Petrologic and Isotopic Data from the Cretaceous (Campanian) Blackhawk Formation and Star Point Sandstone (Mesaverde Group), Wasatch Plateau, Utah

By Neil S. Fishman, Christine E. Turner, and Fred Peterson

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Introduction

The presence of discrete minerals associated with coal—whether (1) detrital or authigenic constituents of the coals or in thin mudstone or siltstone units interbedded with coals, or (2) authigenic phases that formed along cleats—might influence its utilization as an energy resource. The build-up of sintered ash deposits on the surfaces of heat exchangers in coal-fired power plants, due to the alteration of minerals during combustion of the coal (Reid, 1981; Finkelman and Dulong, 1989), can seriously affect the functioning of the boiler and enhance corrosion of combustion equipment (Honea and others, 1982; Vaninetti and Busch, 1982). In particular, the presence of sodium in coals has been considered a key factor in the fouling of boilers (Ely and Barnhart, 1963); however, other elements (such as calcium or magnesium) and the amount of discrete minerals burned with coal can also play a significant role in the inefficiency of and damage to boilers (Finkelman and Dulong, 1989).

Previous studies of the quality of coals in the Cretaceous (Campanian) Blackhawk Formation of the Wasatch Plateau, Utah, revealed that the sodium content of the coals varied across the region (Finkelman, 1988, 1991). To better understand the origin and distribution of sodium in these coals, petrologic studies were undertaken within a sedimentological framework to evaluate the timing and geochemical constraints on the emplacement of sodium-bearing minerals, particularly analcime, which previously had been identified in coals in the Blackhawk Formation (Finkelman, 1988, 1991). Further, the study was broadened to include not just coals in the Blackhawk Formation from various localities across the Wasatch Plateau (fig. 1), but also sandstones interbedded with the coals as well as sandstones in the underlying Star Point Sandstone (fig. 2). The alteration history of the sandstones in both formations was considered a key component of this study because it records the nature and timing of fluids passing through them and the associated precipitation of sodium-bearing minerals; thus, the alteration history could place constraints on the distribution and timing of sodium mineralization in the interbedded or overlying Blackhawk coals. Although some preliminary results were previously presented at scientific meetings (Turner and others, 1997; Fishman and others, 1999), the petrologic and geochemical data have not been fully compiled and reported. The purpose of this report is to present the methods of data acquisition and the results of petrologic and isotopic analyses on coal and sandstone samples from the Blackhawk Formation as well as sandstones of the underlying Star Point Sandstone.

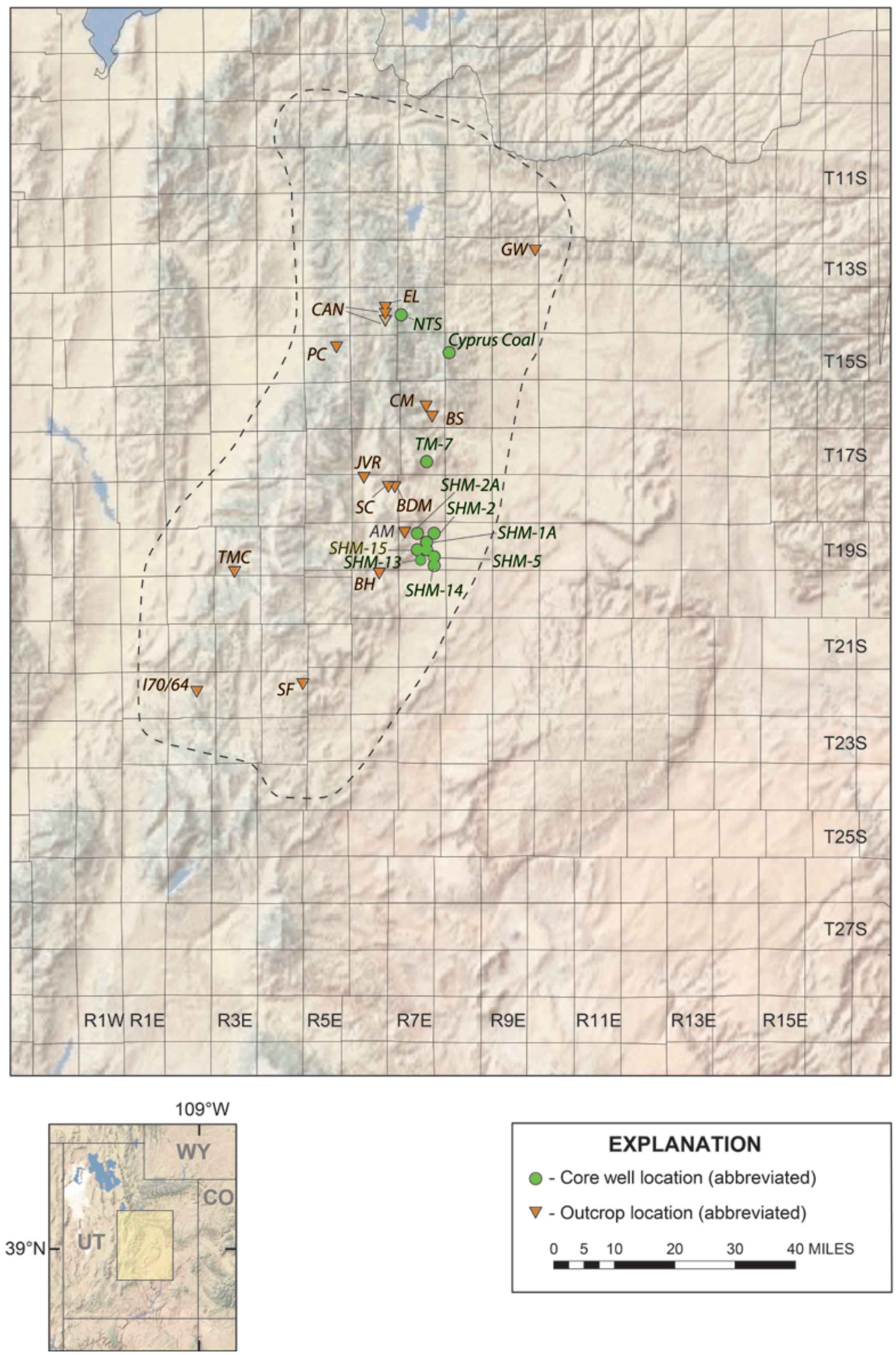

Figure 1. Map showing outcrop and drill core locations across the study area from which samples of the Cretaceous Blackhawk Formation and Star Point Sandstone were obtained. See tables 1 and 2 for location abbreviations. Generalized outline of the Wasatch Plateau also shown (dashed line).

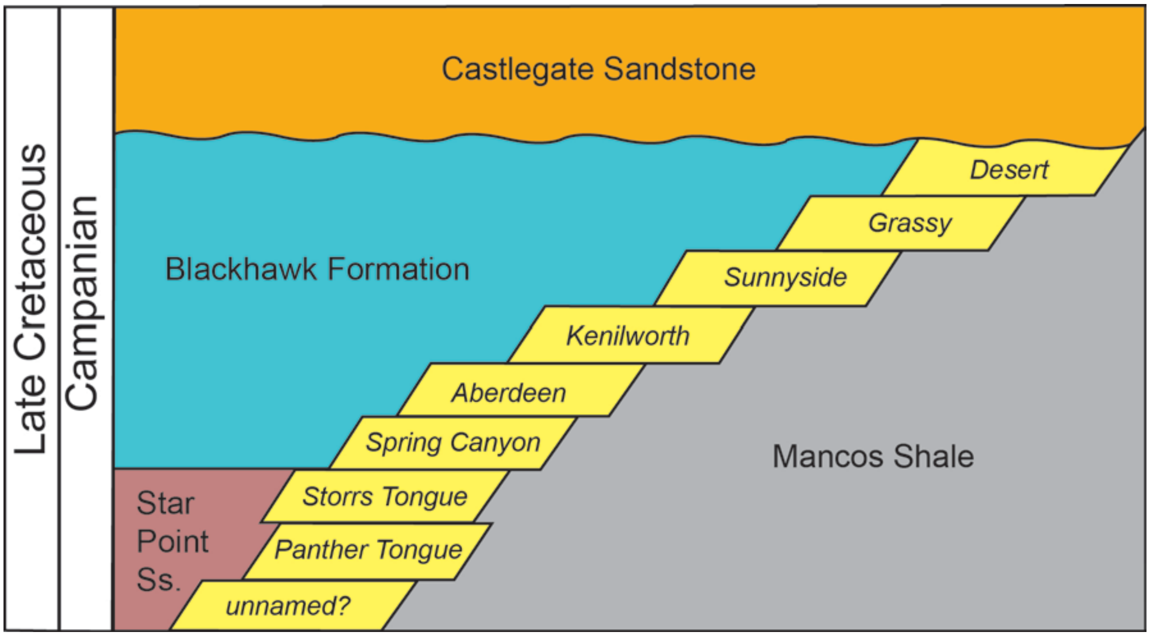

Figure 2. Generalized stratigraphic column showing the relative positions and ages of the units from which samples were taken for this study (modified from Young, 1955). Members of the Blackhawk Formation and Star Point Sandstone (in italics) are shown in yellow boxes. (Ss., sandstone)

Methods and Results

Petrologic and isotopic studies of the Blackhawk Formation and Star Point Sandstone included (1) petrography using standard and polished thin sections, (2) scanning electron microscopic (SEM) analyses, (3) X-ray diffraction analyses, and (4) carbon and oxygen isotopic determinations on calcite in coal samples and along fractures that cut sandstone samples. Samples for this study were obtained from both outcrops and drill cores. Fifteen outcrop sections were described and measured; they are shown on plate 1 (see table 1 for a listing of outcrop localities, locality abbreviations, and location information). The stratigraphic positions of samples collected for petrologic and geochemical studies are also shown in plate 1. Drill core location information is shown in table 2. Sample numbering is keyed to outcrop locality or the well from which the core was obtained. Herein, the first part of a sample number refers to the outcrop or core abbreviation, and the second part refers to the number designated in the measured section or depth for core samples. Numbers with the designation Kbh refer to samples from the Cretaceous Blackhawk Formation, whereas those designated Ksp are from the Cretaceous Star Point Sandstone. Several samples from the Gentile Wash locality were collected from parasequences in the Blackhawk Formation, and the numbering scheme for those samples also references the specific parasequence from which materials were collected (see plate 1).

Table 1. Location information for outcrops from which samples of the Blackhawk Formation and (or) Star Point Sandstone were collected. See plate 1 for measured sections at these localities, including the stratigraphic position of samples. See figure 1 for a map view of these localities.

Outcrop locality name	Locality abbreviation	Outcrop location information			
		Township	Range	Section	County
Anderson Mine	AM	19S	7E	7	Emery
Biddlecomb Hollow	BH	20S	6E	3	Emery
Birch Spring	BS	16S	7E	26	Emery
Black Diamond Mine	BDM	18S	6E	12	Emery
Candland Mountain (partial section)	CAN	14S	6E	26	Emery
Candland Mountain (partial section)	CAN	14S	6E	23	Emery
Co-op Mine	CM	16S	7E	22	Emery
Electric Lake	EL	14S	6E	14	Emery
Gentile Wash	GW	13S	9E	12	Carbon
Interstate 70, mileage post 64	I70/64	22S	2E	15	Emery
Joes Valley Reservoir	JVR	18S	6E	5	Emery
Pleasant Creek	PC	15S	5E	11	Sanpete
Straight Canyon	SC	18S	6E	11	Emery
Suffco Mine	SF	22S	4E	12	Emery
Twelvemile Creek	TMC (TMB-b)	19S	3E	33	Sanpete

Table 2. Location information for core samples of the Cretaceous Blackhawk Formation that were used in this study. Because depths at the Cyprus Coal core are indeterminate, core box number is given instead of sampling depth.

[API, American Petroleum Institute; ft, feet; do, same as above]

Core name	Core abbreviation	Well location information				Well API number	Sample number	Sample depth (ft)	Sample type
		Township	Range	Section	County				
Cyprus Coal 1	Cyprus Coal	15S	8E	18	Carbon	43-007-80000	Cyprus Coal 1	Box 7	coal
							Cyprus Coal 2	Box 6	sandstone
							Cyprus Coal 3	Box 6	sandstone
							Cyprus Coal 4	Box 4	coal
							Cyprus Coal 5	Box 2	coal
North Trough Spring-10	NTS	14S	7E	19	Carbon	43-007-80001	NTS-10-1	59	coal
							NTS-10-3	47.5	coal
South Horn Mountain-1A	SHM-1A	19S	6E	15	Emery	43-015-80000	SHM-1A-1	1,332.5	sandstone
							SHM-1A-2	1,324.0	sandstone
							SHM-1A-3	1,317.5	sandstone
							SHM-1A-4	1,305.0	coal
							SHM-1A-5	1,296.5	coal
							SHM-1A-6	1,273.0	sandstone
							SHM-1A-7	1,269.5	fracture
							SHM-1A-9	1,256.5	fracture
							SHM-1A-11	1,251.0	sandstone
							SHM-1A-12	1,244.5	fracture
South Horn Mountain-2A	SHM-2A	19S	6E	9	Emery	43-015-80002	SHM-2A-1	1,359.0	sandstone
							SHM-2A-2	1,343.0	sandstone
South Horn Mountain-2	SHM-2	19S	6E	11	do	43-015-80000	SHM-2-1	1,118.5	sandstone
							SHM-2-2	1,113.0	sandstone
							SHM-2-3	1,110.0	coal
							SHM-2-4	1,095.0	sandstone

Table 2. Location information for core samples of the Cretaceous Blackhawk Formation that were used in this study. Because depths at the Cyprus Coal core are indeterminate, core box number is given instead of sampling depth.—Continued

[API, American Petroleum Institute; ft, feet; do, same as above]

Core name	Core abbreviation	Well location information				Well API number	Sample number	Sample depth (ft)	Sample type
		Township	Range	Section	County				
							SHM-2-6	1,069.0	Coal
							SHM-2-7	1,059.5	coal
							SHM-2-8	1,055.0	coal
South Horn Mountain-5	SHM-5	19S	6E	22	do	43-015-80001	SHM-5-1	1,035.0	sandstone
							SHM-5-2	1,028.5	sandstone
							SHM-5-3	1,015.5	sandstone
							SHM-5-4	1,007.5	sandstone
							SHM-5-5	1,003.0	sandstone
							SHM-5-6	1,001.0	coal
South Horn Mountain-13	SHM-13	19S	6E	26	do	43-015-80003	SHM-13-2	1,116.0	coal
							SHM-13-3	1,113.0	sandstone
							SHM-13-4	1,111.0	sandstone
South Horn Mountain-14	SHM-14	19S	6E	35	do	43-015-80004	SHM-14-1	987.5	sandstone
							SHM-14-2	983.0	sandstone
							SHM-14-3	982.0	sandstone
							SHM-14-4	941.5	coal
South Horn Mountain-15	SHM-15	19S	6E	21	Emery	43-015-80005	SHM-15-1	1,118	sandstone
Trail Mountain-7	TM-7	17S	6E	27	Emery	43-015-80933	TM-7-1	2,498.5	sandstone
							TM-7-2	2,428.0	sandstone
							TM-7-6	2,368.5	sandstone
							TM-7-7	2,341.5	sandstone
							TM-7-8	2,302.5	sandstone
							TM-7-10	2,242.5	sandstone
							TM-7-11	2,225.5	sandstone

Table 2. Location information for core samples of the Cretaceous Blackhawk Formation that were used in this study. Because depths at the Cyprus Coal core are indeterminate, core box number is given instead of sampling depth.—Continued

[API, American Petroleum Institute; ft, feet; do, same as above]

Core name	Core abbreviation	Well location information				Well API number	Sample number	Sample depth (ft)	Sample type
		Township	Range	Section	County				
							TM-7-12	2,195.0	coal
							TM-7-13	2,190.0	sandstone
							TM-7-16	2,119.5	fracture
							TM-7-17	2,081.0	coal
							TM-7-19	2,052.0	sandstone
							TM-7-20	2,012.0	coal
							TM-7-21	1,953.5	sandstone
							TM-7-23	1,953.0	sandstone
							TM-7-24	1,935.0	sandstone
							TM-7-25	1,925.7	coal
							TM-7-26	1,876.0	sandstone
							TM-7-27	1,868.0	sandstone
							TM-7-29	1,800.5	sandstone
							TM-7-30	1,778.5	sandstone
							TM-7-31	1,758.0	coal
							TM-7-32	1,697.0	fracture
							TM-7-33	1,675.0	sandstone
							TM-7-34	1,640.6	coal
							TM-7-35	1,615.0	sandstone
							TM-7-36	1,599.0	sandstone
							TM-7-37	1,590.0	sandstone
							TM-7-39	1,553.0	sandstone
							TM-7-40	1,535.5	sandstone
							TM-7-41	1,510.0	sandstone
							TM-7-42	1,506.0	sandstone

Petrographic analyses provided data concerning the modal composition of sandstones in the Blackhawk and Star Point, as well as the fundamental relations that facilitated construction of a paragenetic sequence of alterations for the sandstones (fig. 3). Rock chips used in making thin sections (n = 238) were impregnated with blue epoxy to better observe the quantity and distribution of porosity. The thin sections were stained with (1) alizarin red-S and potassium ferricyanide to assist in carbonate mineral compositional determination (after Dickson, 1966) and (2) sodium cobaltinitrite to identify potassium feldspar. Point counts (300 points/thin section) were performed on representative (n = 38) thin sections of sandstones, and the count data were converted to volume percent (see table 3).

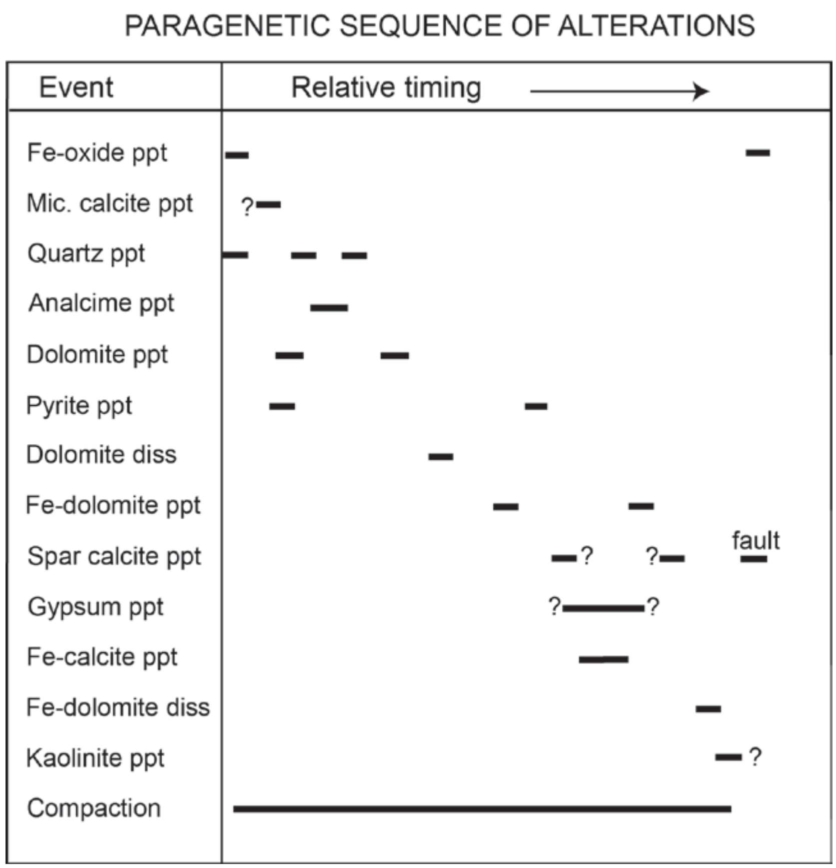

Figure 3. Summary of the paragenetic sequence of alterations in sandstone beds in the Blackhawk Formation and Star Point Sandstone. Arrow points in direction of decreasing age. (ppt, precipitation; Fe, iron; mic., micritic; diss, dissolution; fault, calcite along faults)

Table 3. Point count data (converted to volume percent) for sandstones from either the Blackhawk Formation ("bh" in sample number) or Star Point Sandstone ("sp" in sample number). See tables 1 and 2 for key to outcrop and core abbreviations and locations, respectively.

[%, percent; RF, rock fragments; Misc., miscellaneous detrital grains (such as heavy minerals); Non-Fe Cal., non-ferroan calcite; Fe-calcite, ferroan calcite; Fe-dolomite, ferroan dolomite; OV, overgrowth; Fe-oxide, iron oxide]

Sample number	Formation sampled	Detrital grains (volume %)					Authigenic phases (volume %)					Porosity (volume %)		Total %
		Quartz	Feldspar	RF	Misc.	Non-Fe Cal.	Fe-calcite	Dolomite	Fe-dolomite	Quartz OV	Fe-oxide	Primary	Secondary	
AM-Kbh-2	Blackhawk	61	0	19	0	1	0	2	0	1	1	14	1	100
AM-Kbh-4	Blackhawk	59	0	25	0	2	0	0	0	1	0	12	0	100
AM-Kbh-8	Blackhawk	62	1	21	3	0	0	0	0	1	0	10	0	100
BDM-Kbh-1	Blackhawk	56	4	32	0	4	0	0	0	0	2	3	0	100
BDM-Kbh-11	Blackhawk	51	0	28	2	6	0	0	0	3	1	8	1	100
BDM-Kbh-3	Blackhawk	51	0	30	2	7	0	0	0	1	0	8	1	100
BH-Kbh-1	Blackhawk	56	0	26	0	5	0	1	0	2	2	7	1	100
BH-Ksp-1	Star Point	50	7	24	4	0	2	1	0	0	1	10	0	100
BH-Ksp-10	Star Point	40	1	36	0	0	0	0	0	0	1	20	1	100
BH-Ksp-8	Star Point	48	1	24	1	3	0	1	0	1	1	20	1	100
BS-Kbh-3	Blackhawk	53	0	32	0	7	0	0	0	1	0	6	1	100
BS-Ksp-1	Star Point	55	1	28	0	1	1	0	1	2	0	11	0	100
BS-Ksp-13	Star Point	58	1	25	0	1	1	0	0	1	0	12	0	100
BS-Ksp-6	Star Point	49	3	34	0	10	0	0	0	1	0	4	0	100
GW-Kbhhe-1	Blackhawk	72	3	8	0	7	0	0	0	1	1	8	1	100
GW-Kbhsb-3	Blackhawk	58	0	23	1	1	3	0	2	1	3	7	0	100
I70/64-Kbh-1	Blackhawk	46	3	30	9	2	9	0	0	0	0	0	0	100
I70/64-Kbh-5	Blackhawk	62	1	12	7	0	0	0	0	1	10	7	0	100
I70/64-Kbh-8	Blackhawk	58	1	19	0	0	0	1	1	0	3	16	2	100
SHM-15-1	Blackhawk	65	0	11	0	0	0	0	0	2	0	20	1	100

Table 3. Point count data (converted to volume percent) for sandstones from either the Blackhawk Formation ("bh" in sample number) or Star Point Sandstone ("sp" in sample number). See tables 1 and 2 for key to outcrop and core abbreviations and locations, respectively.—Continued

[%, percent; RF, rock fragments; Misc., miscellaneous detrital grains (such as heavy minerals); Non-Fe Cal., non-ferroan calcite; Fe-calcite, ferroan calcite; Fe-dolomite, ferroan dolomite; OV, overgrowth; Fe-oxide, iron oxide]

Sample number	Formation sampled	Detrital grains (volume %)					Authigenic phases (volume %)					Porosity (volume %)		Total %
		Quartz	Feldspar	RF	Misc.	Non-Fe Cal.	Fe-calcite	Dolomite	Fe-dolomite	Quartz OV	Fe-oxide	Primary	Secondary	
SHM-1A-1	Blackhawk	52	0	27	0	2	0	0	0	4	0	15	1	100
SHM-1A-11	Blackhawk	48	0	33	0	0	12	2	4	0	0	0	0	100
SHM-1A-2	Blackhawk	67	0	13	0	0	0	0	0	3	0	15	1	100
SHM-1A-3	Blackhawk	67	0	4	0	0	0	0	0	1	14	13	1	100
SHM-1A-6	Blackhawk	62	0	11	0	0	11	5	4	5	0	2	0	100
SHM-2-2	Blackhawk	74	0	9	0	0	0	0	0	2	8	7	1	100
SHM-2A-1	Blackhawk	47	1	29	0	4	2	0	1	2	0	15	1	100
SHM-2A-2	Blackhawk	43	0	37	0	5	0	0	2	2	0	11	0	100
SHM-5-3	Blackhawk	57	1	18	0	0	0	0	0	2	0	21	0	100
SHM-5-4	Blackhawk	68	0	8	1	0	0	0	0	3	3	16	1	100
SHM-5-5	Blackhawk	70	0	5	0	0	0	0	0	2	8	15	1	100
TMC-b-Kbh-1	Blackhawk	69	1	20	7	0	0	0	0	0	0	3	1	100
TMC-b-Kbh-2	Blackhawk	71	1	9	4	0	0	0	0	0	0	15	1	100
TMC-b-Kbh-4	Blackhawk	67	1	16	3	0	0	0	0	0	0	13	0	100
TMC-Kbh-5	Blackhawk	65	1	9	4	0	0	0	0	4	0	16	0	100
TMC-Kbh-7	Blackhawk	72	0	13	14	0	0	0	0	0	0	2	0	100
TMC-Kbh-8	Blackhawk	70	1	11	8	0	2	0	0	2	0	4	1	100
TMC-Kbh-9	Blackhawk	79	0	7	2	0	0	0	0	3	0	8	1	100

Paragenetic relations between alteration events in sandstones (see fig. 3) were refined through SEM investigations, and the SEM was also used to determine the composition of authigenic minerals. Rock chips of selected samples were coated with gold for SEM viewing and analyses. The SEM was equipped with an energy dispersive analyzer of X-rays, which provided information concerning the elements within the minerals being studied (after Goldstein and others, 1981). In addition, SEM studies were undertaken on 18 polished thin sections to enhance our understanding of the distribution of elements in detrital and authigenic minerals.

X-ray diffraction (XRD) analysis, using standard XRD techniques with CuK_α radiation, was performed on material collected from coal cleats or fractures. Minerals removed from coals of the Blackhawk Formation were from apertures along one of two types of cleats, either face cleats or butt cleats (cleat terminology after Laubach and others, 1998). Cleats are defined as those fractures approximately normal to bedding and approximately perpendicular to each other. Much of the mineral material used for this study was likely from face cleats, in that these were the cleats that were more prominent and into which the subordinate butt cleats commonly terminated. Minerals were also obtained from fractures that cut across beds, including coals, sandstones, and siltstones. Cleats and fracture surfaces were exposed by pulling rock samples apart, and the minerals present on these surfaces were then removed with a scalpel and tweezers. The minerals that were identified in the cleats and fractures are summarized in table 4.

Table 4. Blackhawk Formation samples from which material was obtained from apertures (either cleats or fractures) and analyzed by X-ray diffraction and (or) scanning electron microscope.

[Fe, iron; NaCl, sodium chloride; coarse, coarse crystal size; fine, fine crystal size. See table 1 for location of AM, GW, and I70/64 sites and table 2 for location of Cyprus Coal, NTS, SHM-1A, SHM-2, SHM-5, SHM-13, SHM-14, and TM cores]

Sample number	Source of mineral(s)	Mineral(s) present											
		Quartz	Non-Fe calcite	Non-Fe dolomite	Fe-dolomite	Ankerite	Analcime	NaCl	Gypsum	Kaolinite	Illite	Pyrite	Barite
AM-Kbh-1	Cleat								X				
BDM-Kbh-10	Cleat						X		X				
BDM-Kbh-5	Cleat								X				
BDM-Kbh-7	Cleat	X	X				X			X			
BH-Ksp-13	Cleat	X								X			
CM-Kbh-3	Cleat		X							X			
Cyprus Coal 1	Cleat			X			X						
Cyprus Coal 4	Cleat		X	X		X	X					X	
Cyprus Coal 5	Cleat		X									X	
GW-Kbhhp-3	Cleat		X	X					X	X			
GW-Kbhsb-11	Cleat							X	X	X			
I70/64 Kbh-4	Cleat	X							X	X			
NTS-10-1	Cleat		X										
NTS-10-3	Cleat		X							X		X	
SC-Kbh-2	Cleat						X			X			
SHM-1A-4	Cleat		X										
SHM-1A-5	Cleat						X					X	
SHM-1A-7	Fracture		X										
SHM-1A-9	Fracture		X	X		X							

Table 4. Blackhawk Formation samples from which material was obtained from apertures (either cleats or fractures) and analyzed by X-ray diffraction and (or) scanning electron microscope.—Continued

[Fe, iron; NaCl, sodium chloride; coarse, coarse crystal size; fine, fine crystal size. See table 1 for location of AM, GW, and I70/64 sites and table 2 for location of Cyprus Coal, NTS, SHM-1A, SHM-2, SHM-5, SHM-13, SHM-14, and TM cores]

Sample number	Source of mineral(s)	Mineral(s) present											
		Quartz	Non-Fe calcite	Non-Fe dolomite	Fe-dolomite	Ankerite	Analcime	NaCl	Gypsum	Kaolinite	Illite	Pyrite	Barite
SHM-1A-12 coarse	Fracture		X										
SHM-1A-12 fine	Fracture		X										
SHM-2-3	Cleat						X					X	
SHM-2-6	Cleat		X										
SHM-2-7	Cleat		X				X					X	
SHM-2-8	Cleat											X	X
SHM-5-6	Cleat									X			X
SHM-13-2	Cleat		X	X		X	X					X	
SHM-13-3	Fracture			X						X			X
SHM-14-4	Cleat		X		X		X		X			X	
TM-7-12	Cleat	X											
TM-7-16 fine	Fracture		X										
TM-7-16 coarse	Fracture		X										
TM-7-17	Cleat		X						X			X	
TM-7-20	Cleat		X				X						
TM-7-25	Cleat		X	X									
TM-7-31	Cleat		X						X	X		X	
TM-7-32	Fracture	X											X
TM-7-34	Cleat									X			X

Where sufficient calcite was present along a cleat or fracture, the carbon and oxygen isotopic composition of the calcite was determined. Isotopic determinations were performed on 20 samples of fracture-fill calcite from various localities and 4 samples of authigenic calcite that was present as a cleat-filling mineral. Isotopic measurements were made on the CO_2 that was produced upon reaction with phosphoric acid at 25°C during the first 6 hours. The isotopic data (table 5) are reported using the delta notation ($\delta^{13}C$ and $\delta^{18}O$) referenced to the PDB standard (*Belemnitella americana* from the Upper Cretaceous Peedee Formation in South Carolina). The carbon and oxygen isotopic data presented in this report were calculated as follows:

$$\delta^{13}C = ((R_{sample})/R_{standard})-1) \bullet 1000 \text{ per mil (‰)}$$

$$\delta^{18}O = ((R_{sample})/R_{standard})-1) \bullet 1000 \text{ per mil (‰)}$$

where

R is $^{13}C/^{12}C$ or $^{18}O/^{16}O$.

Oxygen isotopes are also presented in standard mean ocean water (SMOW) notation in table 5; SMOW values were determined by converting PDB values using the relationship $\delta_{SMOW} = (\delta_{PDB} + 29.94)/0.97006$.

Table 5. Carbon and oxygen isotopic composition of calcite from either cleats or fractures in the Blackhawk Formation (Kbh in sample number) or Star Point Sandstone (Ksp in sample number). See tables 1 and 2 for outcrop and core locations, respectively.

[PDB, Pee Dee Belemnite standard; SMOW, standard mean ocean water]

Sample number	Mineral occurrence	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)	$\delta^{18}O$ (SMOW)
CM-Kbh-3	Cleat	–8.497	–17.406	12.966
Cyprus Coal 4	Cleat	–3.258	–14.079	16.396
Cyprus Coal 5	Cleat	–5.993	–19.578	10.726
TM-7-31	Cleat	1.171	–18.069	12.282
BS-Kbh-3 edge	Fracture, adjacent to sandstone	–8.339	–14.007	16.470
BS-Kbh-3 edge (replicate)	Fracture, adjacent to sandstone	–8.355	–13.972	16.507
BS-Kbh-3 middle	Fracture, adjacent to "edge"	–7.719	–13.846	16.636
BS-Kbh-3-center	Fracture, central part of fracture	–8.237	–13.814	16.669
BS-Ksp-2A	Fracture	–6.857	–16.661	13.734
BS-Ksp-2B	Fracture	–6.691	–16.977	13.408
JVR-Kbh-1 center	Fracture, central part of fracture	–2.177	–13.468	17.025
JVR-Kbh-1 middle	Fracture, adjacent to "edge"	–0.101	–12.847	17.666
JVR-Kbh-1 edge	Fracture, adjacent to sandstone	–0.310	–13.020	17.488
JVR-Kbh-2 center	Fracture, central part of fracture	–3.932	–13.560	16.931
JVR-Kbh-2 middle	Fracture, adjacent to "edge"	–3.163	–13.761	16.723
JVR-Kbh-2 edge	Fracture, adjacent to sandstone	–1.834	–13.767	16.718
SHM-1A-12 coarse	Fracture, coarse crystals	–1.723	–19.167	11.151
SHM-1A-12 fine	Fracture, fine crystals	–1.725	–19.111	11.208
SHM-1A-4	Fracture	0.651	–18.894	11.432
SHM-1A-7	Fracture	–0.901	–18.463	11.876
SHM-1A-9	Fracture	–1.790	–18.750	11.580
SHM-2-7	Fracture	–4.294	–15.092	15.351
TM-7-16 coarse	Fracture, coarse crystals	–1.724	–16.096	14.317
TM-7-16 fine	Fracture, fine crystals	–1.796	–17.218	13.160

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