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Coal Quality Characteristics of the Blind Canyon Coal Bed, Utah, Source of the Argonne #6 Premium Sample

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ABSTRACT

The Blind Canyon coal bed, a high volatile bituminous coal in the Wasatch Plateau coal field in Emery County, Utah was sampled for the Argonne Premium Coal Sample Bank. The Blind Canyon coal bed is in the Upper Cretaceous Blackhawk Formation of the Mesaverde Group. This coal is economically important in Utah because of its thickness (average 6 to 10 ft, 1.8 to 3.0 m) and good quality; the average ash yield and sulfur content of Blind Canyon coal samples in this study are 4.5 percent and 0.6 percent, respectively. The chemical composition of the Blind Canyon coal bed is extremely consistent across the entire Wasatch Plateau, thus enhancing its desirability. The Blind Canyon coal bed has a very high liptinite content, the majority of which are resinite macerals. In addition, relatively high amounts of telinite and corpocollinite in telinite are present. The Blind Canyon coal bed is interpreted to have developed in a slightly acidic, extremely stable swamp environment, which contained very resinous flora. The high resinite content may have contributed to the relatively high heating value and relatively high volatile matter content within the coal bed.

BACKGROUND

The Blind Canyon coal bed was sampled as part of the Argonne National Laboratory's Premium Coal Sample Program and is included as sample #6 of the Premium Coal Sample Bank. The Argonne Premium Coal Sample Program entailed sampling eight coal beds of various ranks and properties throughout the United States. The Premium Coal Sample Bank is intended to be a sample resource containing consistent, high quality coal samples available to coal researchers. A general description of the program may be found in Vorres (1989). Detailed analyses, characterization of the coal from coal bed facies samples, and interpretation of the data are the subject of this paper.

INTRODUCTION

The Blind Canyon coal bed, a high volatile bituminous coal, was sampled in the Little Dove Mine, Emery County, near the town of Huntington, Utah, about 120 mi southeast of Salt Lake City (fig. 1). The Little Dove Mine (fig. 2), which is owned and operated by The Utah Power and Light Company, is located on the eastern flank of the Wasatch Plateau. The Wasatch Plateau has rugged topography and is bordered on the east by the Castle Valley and on the west by the Sanpete Valley. The Blind Canyon coal bed is located in the Wasatch Plateau coal field within the Wasatch Plateau (fig. 2). The Wasatch Plateau coal field is oriented approximately north-south and is about 90 mi (145 km) long and 7 to 20 mi (11 to 32 km) wide. The eastern boundary of the coal field is an erosional escarpment and its western boundary approximates the drainage divide for the Wasatch Plateau.

The Blind Canyon coal bed is Late Cretaceous [early Campanian (Van de Graaff, 1972), middle Montanan (Spieker, 1931)] in age and is associated with other thick (average 6 to 10 ft), minable coal beds within the Blackhawk Formation. The Blackhawk Formation is the middle member of the Mesaverde Group (fig. 3) and is the only coal-bearing formation within the group. Stratigraphically, the Blind Canyon coal bed is the second coal from the base of the Blackhawk Formation. It generally occurs 60-80 ft (18-24 m) above the base of the formation and 40 to 60 ft (12 to 20 m) above the first coal, the Hiawatha coal bed, which is very persistent in the study area. The Blind Canyon coal bed ranges from 4 to 15 ft (1.2 to 4.6 m) in thickness within the study area. Within the Little Dove mine, the coal bed is approximately 10.5 ft (3.2 m) thick, but only 8.5 ft (2.6 m) of the bed is mined.

Economically, the Blind Canyon coal bed is an important resource in the Wasatch Plateau coal field (fig. 2) in central Utah. The Wasatch Plateau coal field is currently the most productive field in Utah (Keystone, 1987). Coal was first discovered in the Wasatch Plateau coal field in 1874 and mining began in 1875 (Spieker, 1931).

DEPOSITIONAL ENVIRONMENT

The first in-depth work in the Wasatch Plateau and the classic study of this sequence of rocks was done by Spieker (1931). The area has since been studied by many workers. The interval consisted of a sediment complex prograding eastward into the regressing Cretaceous epeiric sea that extended from the Gulf of Mexico to the Arctic Sea (Van de Graaff, 1972). The strandline of this epicontinental seaway extended generally north-south. The grain size decreases irregularly eastward through all the facies (and downward in the section) (Van de Graaff, 1972) and the source of these sediments is from the erosion associated with the uplift of the Sevier orogenic belt located to the west, in western Utah and eastern Nevada (Armstrong, 1968).

The oldest Campanian stratigraphic unit is the Star Point Sandstone (fig. 3) and was interpreted as representing beach or littoral sandstone deposits by Spieker (1931). Basinal marine mud was deposited further to the east in the Wasatch Plateau (Spieker, 1931; Van de Graaff, 1972), which today is the Mancos Shale. The "spasmodic" nature of the orogenic activity to the west caused the variations in the stratigraphic units in the Mancos Shale (fig. 3) (Doelling, 1972). Periods of high orogenic activity resulted in deposition of units such as the Ferron Sandstone Member and Emery Sandstone. Relative quiescence resulted in trangression and marine mud deposition, which are today the Tununk Shale Member, Blue Gate Member, and Masuk Shale (fig. 3), respectively.

The final retreat of the Mancos (Masuk) sea resulted in deposition of the Star Point Sandstone (Doelling, 1972). Oscillations in the shore face resulted in the intertonguing of the Mancos Shale and the Star Point Sandstone (Spieker, 1931). The main shoreface contact withdrew to the east during Mesaverde time (Spieker, 1931; Van de Graaff, 1972).

The contact between the Star Point Sandstone and the Blackhawk Formation was first believed to be consistent and mappable over most of the Wasatch Plateau (Spieker, 1931), but is in reality an intertonguing relationship (Clark, 1938; Marley and others, 1979; Blanchard, 1981; Sanchez, 1983). The Blackhawk Formation is composed of low gradient distributary channel sandstones interbedded with mudstones and siltstones. The lower half of the formation contains thick (up to 15 ft, 4.6 m), minable coal beds.

Spieker (1931) interpreted the rocks in the Blackhawk Formation to have originated from broad flood plain or coastal plain sediments, what Van de Graaff (1972) termed the "delta plain facies." Marley and others (1979) further refined these interpretations and reported that the Blackhawk represents the marginal deltaic facies of an easterly prograding deltaic-alluvial detrital wedge. Although the area was susceptible to marine incursions, as evidenced by the presence of brackish water fossils within the lagoonal sediments (Spieker, 1931; Marley and others, 1979), extensive swamps were present on the coastal plain sediments, accounting for the very thick coal beds present today. Due to the incursions by the Mancos sea, the coal divisions within the lower Blackhawk Formation are not single, continuous beds fixed in time stratigraphic zones (Doelling, 1972; Flores and others, 1984), but rather are a series of related, yet discontinuous coal beds.

The contact between the Blackhawk Formation and the Price River Formation (fig. 3) is marked by an abrupt increase in grain size (Spieker, 1931; Armstrong, 1968) resulting from a strong orogenic pulse from the west (Doelling, 1972). Van de Graaff (1972) interpreted the Castlegate Sandstone Member, the lowermost unit of the Price River Formation, as having originated from numerous coalescing streams, in other words, braided alluvial sands and named it the "fluvial facies." Above the Castlegate Sandstone, the Price River Formation, or the Price River-North Horn Formations (undifferentiated), is composed of poorly sorted, red bed conglomerates which Van de Graaff (1972) named the "piedmont facies" because they originated from coalescing alluvial fans originating from the highlands to the west.

COALS OF THE BLACKHAWK FORMATION

The thickest, most economically important coal beds are found only in the lowest section of the Blackhawk Formation. The 22 coal beds in the Blackhawk Formation, all greater than four ft (1.22 m) thick, occur in the lower third of this formation (Doelling, 1972). The thickest, most persistent coal beds developed in swamps that were located closest to the Mancos sea. Coal beds stratigraphically higher in the section are thinner and not laterally extensive. As the Cretaceous sea regressed eastward, these thinner and less extensive coals were formed in swamps that were located further inland from the sea. According to Marley and others (1979), there are two types of coal beds within the Blackhawk Formation - deltaic and backbarrier. The coal beds formed in the backbarrier environment tend to be poorly developed, are few in number, thin and not laterally continuous. The coal beds deposited in the marginal deltaic environments, on the other hand, are better developed, numerous, thick, and laterally continuous. Minable coal is restricted to the marginal deltaic deposits, landward of lagoonal subfacies shales (Marley and others, 1979).

SAMPLING SCHEME FOR THE BLIND CANYON COAL

As in the previous sampling of other coal beds for the Argonne Premium Coal Sample Bank, one ton of coal was collected by hand with pick axes to avoid all possible contamination, such as that from mining equipment. The Little Dove mine was in the process of retreat mining when the Argonne sample was obtained, which meant that the sampled coal block was not as fresh as some of the other Argonne samples. Therefore, to avoid possible effects of oxidation, the mining cut was removed to a depth of about one ft before the sample was taken. The Argonne Premium sample was taken along a passageway at an abandoned entry on a somewhat angled surface. The coal was sampled by using hand-held picks from "floor" to roof, and then loaded into stainless steel drums that had been transported into the mine near the sample site. The drums were removed from the mine on a shuttle car and then purged with argon gas to prevent further oxidation following the Argonne Premium Coal Sample procedure. The bottom two feet of the Blind Canyon coal bed is not mined in the Little Dove mine to increase stability of the mine walls. The Argonne Premium sample therefore included all coal except the bottom two ft, which comprises the mine floor, and excluded a two-in. claystone parting.

After collecting the gross channel sample for the Argonne Premium sample, the coal bed was described and facies boundaries were determined. The facies within the Blind Canyon coal bed were described mainly on the basis of very distinct differences in the breakage characteristics and degree of bright and dull layers comprising the coal. After the facies were described, the facies were channel sampled for additional petrographic and chemical analyses. The description of the coal bed taken in the mine is shown in Figure 4.

SAMPLE PREPARATION

Sample preparation consisted of (1) the Argonne Premium Coal Sample Method for the gross channel sample (Vorres, 1989) and (2) facies channel sample preparation at U.S. Geological Survey laboratories. Facies channel samples were ground to -20 mesh and split for a variety of analyses. A commercial laboratory performed proximate analyses (percent moisture, percent ash, percent volatile matter, and percent fixed carbon), and determined sulfur forms and calorific value (Btu per pound). All procedures of sampling and analyses conformed to the American Society of Testing Materials (ASTM) guidelines (ASTM, 1985).

Other subsplits of the coal were used to make coal pellets for petrographic analyses. The coal was mixed with a binding agent of epoxy resin, allowed to cure and then ground and polished to obtain a scratch-free surface. These pellets were then analyzed petrographically using reflected-light microscopy. The pellets were point counted, 500 points per pellet, using fluorescent-light (blue irradiation) to identify and count the macerals of the liptinite group. Examination consisted of excitation by light filtered to transmit a peak intensity of 450nm and observation of the fluorescence by using a 510nm barrier filter. The pellets were then etched in a solution of potassium permanganate and sulfuric acid to bring out the details of the vitrinite macerals (Stach and others, 1982). The coal pellets were point counted again using white light, bright field illumination to identify and count the macerals of the inertinite and vitrinite groups. For each sample, two pellets were analyzed and compared to ensure that the results were within two percent mean variation (ASTM, 1985). All laboratory procedures for sample preparation conformed to ASTM guidelines (ASTM, 1985). The reflectance of vitrinite was measured in accordance with ASTM standard method D2798 (ASTM, 1989).

CHEMISTRY AND COAL QUALITY

The Blind Canyon coal bed is a high volatile bituminous coal, probably in the B group of the high volatile class. The vitrinite reflectance (mean-maximum R_o), determined on the whole bed sample, is 0.51 percent. The rank-determining calorific value is 13973 (Btu per pound, on a moist, mineral-matter-free basis). The reflectance indicates a rank close to the high volatile A - B border; the calorific value indicates a rank at the high end of the high volatile B group's range. The higher than average calorific value for a coal with 0.51 R_o is probably the result of the high resin content of the Blind Canyon coal (Spieker, 1931).

The quality of each coal bed in the lower Blackhawk Formation is very consistent across the entire Wasatch Plateau (Spieker, 1931). An examination of chemical data from different published sources illustrates a consistency of the Blind Canyon coal bed for values of moisture, volatile matter, ash yield, calorific value (Btu/lb), and sulfur content (Table 1). Exact locations for most of the data in Table 1 are not available. However, values represent analyses of many drill holes from the northern two-thirds of the Wasatch

Plateau coal field. The quality data for the Blind Canyon Premium sample are shown in Table 2. The Blind Canyon coal bed is a remarkably consistent, high quality coal with low ash yield, sulfur content, and high calorific value. It appears that the environment of formation for the Blind Canyon peat would have to have been somewhat stable throughout the development of the peat for the chemical variables to be so consistent.

PETROGRAPHY

The Blind Canyon coal was chosen as part of the Argonne sampling scheme because of its reportedly high visible resin content. The relatively high liptinite content is evident from the petrographic analyses (Table 3). In some cases, the liptinite content reaches 32 percent on a whole coal, mineral free basis. Facies 1.1 and 1.3 have high vitrinite and low inertinite contents, whereas facies 1.2 has a relatively low vitrinite and high inertinite content. The lowermost facies, 1.5, has both relatively low vitrinite and inertinite contents, and a very high liptinite content. Where there is an abundance of vitrinite (facies 1.1 and 1.3), the main constituent is telinite (preserved cell wall material). In addition, a large portion of the vitrinite content in facies 1.1 and 1.3 is corpocollinite bodies contained in telinite. When the total vitrinite content is low, the relative abundance of telinite is also low. The desmocollinite (degraded vitrinite) content, on the other hand, is more or less constant, except for the uppermost facies in which it is somewhat lower. The high percentage of telinite and corpocollinite in certain facies suggests a preservational mode indicative of either plants that were resistant to decay or most probably an overall acidic environment.

The high liptinite content of the Blind Canyon coal bed made it desirable for inclusion in the Argonne Premium Coal Sample Bank. Virtually every worker in the Wasatch Plateau has commented on the resinous nature of the coals within the Blackhawk

Formation (Spieker, 1931; Buranek and Crawford, 1943; Doelling, 1972 and 1977; Marley and others, 1979; Crelling and others, 1982). Indeed, an abundance of visible resin was coalesced on and coated the surface of the Blind Canyon coal bed where the coal was described underground. This phenomenon has been observed in other western coals of Cretaceous and Tertiary age (Thiessen and Sprunk, 1937; Buranek and Crawford, 1943). A similar phenomenon has been described in Carboniferous bituminous coals of Great Britain (Jones and Murchison, 1963; Murchison and Jones, 1964).

In addition to the macroscopically visible resin, microscopic primary resinite and its secondary forms, exsudatinite and bituminite are also present in the Blind Canyon coal bed (Table 3). Three types of resinite were observed and counted in the petrographic analyses of the Blind Canyon coal bed: primary resinite, which are resinite bodies contained within another maceral such as vitrinite (fig. 5); secondary resinite, which includes exsudatinite and bituminite; and free-floating resinite bodies which are independent of any other maceral (fig. 5). These three resinite types were added together (Table 3) to determine the amount of total microscopic resinite contained within the Blind Canyon coal samples. The amount of total resinite is greater than the total of other liptinite macerals, excluding liptodetrinite. There is a possibility that some, or a good deal, of the liptodetrinite may be bituminite. In that case, the (secondary) resinite content may be even higher. It is unusual for a coal bed to have such a relatively high resinite content; in most coal beds sporinite is the dominant liptinite maceral (Murchison and Jones, 1964; Crelling and others, 1982). A petrographic study conducted by the Utah Geological and Mineralogical Survey indicated the same trend: the percentage of resinite is greater than or equal to the percentage of sporinite in the Blind Canyon coal bed (Sommer, S.N., 1989).

The greatest amount of primary and total resinite is in facies 1.2 and 1.5 (Table 3). These are also the facies in which the most surficial resin was noticed and described megascopically (fig. 4). It is believed that the resinite is fluidized by the slightly increased temperature and pressure conditions of burial under sedimentary cover (Jones and Murchison, 1963). The Blind Canyon was sampled within the Little Dove mine at a point that was greater than 900 ft underground. A great deal of resin has been mobilized within the Blind Canyon coal, given the abundance of resin on the surface of the coal, as well as the presence of secondary resinite, i.e. bituminite and exsudatinite. Collectively, the high percentage of resinite in the coal bed indicates that the initial vegetation that comprised the peat of the Blind Canyon swamp must have been very resinous.

The flora of the Blackhawk Formation was reconstructed by Parker (1976). The climate was seasonal, warm-temperate to subtropical (Parker, 1976). The dominant flora in the Blackhawk swamps were arborescent plants, namely evergreen conifers (dominantly Sequoia cuneata) and deciduous angiosperms (dominantly Rhamnites eminens), similar to the present-day bald cypress and water tupelo, respectively (Parker, 1976). These flora could have accounted for the high resin content found in the Blackhawk coals (Doelling, 1977).

The two living analogues (cypress and tupelo) to the Blackhawk flora prefer wet acidic peats with shallow water cover and therefore Parker (1976) interpreted the Blackhawk swamps to have been shallow, wet, and acidic. Unlike present-day swamps which contain only about three species of gymnosperms, the swamp conifers of the Blackhawk comprised a large number of gymnosperm species (Parker, 1976). The species present within the Blackhawk coal beds appear to represent the transition between the earlier dominance of Mesozoic conifers and the later Cenozoic dominance of angiosperms (Parker, 1976).

The high resinite content of the Blackhawk Formation coals in Utah has some interesting economic benefits. Buranek and Crawford (1943) investigated the economics of extracting the natural resinite from the Blackhawk coals for varnishes and lacquers because the supply of resin from the East Indies was cut off during World War II. Paint manufacturers were very interested because of the potential for using the natural resins from the Blackhawk coals as opposed to using the synthetics that were by-products from other coals (Buranek and Crawford, 1943).

Perhaps more importantly, the high resinite content is beneficial in terms of utilization of the coal because, at this level of maturation, the resinite increases the volatile matter of the coal (Murchison and Jones, 1964; Doelling, 1972) without interfering with its coking properties (Doelling, 1972). In addition, the resinite increases the calorific value of the coal, with the only drawback being an increase in smokiness (Spieker, 1931).

The resinite in the Blind Canyon coal bed can be correlated to the calorific value (Btu/lb) and the volatile matter (Table 4 and fig. 6). Facies 1.5 has the greatest amount of primary and primary plus secondary resinite, as well as the highest percentage of volatile matter and highest calorific value. Alternatively, facies 1.3 has the lowest total resinite content as well as low calorific values and volatile matter content. This correlation between calorific value and resinite content is true without exception (fig. 6) and a positive slope on the graph is evident. The same general trend is followed in the volatile matter graph (fig. 6) except for the small inversion of the two facies in the middle ranges (facies 1.1 and 1.2). The samples represented by asterisks in Figure 6 are data obtained from the Utah Geological and Mineralogical Survey (Sommer, S.N., in prep.). The data from the UGMS fit in quite well to the trend observed from the present study. However, more work would certainly be needed to ensure a true trend. This correlation may have implications in terms of exploration and utilization, especially since facies thicknesses change over the extent of an area or mine.

Because of the very resinous nature of the Blind Canyon coal bed, additional point counts were made on the resins within the coal. Only primary and secondary resinite were counted, 100 counts per pellet. The results are found in Table 5, and some additional trends are present. It is evident that facies 1.1 and 1.3 have higher exsudatinite contents than bituminite, and facies 1.2 and 1.5 have higher bituminite contents than exsudatinite. This was not evident when looking at the whole-maceral data (Table 3) because of the overabundance of other macerals, especially the vitrinites, relative to the individual liptinite macerals.

A fair number of "free-floating" angular resinite bodies that had no physical connection to vitrinite, as do primary resinite bodies, were counted in the Blind Canyon coal samples. This is the differentiation in Table 5 between the "resinite," i.e. primary resinite, classified by color, and "free-floating" resinite, classified by color. Examples of each type of resinite are shown in Figure 5. These "free-floating" resinites have two possible origins. One possibility is that this resinite was originally a type of wound resin exuded by the initial vegetation. Alternatively, this resinite may have been secondary in nature, having been mobilized during coalification. With either origin, it is most likely that this resinite became angular and "free-floating" when the coal was ground for petrographic analyses.

The free-floating resinites and the primary resinite seem to have no correlation with each other. For example, facies 1.1 contained an average of eight free-floating yellow resinites, but only two yellow primary resinites. Alternatively, within facies 1.3, an average of six primary yellow resinites were counted and only one yellow free-floating resinite was present within two pellets. The greatest portion of free-floating resinites are yellow and yellow-green, yet there is almost no yellow-green primary resinite contained within the vitrinite. In addition, no brown free-floating resinites were observed. This may indicate that the brown resinite counted was therefore exsudatinite, however care was taken that if this brown material was clearly filling material such as inertinite cells, it was counted as exsudatinite.

It is not known if the different colored resinites have any significance other than originating from different types of resins within the original peat vegetation. There seem to be a few trends between resinite color and the facies within which the resinites are present. For example, the yellow-green free-floating resinite is abundant in all the facies. However, the yellow free-floating resinite is most abundant in facies 1.1 and 1.2. The yellow primary resinite seems most abundant in facies 1.2 and 1.3. Since only one facies channel sample was taken, it is unclear as to whether this is a trend indicating differences in vegetation through the lateral or vertical development of the swamp, perhaps representing successional vegetational changes, or if these resins were present throughout all facies in varying abundances.

The exsudatinite was also present in different colors, although it is not differentiated within the table. By far, most of the exsudatinite was brown, but it was sometimes yellow, and one green occurrence was noted. The color of the exsudatinite is dependent upon the fluorescence of the original material from which this secondary maceral was exuded, and perhaps how far it had to migrate. Teichmuller (1973) believes that the fluorescence of exsudatinite is very weak compared to its source, even if it fills a crack immediately adjacent to that source. However, one exsudatinite in the Blind Canyon coal immediately adjacent to a highly fluorescent resinite body was highly fluorescent as well. The point source was not always known for the exsudatinite, and the ones whose fluorescence was of much less intensity may have migrated further.

Jones and Murchison (1963) and Murchison and Jones (1964) believe that the resinite is mobilized and subsequently coalesced into these globules and in fissures by the increased temperature and pressure conditions due to sedimentary overburden. They noted that this temperature and pressure increase was not sufficient to increase the reflectance or cause vesiculation of the resinite or reaction with other macerals. The fluid migration of resinite is believed to take place in the bituminous stage of coalification (Murchison and Jones, 1964). Teichmuller (1973) believed these "petroleum-like substances," e.g. fluorescing exudates, form in sub-bituminous and high volatile C and B coals.

CONCLUSIONS

The environment in which the Blind Canyon and stratigraphically-related coal beds developed must have been extremely stable to allow such extensive swamp formation. The average thickness of the coal beds within the lower Blackhawk is 6 to 10 ft (1.8 to 3.0 m), and some beds are as thick as 17 ft (5.2 m). The Blind Canyon coal bed has an average ash yield of 4.5 percent and total sulfur content of 0.6 percent (Table 2). There is a lack of abundant parting material within the Blind Canyon (fig. 4); only one thin claystone parting is present, which implies that little sediment was input to the swamp. Each individual facies has a very low ash yield as well. The chemistry of the Blind Canyon coal bed facies does not vary, and the whole bed analyses (Table 1) are remarkably consistent. These consistencies in coal quality support the interpretation that the whole area was very stable, allowing such coal beds to develop. These coal beds developed in swamps which were very close to the shoreline, yet are thick, extensive, and relatively low in ash and sulfur. There was gradual subsidence in the study area from the late Triassic to the late Cretaceous (Spieker, 1931; Doelling, 1972) which probably produced these favorable environments for peat formation and accumulation.

The Blackhawk peats formed in wet acidic environments with shallow water cover (Parker, 1976) as inferred from the living analogues of the major flora in the coal beds. If, as Parker (1976) infers from the palynological evidence, the Blind Canyon swamp was acidic and shallowly subaqueous, this could account for the high amount of preservational macerals such as telinite and corpocollinite in telinite in the Blind Canyon coal bed. A slightly fluctuating water table could account for the alternating abundances of total vitrinite and total inertinite.

The high liptinite content originated from primary vegetable material in the Blind Canyon swamp. The Blind Canyon coal bed is highly resinous compared to other coal beds, which implies that the Blind Canyon swamp must have contained vegetable material that was highly resinous. The different colored resinites may indicate differences in plant types, however, such a correlation at this time is premature. The relative abundances of resin on the surface of the coal bed may be indicative of the relative amounts of microscopic resinite. Again, more work is needed to verify the correlation, but this may have implications for the manner and distance of resin migration within coal. The high resinite content of the Blind Canyon coal bed is also positively correlated with the heating value of the coal and the volatile matter within the bed, thereby having implications for coal utilization.

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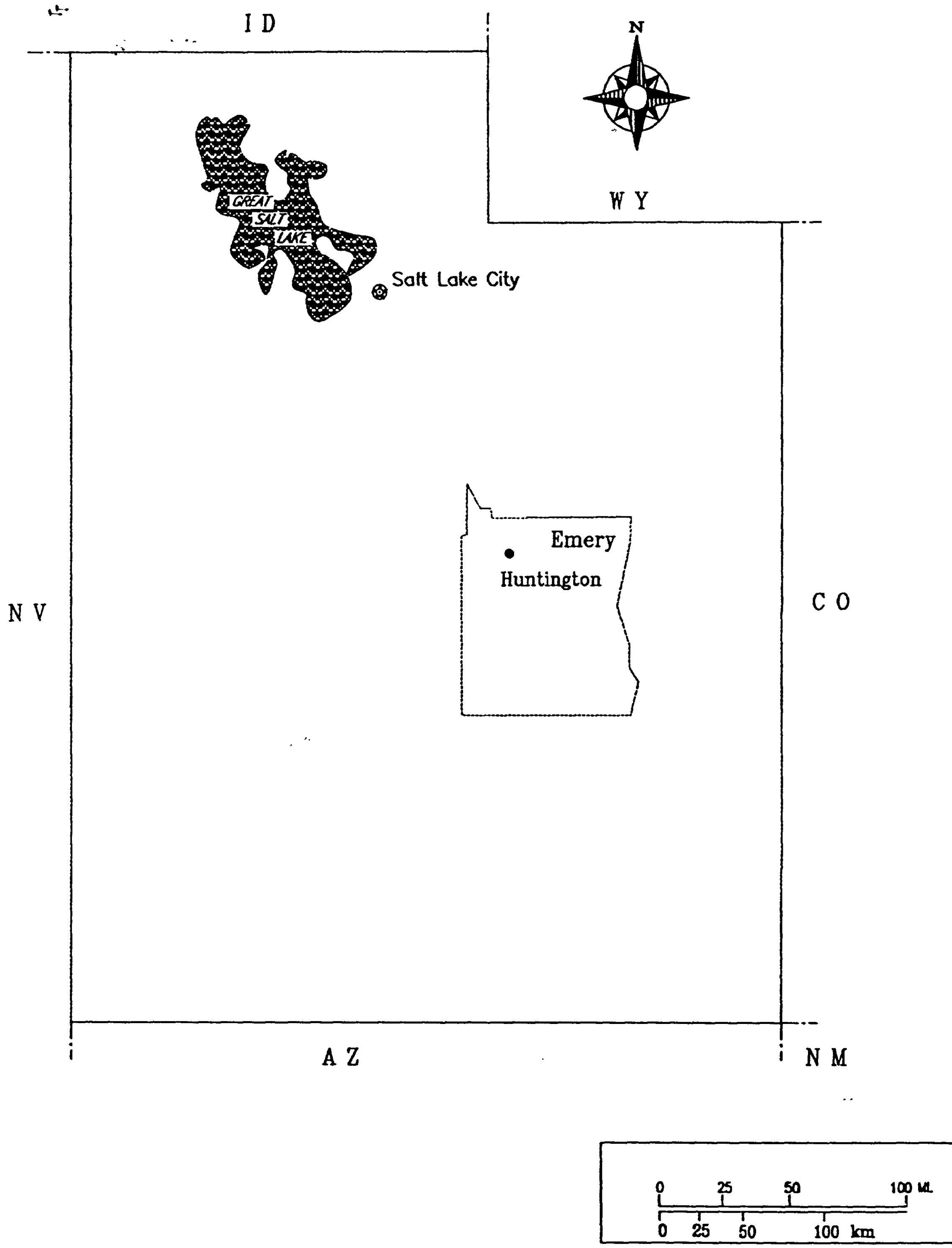


Figure 1. Location of Huntington, Emery County, Utah.

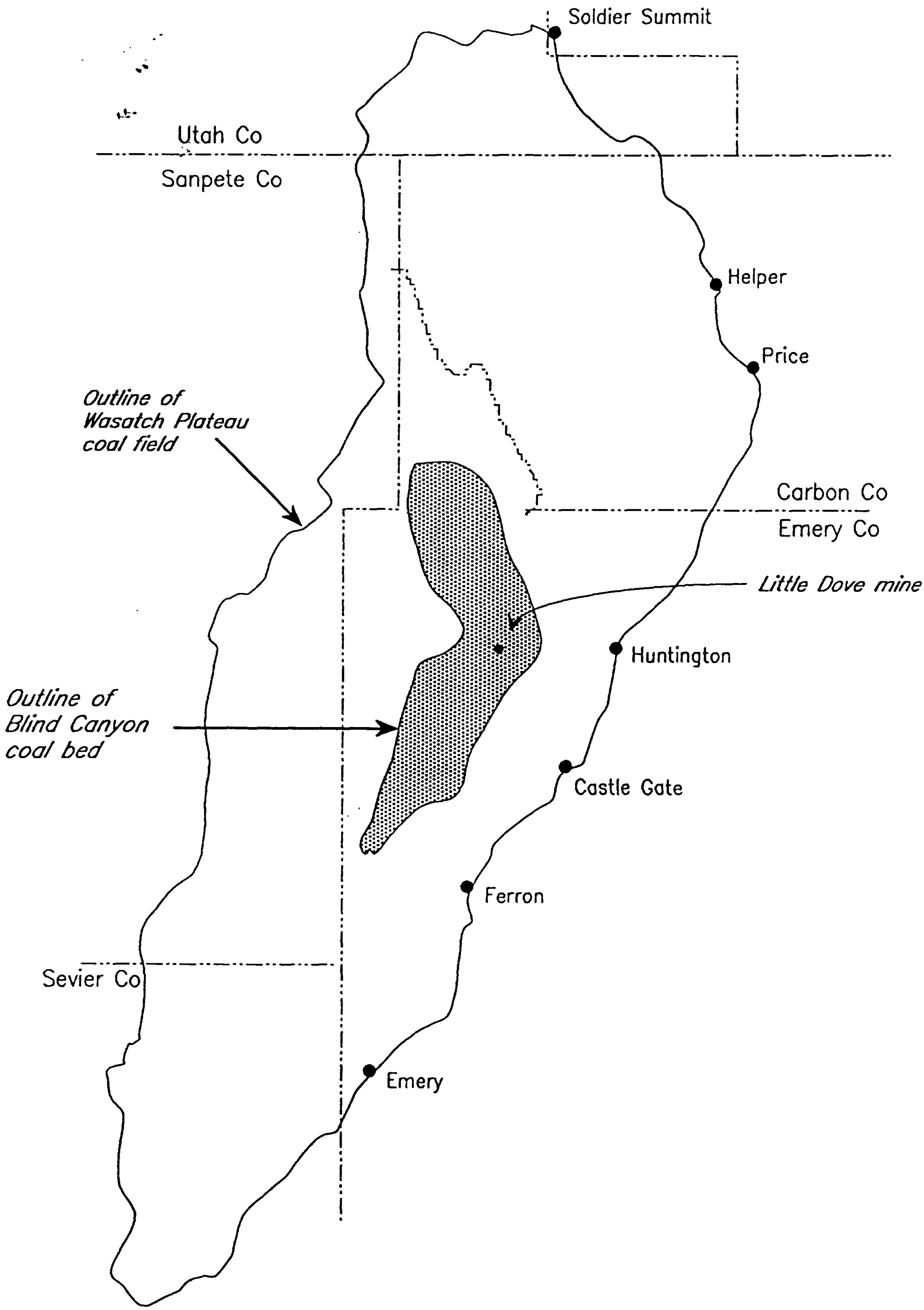
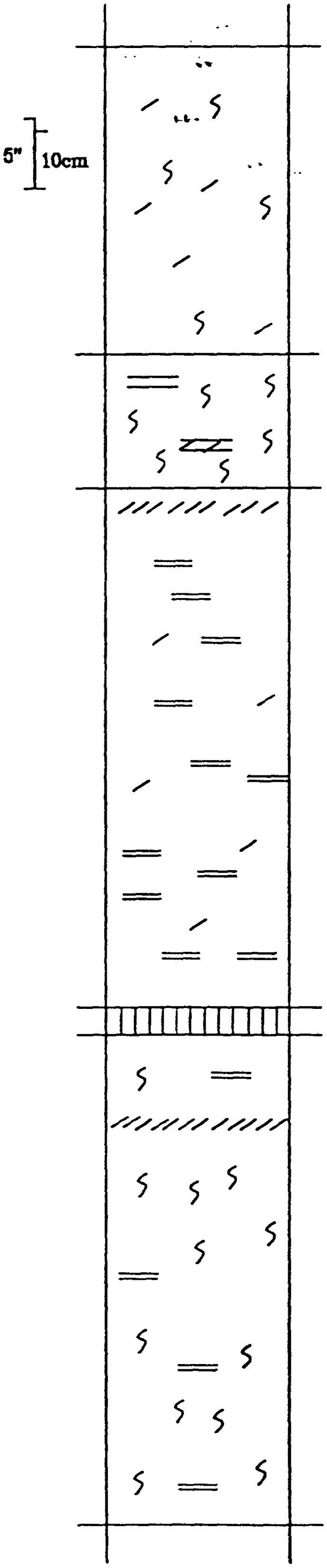


Figure 2. Approximate outline of the Wasatch Plateau coal field, in the Wasatch Plateau, Utah (after Doelling, 1972).

SYSTEM	SERIES	STRATIGRAPHIC UNIT		DESCRIPTION
TERTIARY	Paleocene	Wasatch Group	Flagstaff Limestone	evenly bedded limestone w/ subordinate sandstone, shale, and volcanic ash
CRETACEOUS	?? / Maestrichtian	Wasatch Group	North Horn Formation (L Wasatch)	shale w/ subordinate sandstone, conglomerate, freshwater limestone; thickens to north
CRETACEOUS	Maestrichtian / Campanian	Mesaverde Group	Price River Formation	sandstone w/ subordinate shale and conglomerate; poorly sorted, red bed conglomerates (e) even higher reaches of streams (a); alluvial fans (e)
	Campanian	Mesaverde Group	*inc.* Castlegate Sandstone	coarse grained sandstone higher stream reaches (a); braided streams (e)
	Campanian	Mesaverde Group	Blackhawk Formation	fine to medium grained sandstone, w/ carbonaceous shale & major coal beds delta plain/strandplain (b); broad coastal flood plain with lagoons and extensive swamps (a); back barrier and delta plain (d)
	Campanian	Mesaverde Group	Star Point Sandstone	massive sandstone; thickens to west; intertongues with Masuk Shale beach or near shore (a) (c); intertonguing from oscillations of shoreface (a); accretion ridge barrier sands (c)
	Santonian	Mancos Shale	Masuk Shale	sandy shale; thins to south offshore muds (c); marginal marine deposits (f)
	Santonian	Mancos Shale	Emery Sandstone	sandstone tongues; possible coal in south and west
	Coniacian / Turonian	Mancos Shale	Blue Gate Member	nodular and irregularly bedded marine mudstone and siltstone basinal marine deposits (e)
	Turonian	Mancos Shale	Ferron Sandstone Member	sandstone, sandy shale, and shale; thickens to south; major coal beds in Emery field
	Cenomanian	Mancos Shale	Tununk Shale Member	sandy marine mudstone
	Cenomanian / Albian	Dakota Sandstone		sandstone, conglomeratic shale, and coal

Figure 3. Generalized stratigraphic section of rocks in the Wasatch Plateau (modified from Doelling, 1972) and interpretation of rocks from study area (a – Spieker, 1931; b – Sanchez, 1983; c – Blanchard, 1981; d – Marley and others, 1979; e – Van de Graaff, 1972).



Facies 1.1

0.0–21.5"
very bright at top, almost all vitrain
no visible pyrite or fusain
moderately bright lower in section
vitrain bands 1–2 mm, attritus 3–4 mm
occasional discontinuous pyrite bands throughout, ~2mm thick
blocky, moderately friable, columnar fracture
small occurrences of mineral coating (kaolinite?)
small resin blebs coating surface

Facies 1.2

21.5–31.0"
moderately dull
vitrain 1–2 mm, attritus ~5 mm
discontinuos fusain bands ~5 mm thick
fusain with pyrite stringers
hard, blocky, columnar fracture
moderate resin coating surface in this facies

Facies 1.3

31.0–67.0"
brighter
vitrain 2–3 mm, attritus 1–2 mm
attritus thickens about half way down,
becomes duller
some bands of attritus ~10 mm thick
small fusain bands throughout, ~1 mm thick
small, discontinuous pyrite bands throughout
pyrite at 32", 2 mm thick
small mineral spherules: calcite and kaolinite
very friable
no visible resin

Facies 1.4

67.0–69.0"
very hard, dark gray claystone parting
some small pyrite bands
some very thin vitrain stringers

Facies 1.5

69.0–103.0" (minimum thickness – bottom 2' of coal not mined)
very dull
vitrain 1–2 mm, attritus up to 10 mm
facies very consistent, does not change
pyrite 6 mm thick, at 75"
occasional small fusain
very hard
abundant surficial resin

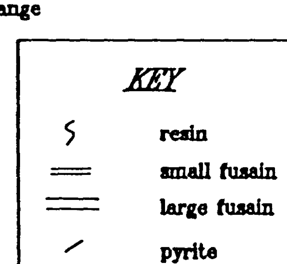


Figure 4. Description of coal facies in the Blind Canyon coal.

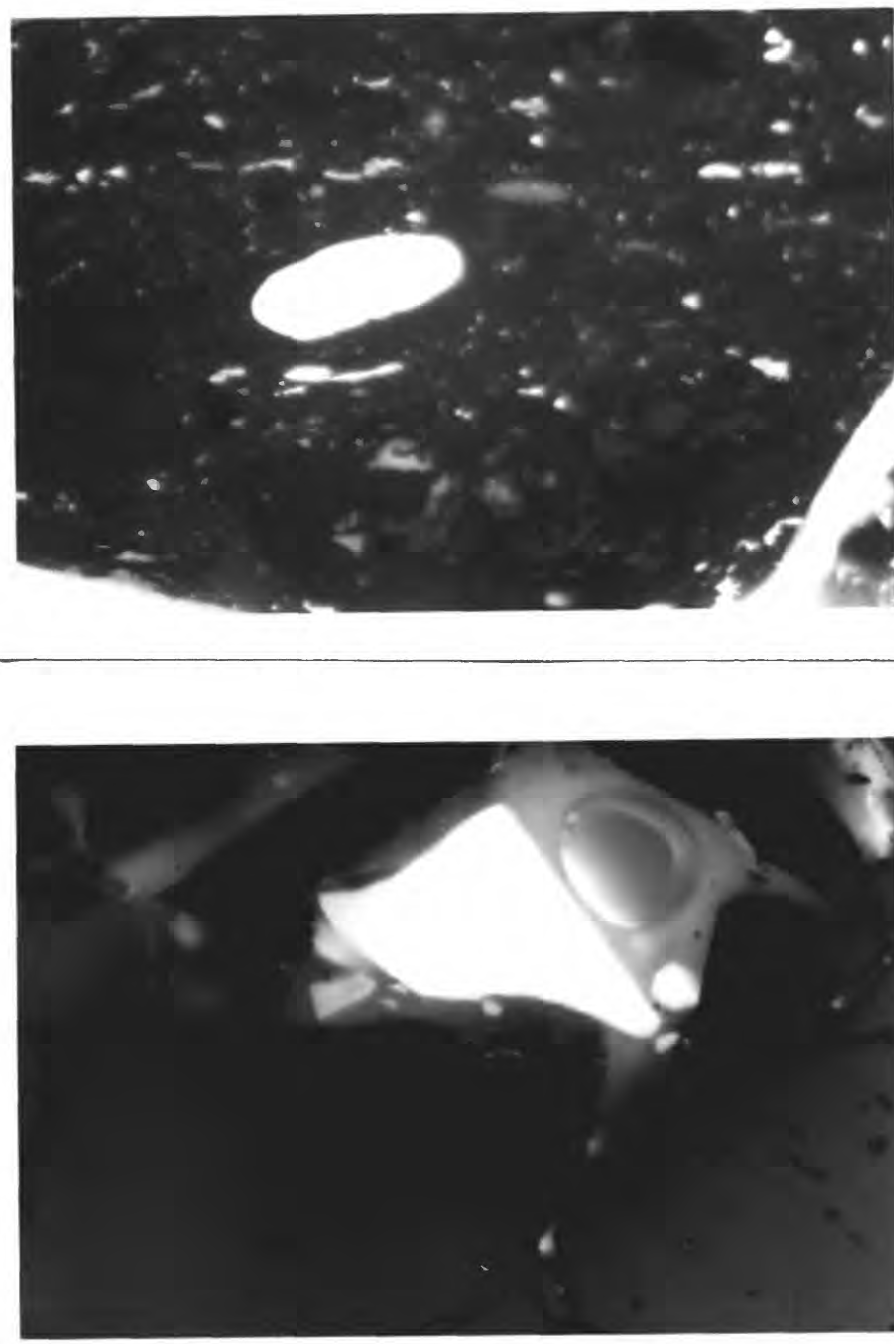


Figure 5. Examples of resinite observed in the Blind Canyon coal bed. (a) is primary resinite; (b) is free-floating resinite.

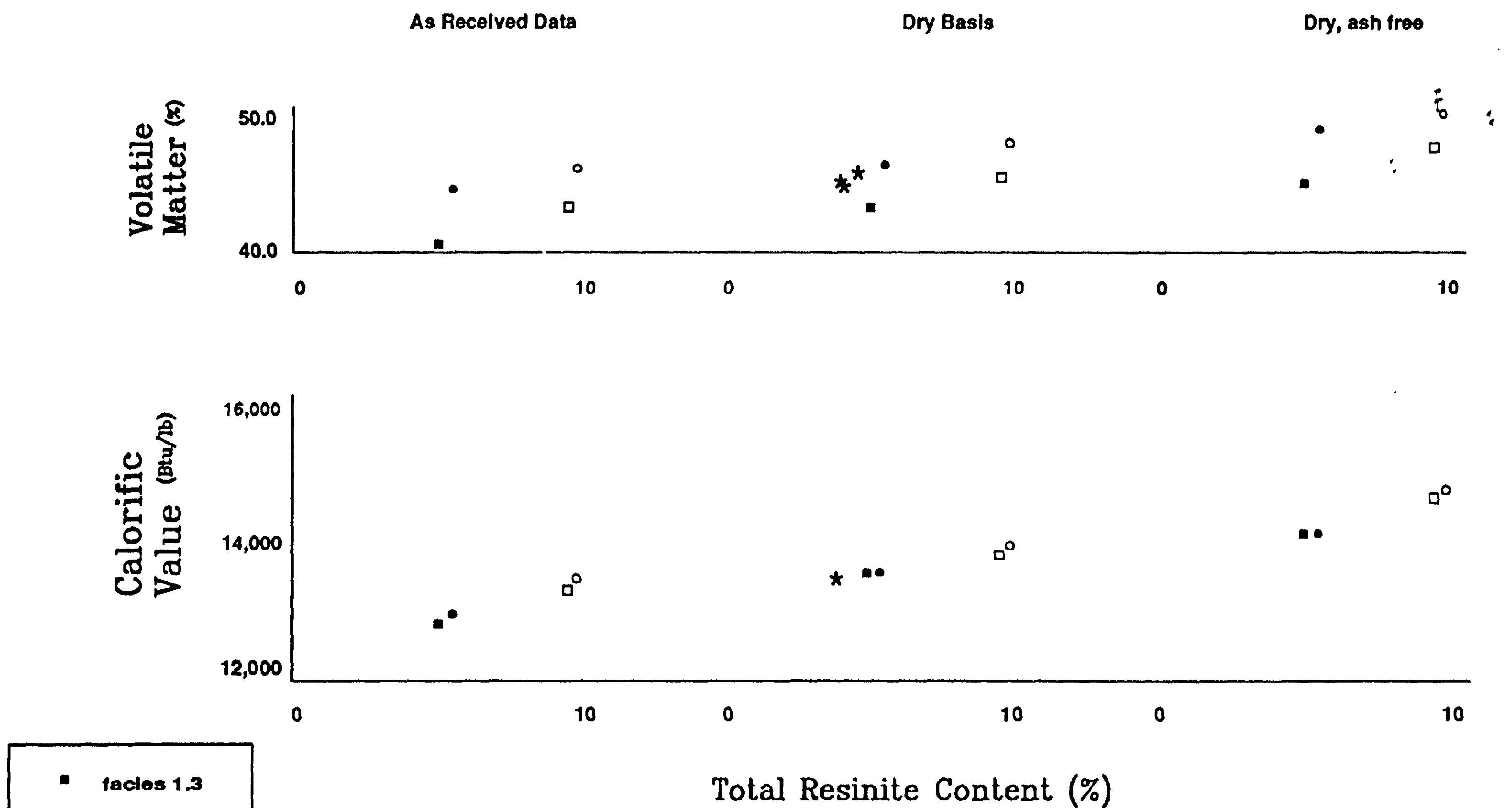


Figure 6. Correlation of resinite content with calorific value and volatile matter content in the Blind Canyon coal bed. (1.1 – 1.5 = facies data; * = data from the Utah Geological and Mineralogical Survey, Sommer, S.N., 1989.)

Table 1. Published proximate analyses, calorific values, and forms of sulfur of the Blind Canyon coal bed in the Wasatch Plateau of Utah. If number of samples is greater than 1, (n)* = number of analyses, and analysis value is average of all samples. Sources: A = Spieker, 1931; B = Hatch et al, 1979; C = Doelling, 1972; D = Fieldner et al, 1925. First line of analyses [a] is as received data, second line [b] is dry basis, third line [c] is dry, ash free basis.

number of samples	1	3	4	1	8-10	83-108	2
moisture (%)	[a]4.6	3.7	4.5	2.3	4.8(10)*	5.1(108)*	4.6
	[b] ---	---	---	---	---	---	---
	[c] ---	---	---	---	---	---	---
volatile matter (%)	[a]45.2	44.0	43.8	44.3	41.7(9)	42.5(100)	44.4
	[b]47.4	45.7	45.8	45.3			46.5
	[c]50.1	48.4	49.8	49.3			
fixed carbon (%)	[a]45.1	46.9	44.2	45.6	44.3(9)	44.8(100)	45.5
	[b]47.3	48.7	46.2	46.7			47.7
	[c]49.9	51.6	50.2	50.7			
ash yield (%)	[a]5.1	5.4	7.4	7.8	8.9(10)	7.4(104)	5.4
	[b]5.3	5.6	7.8	8.0			5.7
	[c] ---	---	---	---			
calorific value (Btu/lb)	[a]13290	13270	12685	13070	12492(9)	12803(104)	13195
	[b]13940	13780	13285	13380			13838
	[c]14720	14600	14405	14540			
sulfur (%)	[a]0.64	0.5	0.4	0.8	0.5(8)	0.60(3)	0.6
	[b]0.67	0.5	0.4	0.8			0.6
	[c]0.71	0.6	0.6	0.9			
sulfate		0.01	0.02	0.02	0.01	0.01	
		0.01	0.02	0.02			
		0.01	0.02	0.02			
pyritic		0.05	0.09	0.14	0.04	0.13	
		0.05	0.09	0.14			
		0.06	0.10	0.16			
organic		0.39	0.37	0.61	0.45	0.46	
		0.40	0.38	0.62			
		0.43	0.42	0.68			
source	A	B	B	B	C	C	D

Table 2. Chemical analyses of the Blind Canyon coal bed, Wasatch Plateau, central Utah. 1.1 - 1.5 = facies samples; 1.4 is non coal parting; NA = no chemical data available; [1]w.c. = whole coal sample, from Commercial Testing and Engineering Co, in, Vorres, 1989.

sample number	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**w.c.**[1]
thickness (in)	21.5	9.5	36.0	2.0	34.0	103.0
As Received Data:						
Moisture (%)	4.31	3.83	5.61	3.21	3.75	4.63
Ash (%)	3.86	5.09	3.43	63.79	4.62	4.49
Vol. Matter (%)	44.58	43.08	40.59	NA	45.77	43.72
Fixed Carbon (%)	47.25	48.00	50.37	NA	45.86	47.16
Calorific Value (Btu/lb)	12954	13225	12835	3921	13386	13280
Sulfur Forms (%)						
Pyritic	0.39	0.43	0.42	NA	0.42	NA
Sulfate	0.02	0.03	0.03	NA	0.03	NA
Organic	0.20	0.03	0.06	NA	0.07	NA
Total	0.61	0.49	0.51	1.03	0.52	0.59
Dry basis:						
Ash (%)	4.03	5.29	3.63	65.91	4.80	4.71
Vol. Matter (%)	46.59	44.79	43.00	NA	47.55	45.84
Fixed Carbon (%)	49.38	49.92	53.37	NA	47.65	NA
Calorific Value (Btu/lb)	13537	13752	13598	4052	13907	13925
Sulfur Forms (%)						
Pyritic	0.41	0.45	0.44	NA	0.44	0.24
Sulfate	0.02	0.03	0.03	NA	0.03	0.03
Organic	0.20	0.03	0.07	NA	0.07	0.35
Total	0.63	0.51	0.54	1.06	0.54	0.62
Dry, Ash-free basis:						
Vol. Matter (%)	48.54	47.30	44.62	NA	49.95	NA
Fixed Carbon (%)	51.46	52.70	55.38	NA	50.05	NA
Calorific Value (Btu/lb)	14106	14520	14111	11886	14609	14613
Sulfur Forms (%)						
Pyritic	0.43	0.47	0.46	NA	0.46	NA
Sulfate	0.02	0.03	0.03	NA	0.03	NA
Organic	0.21	0.04	0.07	NA	0.08	0.37
Total	0.66	0.54	0.56	NA	0.57	NA

Table 3. Petrographic analyses of the Blind Canyon coal bed, Emery county, Utah (maceral data are on a mineral matter free basis and are normalized and rounded to nearest whole number). 1.1 - 1.5 = facies samples; w.c. = whole coal sample, -20 mesh split of the Argonne one ton sample.

Sample number	1.1	1.2	1.3	1.5	w.c.
Total Vitrinite	64	43	74	58	69
Telinite	34	12	34	21	30
Corpocollinite in telinite	13	7	12	9	10
Desmocollinite	13	21	23	23	24
Vitrodetrinite	2	1	1	2	1
Corpocollinite in desmocoll.	2	2	4	3	3
Poricollinite	0	0	0	0	1
Total Liptinite	23	27	14	32	17
Sporinite	2	3	3	5	2
Cutinite	0	0	0	1	0
Resinite	2	5	3	6	3
Exsudatinite	3	2	1	2	3
Fluorinite	0	1	0	1	0
Bituminite	1	2	1	2	5
Alginite	0	0	0	0	0
Liptodetrinite	15	13	6	14	4
Total Inertinite	12	29	13	9	12
Fusinite	6	14	7	3	6
Semifusinite	2	6	3	3	4
Micrinite	0	0	0	0	0
Macrinite	0	0	0	0	0
Inertodetrinite	4	9	3	3	2
Sclerotinite	0	0	0	0	0
Primary Resinite	2	5	3	6	3
Total Resinite	6	9	5	10	11

Table 4. Comparison by facies of resinite (primary, secondary, and total) content and calorific value (Btu/lb) and volatile matter of the Blind Canyon coal bed. 1.1 - 1.5 = facies; w.c. = whole coal (from Vorres, 1989); NA = data not available.

	1.1	1.2	1.3	1.5	w.c
Primary Resinite	2	4	2	5	2
Secondary Resinite	4	5	3	5	9
Total Resinite	6	9	5	10	11
Calorific Value (Btu/lb)					
as received	12,954	13,225	12,835	13,386	13,280
dry basis	13,537	13,752	13,598	13,907	13,925
dry, ash free	14,106	14,520	14,111	14,609	14,613
Volatile Matter (%)					
as received	44.58	43.08	40.59	45.77	43.72
dry basis	46.59	44.79	43.00	47.55	45.84
dry, ash free	48.54	47.30	44.62	49.95	NA

Table 5. Percentage of primary and secondary resinite macerals within the Blind Canyon coal bed. Two pellets per facies (1.1 - 1.5) were counted, 100 counts each. Numbers represent average of the two counts.

	1.1	1.2	1.3	1.5
Secondary Resinite				
Exsudatinite	49	26	54	26
Bituminite	24	50	27	51
Fluorinite	1	1	2	1
Primary Resinite				
Resinite - brown	4	2	0	2
Resinite - green	0	1	1	1
Resinite - yellow	2	4	6	2
Resinite - yl grn	0	2	0	0
Resinite - yl brn	1	4	4	2
Resinite - yl or	1	1	0	2
Free-Floating Resinite				
Yellow	8	8	1	4
Green	4	0	0	1
Yellow-Green	6	4	6	6
Yellow-Orange	1	1	0	2