrical conductivity is localized in the vicinity of the gas well may be significant, considering that the radial pattern of scour marks is located in the same entry within a few tens of feet, and radiate out from the entry corner beyond which is located the cased gas well (Figure 9). Of all the water samples collected, it appears that Sample W4064-31 would be the most likely to represent an electrolytic solution capable of conducting electricity. It should also be noted that during the sample collection effort, a significant amount of water was heard draining through the rib, which is an indication that this is not a solid, impermeable coal rib.

If you should have any questions or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.