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COAL RECOVERY FROM MINE WASTES OF THE HISTORIC LONGWALL MINING DISTRICT OF NORTH-CENTRAL ILLINOIS

Latif A. Khan, Dwain J. Berggren, and Larry R. Camp

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ABSTRACT

Recovery of coal from mine wastes produced by historic longwall mines in north-central Illinois was studied as part of a project undertaken in 1982 for the Illinois Abandoned Mined Lands Reclamation Council. About 100 of these mines operated in the Wilmington and La Salle Districts of the Illinois Coal Field between about 1870 and 1940; all worked the Colchester (No. 2) Coal Seam, using a manual high-extraction mining method.

Large samples of the three major kinds of mine waste—gray mining gob, preparation gob, and preparation slurry—were collected from deposits at nine of the larger mine sites and analyzed to determine their general ranges of sulfur, ash, and heating values. Preparation gob and slurry from six of the sites had significant combustible contents, and were evaluated by a simple procedure in which ash analyses and wet-screening tests were used to determine the washability and yield of combustibles by recovery processes.

Results of these tests indicated that the three major types of mine waste found in the historic Longwall District have distinctive characteristics and support the conclusions of other Survey studies indicating that nomenclature applied to these materials is inadequate. Study data should help those undertaking recovery and reclamation work at these sites to conduct more effective operations.

Gray mining gob is a medium gray, shaly waste—more than 90 percent of it consists of silty clay shale and siltstone of the Francis Creek Shale Member that lay over the coal seam in the mines. Mining gob also contains about 4 percent discarded coal and 1 or 2 percent of pyrite and stony impurities from the seam. Six mining gob samples contained from 85.8 to 89.7 percent ash, 0.36 to 1.55 percent sulfur, and 119 to 759 Btu/lb (dry basis). It is not feasible to attempt coal recovery from mining gob.

Preparation gob, a dark gray, clayey waste containing about 30 percent coal, was conveyed out of the bottoms of coal washers to waste piles. Analyses of eight samples show a range of 51.0 to 67.2 percent ash, 3.13 to 7.84 percent sulfur, and 1777 to 5259 Btu/lb (dry basis). Washing tests indicate that only small amounts of coal can be recovered from preparation gobs.

Preparation slurry is a fine-grained material that waste water from coal washers deposited in alternating laminae of gray clay and black coaly silt and sand across impoundments or collecting areas. Analyses of slurry samples from two deposits show the typical decrease in sulfur and heating value and increase in ash with distance from the washer discharge outlet. These two slurry deposits have the highest potential for coal recovery of the wastes studied, but have been buried by reclamation work.

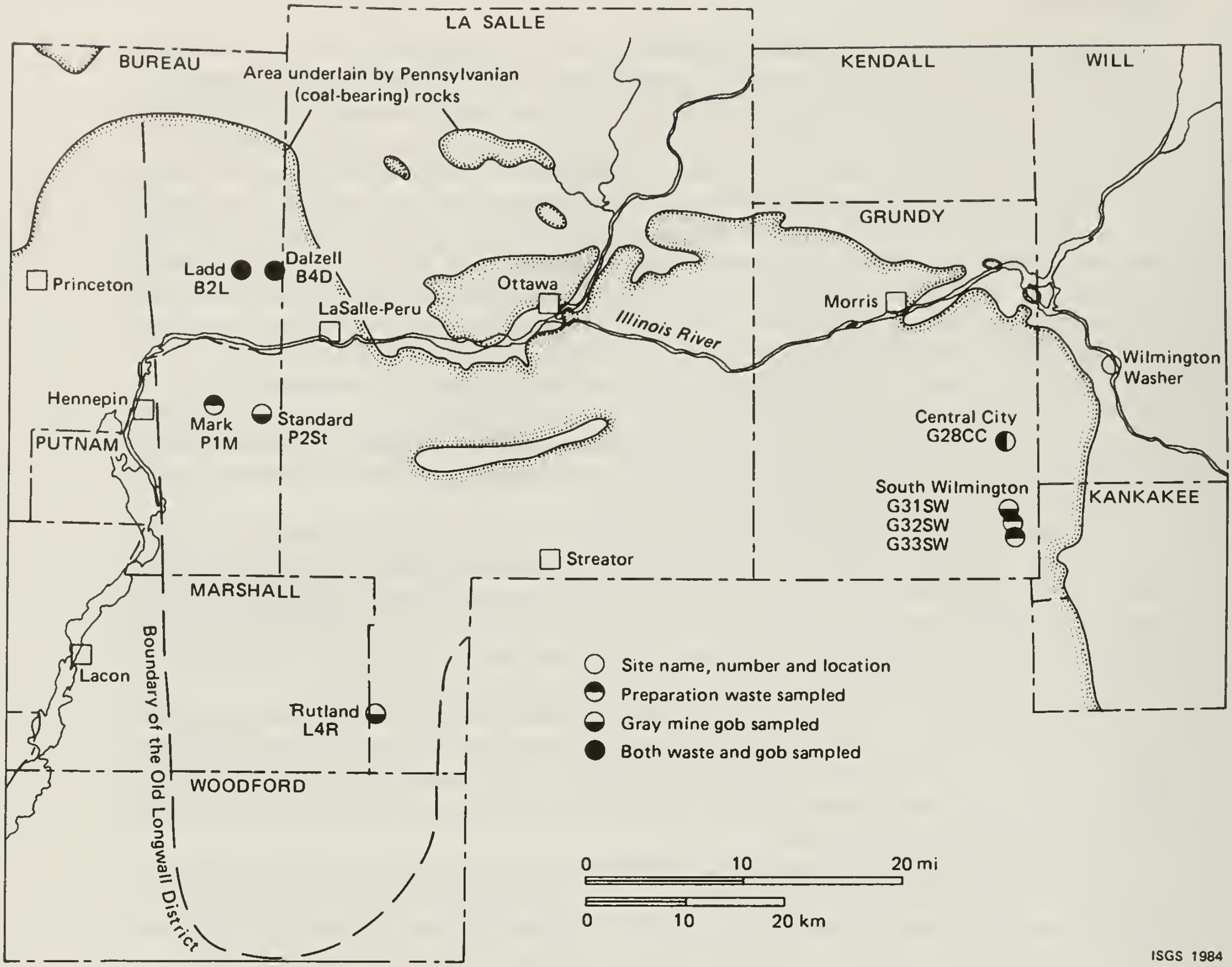

Figure 1. Locations of historic longwall mines and associated preparation plants described in this report (adapted from Illinois State Geological Survey, 1983).

INTRODUCTION

The historic Longwall District is located at the northeastern edge of the Illinois Basin Coal Field (fig. 1). Almost all the long-abandoned mines that give the District its name lie in a belt that is about 20 miles wide and parallel to the Illinois River between Lacon, Hennepin, and Wilmington. Most of the mine locations are still marked by the conspicuous conical, red and gray piles of roof shale beside the mine shafts. Dark gray piles of coaly waste are found at a few sites where coal washing plants were located.

Some of the waste piles are troublesome heritages for the villages and towns the miners built beside them. The largest of the piles—like those at Ladd, Cherry, and Mark—are 180 to 190 feet high and cover 25 to 30 acres. Grasses, weeds, and trees do not grow on the steeper slopes. Runoff washes and gullies their sides, carrying mud and chemicals weathered from their pyritic rocks to adjacent lands and waters. Their high slopes are unstable and landslide prone. However, some of the piles have status as historic landmarks, some are used for recreational purposes, and some may contain mineral materials that have economic value.

In 1982, the Illinois Abandoned Mined Lands Reclamation Council granted a contract to the Illinois State Geological Survey (ISGS) for a study of the sites and materials to determine what uses and what kinds of reclamation might be practical (ISGS, 1983). ISGS geologists identified about 100 longwall mine sites across the District, and sampled materials at 22 of them to determine their composition and identify significant similarities and differences between them. Part 5 of the ISGS study, upon which this report is based, involved sampling the various waste materials found at mine sites and analyzing the samples to determine their potential as fuel resources and for coal recovery processing. These data are included and interpreted in this report to help those planning to reclaim these sites or recover coal from them recognize different types of wastes, avoid unproductive exploration and analyses, and design their operations more effectively.

PREVIOUS INVESTIGATIONS

Lincoln (1913) described coal preparation methods at 35 unnamed coal washeries in Illinois and included information about the washeries operating in the historic Longwall District of northern Illinois.

Andros (1914) studied the operations of 11 longwall mines in the Longwall District (State District I) and described in detail the mining processes and the methods employed. Cady's companion report on District I (1915) was a compilation and interpretation of geologic, chemical, and economic information related to the coal resources.

Nawrot and others (1977) described longwall mine sites in their survey of state lands affected by abandoned underground coal mines. Their report describes each mine site and its hazards and environmental problems, provides chemical analyses of mine refuse and drainage, and assigns each site a Problem Area Index score to indicate the relative severity of its problems. A later review of these data (Nawrot et al., 1982) summarized the chemical characteristics of the refuse generated by mining the Colchester (No. 2) Coal seam in the historic longwall mines, compared these characteristics with those of wastes from mines in other seams, and made general recommendations for reclamation of the historic longwall mine sites.

Dames and Moore drilled and sampled waste piles at two of the historic longwall mine sites (Mark in Putnam County, and the No. 3 Coal Corporation site in Grundy County) as part of a study of coal mine wastes in the midwestern coal fields (Conroy et al., 1981). The study measured selected physical, engineering, and chemical properties of waste materials from 20 mine sites in Illinois, Indiana, Kentucky, and Kansas.

Cobb and others (1979) sampled the slurry deposit of a coal preparation plant in west central Illinois—an area adjacent to the historic Longwall District. They reported the distribution and estimated quantities of fine coal and sphalerite in the 45-acre slurry fan exposed in the slurry impoundment.

In the ISGS study (1983), researchers conducted coordinated geological, chemical, mineralogical, and engineering studies and developed recommendations for uses and reclamation of the longwall mine waste materials and sites. The coal resource data included in this report are taken from parts 3 and 5 of the 1983 report, which was published by the Illinois Abandoned Mined Lands Reclamation Council.

WASTES FROM HISTORIC LONGWALL MINES

Conroy et al. (1981) and Nawrot et al. (1977, 1982) identify mine wastes in the historic Longwall District with a simple two-part classification. Conroy and his colleagues use the phrase *coal mine waste* (and its variant *mine waste*) as the generic term for the several mixtures of rock, coal, and other materials that are produced as wastes by coal mining and cleaning operations but are not surface mine "spoils." Nawrot and his colleagues prefer the term *refuse* rather than *waste* for the same materials. Both groups identify the same two subclasses of coal mine waste/refuse: *gob* for the waste materials that are piled, and *slurry* for materials that are discharged suspended in water to impoundments or collecting areas.

However, ISGS studies (1983) demonstrate that a simple "gob and slurry" classification does not adequately describe the wastes produced by the historic longwall mines. Two fundamentally different kinds of gob were produced by these mines: *mining gob,* a clayey shale gob produced by mining operations that contains very little coal; and *preparation gob,* a clayey, coaly gob produced by coal washing. In addition to the gobs, *preparation slurry,* the fine-grained reject from coal washing, was also produced.

Mining gob

Mining gob is the mixture of roof rock and coal seam wastes produced underground by miners handpicking impurities from the coal and digging out and maintaining their haulage ways. Mining gob is the most common and abundant mine waste material in the District; piles of it accumulated at every mine site. Mining gob in the District typically consists of more than 90 percent clay shale and silty-clay shale of the Francis Creek Shale Member, which formed the roof of the mines. Roof falls of the shale continually blocked mine haulage ways because longwall mining removed the whole coal seam and the rock overhead inevitably settled and fell into the mine openings. Roof falls in the main entries were loaded out to the gob piles because there was no place to stow the rock in the mine once the overburden had squeezed the openings closed.

Figure 2. The mining gob pile at Rutland, La Salle County, is 112 feet high and 550 feet long. The rails ran up the longer slope on the right between the hoisting shaft and the peak.

Figure 3. A borrow pit in a mining gob pile at Toluca, Marshall County (NW¼ NE¼ Sec. 8, T 29 N, R 1 E). The shaly mining gob has been burned to a hard, red, bricklike gravel that is used locally as surfacing and fill material.

In addition to shale, mining gob contains about 5 percent (by weight) coal and coaly and pyritic partings and masses. Coaly and pyritic wastes were hauled out to the dump to prevent their spontaneous combustion in the mines. Mining gob also contains a small amount of underclay and other types of rocks from the mine roof: siderite concretions, blocks of sandstone, and plates of black, fissile shale. Junk and timbering scraps are found in all the piles.

Mining gob piles were made by dumping mine cars at the high end of inclined trestles that were extended whenever the gob piled up to the rails. Consequently, the mining gob piles are shaped like skewed or lopsided cones (fig. 2).

The mineralogy, color, and lamination of the Francis Creek Shale and the coarse texture of the fallen rock gave the mining gob many of its characteristics. The unburned and less weatherstained mining gob is an overall medium gray—the color of the shale. Older, more weathered piles are gray with faint red or brown casts. The burned parts of piles (fig. 3) are mottled with light pinkish or yellowish browns and with the light and dark brownish reds that are common brick colors. Mining gob particles originally ranged in size from dust grains to slabs 2 to 3 feet across. Most particles are flat-sided flakes, books, and slabs of gray shale. When the larger of these tabular particles were dumped on the slopes of the pile, they came to rest on their flat sides, forming thin, obscure beds parallel to the sides of the piles. The bedding and original texture of unburned mining gob can be seen below the earthy, fine-grained surface zone formed by wet-dry and freeze-thaw cycles. However, the originally loose, hard shale gob has been compacted and softened by its exposure on the pile surface before subsequent dumping buried it, by overburden pressure, and by infiltrating water.

Figure 4. Three mine waste deposits at Mark, Putnam County, 1982. At center, a long, furrowed pile of preparation gob; at right, the corner of the slurry empoundment; in the foreground, the southeast slope of the largest mining gob pile. Later reclamation has leveled and buried all but the mining gob pile.

Figure 5. The preparation gob piles at Central City, Grundy County, 1982. The barren, deeply eroded and weathered piles, part of a 63-acre site, have been reclaimed since the photograph was taken.

Preparation gob

Preparation gob associated with the historic longwall mine sites is pebbly, sandy mud consisting of mineral, rock, and coal particles that were separated from the coal products by jig washers and conveyed sopping wet to a pile for disposal (Lincoln, 1913). Lumps of clay and particles of pyrite, calcite, black shale, gray shale, bony coal, and coal can be identified in these wastes. Longwall preparation gob samples are approximately one-third combustible and two-thirds mineral matter. Preparation gob was sampled at only seven of the approximately 100 historic longwall mine sites investigated. Another preparation gob deposit, which was not sampled, remains at Wilmington in Will County. It was produced at a washery that prepared coal shipped to it from nearby mines (Lincoln, 1913).

Because preparation gob piles contain more coal than mining gob piles do, they are usually dark gray (fig. 4), but the severely weathered piles at Central City are brownish gray. The surficial zones of preparation gob piles, well exposed in gully sides, are distinctly banded along the bedding by yellowish and brownish rust stains. White gypsum crusts, principally an inch or two in diameter, and small gypsum crystals (usually less than 2 mm long) are common in the surficial zones. Samples of longwall preparation gob, all taken from near the bases of the piles, are about half mud (mixtures of fine sand, silt, and clay) and half granular, pebbly sand. Generally, the largest particles are about two inches in diameter.

Preparation gob—like mining gob— was dumped off the end of a trestle to form a lopsided conical pile (figs. 4 and 5). Similar in shape to mining gob piles, preparation gob piles are distinctly darker and most have flatter slopes because the wet preparation gob was less stable than the dry mining gob. Preparation gob has laminae and beds that are parallel to the pile slopes; it is more distinctly bedded than mining gob piles because water running off it tended to sort the materials. Bedding ranges from less than an inch to several inches in thickness, and bedding contacts are usually indistinct.

Preparation slurry

Slurry associated with the old longwall mine sites consists of mineral, rock, and coal particles separated from coal products by washing processes and discharged, suspended in waste water, to impoundments or discharge areas (fig. 4). Slurry materials from longwall sites are essentially like the coal slurry wastes found in other parts of the state. The deposits are interlaminated and interbedded muds and sands; the coarsest particles are about 0.2-inch in diameter. Mineral matter content of the slurry samples analyzed for this study ranged from about 45 to 70 percent. Slurry deposits were found at only two of the old longwall sites, apparently because most preparation plants discharged their waste waters into natural streams or sent the fine particulate wastes to the preparation gob piles.

Slurry deposits are medium to dark gray overall. The mud laminae and beds are medium gray; the coarser sand laminae and beds are black with coal (fig. 6). Surficial zones of slurry deposits are rust stained along coaly laminae and beds, which contain abundant gypsum crystals less than 2 mm long.

Slurry deposits partly fill impoundments, as at the Mark Site in Putnam County, or cover the area on which they were discharged, as at Central City in Grundy County. Slurry deposits have typical lacustrine and deltaic bedding: alternating, near-horizontal laminae and thin beds of mud and sand that have sharp distinct contacts. Sediments in slurry deposits are systematically distributed by size and density. The larger and heavier particles (pyrite, coal, and rock) are concentrated close to the outlet of the washery discharge pipe; the smaller and lighter particles (clay and fine coal) are concentrated farthest from the discharge outlet; particles intermediate in size and weight are found between these extremes.

Figure 6. Slurry deposits exposed in Backhoe Pit 1 at the Central City site, Grundy County. Dark, coaly laminae are alternated with gray clay laminae. The pick handle is 18 inches long.

SAMPLING AND ANALYTICAL PROCEDURES

Sample collection

For this study we collected 14 samples of preparation waste and six samples of gray mining gob from nine mine sites. Table 1 gives sample descriptions and locations.

One additional coal preparation waste deposit, identified but not sampled, is located in Wilmington at the Illinois Central Gulf Railroad Bridge (SE¼ NE¼ SE¼ Sec. 26, T 33 N, R 9 E, Will County). The deposit lies inside the angle formed by the railroad and the west bank of the Kankakee River, south of the tracks. The deposit probably is neither a problem nor a potential resource; it has been leveled off, and part of it is thickly overgrown with trees. Gully exposures show severely weathered gob. It is unlikely that a secondary recovery operation could work here because of the small size of the site (2 to 3 acres) and the bordering river, houses, and railroad.

Three types of samples (backhoe pit, surface, and auger) were collected.

Backhoe pit channel samples, taken from the backhoe pits excavated at the six major study sites, consisted of material dug from a shallow channel about 1.5 feet wide, cut vertically down a highwall of a backhoe pit. Before the sample was taken, the channel was formed by scraping and chipping an inch or two of gob off the face of the pit to remove material smeared and disturbed by the backhoe bucket. A sample was then collected by chipping large pieces of material from the channel into a bucket so that equal volumes of material could be taken off equal intervals of the channel and the natural particles would be broken up as little as possible. Channel intervals sampled ranged from 2.5 to 23 feet, and samples weighed about 25 to 150 pounds.

Surface channel samples were taken from the gully sides of piles when a backhoe was not available. The same procedures used to prepare and take samples from backhoe pit channels were used for surface channel samples. Lengths of surface channels ranged from 10 to 15 feet, and samples weighed about 50 to 75 pounds.

Auger samples were taken at two sites with a 3.25-inch hand auger. Each sample consisted of the entire content of the auger hole.

Sample preparation

Most waste samples were partly air dried and split in the field to reduce the very large channel samples to more manageable volumes and to obtain sample splits for analyses of particle size, chemistry, and mineralogy. All the samples for coal analysis were air dried until they could be broken in a jaw crusher, rolls, and grinder. Smaller samples for coal analyses generally weighed 5 to 10 pounds and were air dried in open ovens at low temperatures. Larger samples (40 to 60 lbs) for particle size and coal analyses were air dried on the laboratory floor and then split into samples for grinding and wet screening.

Table 1. Descriptions and locations of samples

Site no.	Site name	Sample description*	Sample location
B2L	Ladd	P, BPC, 18	Pit 1: 2400 ft N., 1200 ft E. of SW corner, Sec. 10, T. 16N., R. 11 E., Bureau Co.
		G, BPC, 19	Pit 2: 300 ft W. of Pit 1
		P, SC, 15	In gully beside Pit 1
B4D	Dalzell	G, BPC, 17	Pit 3: 1800 ft N., 2400 ft W. SE corner Sec. 24, T. 16N., R. 11E., Bureau Co.
		P, BPC, 23	Pit 5: 700 ft S., 100 ft E. of Pit 3
		P, SC, 10	In gully beside Pit 5
G28CC	Central City	S, BPC, 6.7	Pit 1: 1300 ft S., 1600 ft E. of NW corner, Sec. 23, T. 32N., R. 8E., Grundy Co.
		G, BPC, 12	Pit 2: 60 ft NW of Pit 1
		P, BPC, 11.5	Pit 3: 1500 ft S., 1200 ft E. of NW corner, Sec. 23
		S, BPC, 4.3	Pit 4: 1100 ft S., 1400 ft E. of NW corner, Sec. 23
		S, BPC, 2.5	Pit 5: 825 ft S., 1300 ft E of NW corner, Sec. 23
G31SW	South Wilmington	G, A, 5 + 4.5 + 3.5	Composite of 3 holes in peak; 800 ft N., 2100 ft W. of SE corner, Sec. 11, T. 31N., R. 8E., Grundy Co.
G32SW	C.W. & V. No. 1	P, BPC, 15	2200 ft S., 2000 ft E. of NW corner, Sec. 14, T. 31N., R. 8E., Grundy Co.
G33SW	No. 3 Coal Corp.	P, SC, 4 + 4 + 4	Composite of 3 samples from terrace around base of gray mining gob pile in NW ¼ NW ¼ SE ¼, Sec. 23, T. 31N., R. 8E., Grundy Co.
		P, SC, 15	2000 ft S., 2700 ft E., of NW corner, Sec. 23
L4R	Rutland	G, BPC, 13	Pit 1: 150 ft E. of pile's peak, SW¼ NW ¼, Sec. 18, T. 29N., R. 2E., La Salle Co.
P1M	Mark	P, SC, 10	1900 ft S., 1400 ft W., Sec. 8, T. 32N., R. 1 W., Putnam Co.
		S, A, 13/8	P1Mc-1A (13 ft) and -1B (8 ft): 2000 ft S., 1700 ft W. of NE corner, Sec. 8
		S, A, 11	P1Mc-3A: 300 ft SW of P1Mc-1
P2St	Standard	G, BPC, 19	Pit 3: 800 ft N., 600 ft W of SE corner, Sec. 11. T. 32N.. R. 1W.. Putnam Co.

*Waste type: G, gray mining gob; P, preparation gob; S, slurry. Sample type: BPC, backhoe pit channel; SC, surface channel; A, auger hole. Vertical interval sampled (given in feet)

Each 5- to 10-pound sample for coal analyses was passed through various mills and sample splitters to reduce its particle size to less than 60-mesh and its weight to about 60 grams. During the final stages of grinding, the fine material was homogenized several times in a wheel mixer.

Sample analysis

All preparation waste and gray mining gob samples were analyzed with the standard procedures for coal analyses: sample moisture, ASTM D3173-73; ash, ASTM D3174-82; gross caloric value, ASTM D2015-77; and total sulfur by the Eschka Method, ASTM D3177.

For a few samples, additional procedures were used to determine sulfate sulfur (ASTM D2492-80), pyritic sulfur (ASTM D2492-80), and volatile matter (ASTM D3175-77).

Duplicates of each waste sample were analyzed to check whether the difference between individual results exceeded the limit prescribed for the ASTM methods. No differences found for any pair of analytical results exceeded the amount of permissible difference, although the differences were generally larger than those between paired analyses of ordinary coal samples. The results reported are the averages of each pair of analyses. Because of the high ash content of the samples, the dry mineral-matter-free values must be interpreted cautiously.

Samples were first sieved wet to clean clay coatings off the coarser particles and to break up agglomerates of clay and silt that would otherwise have been held in the coarser fractions. Each sample was placed on the 48-mesh sieve and washed with water until clean water came through the sieve and no more particles could be observed passing through. The material held in the sieve (+48-mesh) and that passing through it (-48-mesh) were collected and dried. If further classification of the +48-mesh material were required, the material was sieved dry in a mechanically shaken sieve stack for 15 to 20 minutes.

The weight percent of each part of a sample classified by sieving was calculated by dividing the air-dried weight of material taken from the sieve by the total weight of the whole air-dried sample before sieving.

CHEMICAL ANALYSES AND WASHING TESTS

Gray mining gob

Visual examination of the gray mining gob in exposures and samples established that the material was typically more than 90 percent shale and clay and less than 5 percent coal and coaly material (the balance consisted of other kinds of rock). This estimate is confirmed by the average weight content of the mineral matter (96.1%) and combustible matter (3.9%) of the six samples from the major study sites (table 2).

Table 2. Total sulfur, ash, and heating values of gray mining gob samples

Sample no.	Location	Dry basis % Sulfur	Dry basis % Ash	Dry basis Btu/lb	Dmmf* Btu/lb
C-22013	Central City—Backhoe Pit 2	0.36	88.9	613	15,906
C-22014	Rutland—Backhoe Pit 1	1.35	85.8	759	10,489
C-22015	Dalzell—Backhoe Pit 3	1.11	89.6	158	3,882
C-22021	Ladd—Backhoe Pit 2	1.55	88.1	174	2,414
C-22022	Standard—Backhoe Pit 3	1.07	89.7	119	2,572
C-22099	South Wilmington—Auger Composite	1.14	88.5	428	2,860
Averages		1.09	88.4	375	

*Dry, mineral-matter-free basis

Because the ranges of ash and sulfur values for the samples were small, it was convenient to use their average values to calculate mineral matter (MM) and combustible matter (CM) with the Parr Formula (Rees, 1966).

$$MM = 1.08 \times \text{ash} + 0.55 \times \text{sulfur}$$
$$MM = 1.08\ (88.4) + 0.55\ \ (1.09) = 96.1 \text{ percent}$$

$$CM = 100 \text{ percent} - MM$$
$$CM = 3.9 \text{ percent}$$

Some small error is involved in this calculation because the formula is intended to apply to ordinary coal samples and not high-ash, severely weathered coal waste materials.

The very low Btu/lb values reported for the samples are consistent with the assumption that the samples contain an average of 4 percent coal and other combustibles. The average of county averages of Btu analyses for fresh Colchester (No. 2) Coal in Bureau, La Salle, Will, and Grundy Counties (Cady, 1935, 1948) is 14,490 Btu/lb (Dmmf). A hypothetical gray mining gob sample that contained fresh Colchester Coal and had an average composition of 1.09 percent sulfur and 88.4 percent ash (96.1% MM) would yield 620 Btu/lb: dry Btu/lb = 14,490 (1-0.961) + 5000 (0.0109). Four samples have values significantly lower than this calculated value (table 2). Dmmf analyses, which express the calculated heating values of only the coal in the samples, show that four samples have heating values much less than the 14,490 Btu/lb value of fresh coal—evidence that the coal in the samples has been degraded by weathering.

A study by Conroy and others (1981, table 7.4.1.1) of coal wastes in the midwestern coal fields reports analyses of four mining gob samples taken from three piles at the Mark site (P1M, Putnam County) and one pile at the No. 3 Coal Corporation site (G33SW, Grundy County). The samples were found to have no heating value. Drilling logs given to us by the company (Peter J. Conroy, personal communication) reveal that all the samples were red clinker taken from burned parts of the piles in which no combustibles remained.

No washability tests were made of the mining gob samples.

Preparation gob

The preparation gobs in the study area are the pebbly, sandy materials that were taken from the bottoms of coal washer compartments and conveyed sopping wet to piles for disposal. Table 3 gives the sulfur, ash, and Btu/lb values of the preparation gob samples. Sulfur analyses of the preparation gob samples (table 3) reveal that most of the samples had the high sulfur contents expected for preparation wastes. Cady (1935, 1948) reported that the average sulfur contents (on a dry basis) of mine samples of the Colchester (No. 2) Coal from counties in the study area were 3.5 percent (Bureau), 3.9 percent (La Salle, west of the La Salle Anticline), 3.3 percent (Grundy), and 1.9 percent (Will). The average of the four county averages was 3.15 percent. Seven preparation waste analyses, which ranged from 4.38 percent to 7.84 percent total sulfur, exceeded this average by 1.4 to 2.5 times.

The No. 3 Coal Corporation terrace waste (C-22097) is not a coal washing waste but is included with the preparation gob for convenience because of its high coal content. It is a very coarse-grained material; its particles range from dust size to two feet in diameter, so it cannot have been crushed and washed. It appears to be a mine-run coal that was piled to form a terrace 10 feet high at the base of the east and south sides of the gray mining gob pile.

The average ash value (60.6%) and sulfur value (5.97%) of the preparation gob samples yielded a calculated average mineral matter value of 68.7 percent. In general, then, the samples of preparation gobs have an average combustible content of about 30 percent by weight.

Table 3. Total sulfur, ash, and heating values of preparation gob samples

Sample no.	Location	Dry basis % Sulfur	% Ash	Btu/lb	Dmmf* Btu/lb
C-22010	Central City—Backhoe Pit 3	5.78	61.7	2682	7,917
C-22011	Dalzell—Backhoe Pit 5	7.35	51.0	5259	11,952
C-22012	Ladd—Backhoe Pit 1	7.32	63.0	3906	12,697
C-22097**	No. 3 Coal Corporation Terrace—Surface Channel Composite	1.25**	40.6**	6919**	12,373**
C-22098	No. 3 Coal Corporation—Surface Channel	3.13	60.4	3862	11,220
C-22100	C. W. and V. No. 1—Backhoe Pit	4.38	53.9	3683	8,785
C-22101	Mark—Surface Channel	7.84	65.5	1777	5,545
C-22102	Dalzell—Surface Channel	5.97	62.1	2909	8,809
C-22103	Ladd—Surface Channel	5.95	67.2	2095	7,452
Averages		5.97	60.6	3272	9,279

*Dry, mineral-matter-free basis

**Reject of unknown origin, not included in averages

These average values, though useful and convenient generalizations, should not be considered highly accurate. We did not determine variations in the composition of each pile; only one or two samples were taken from each pile, and these were all from the bases of the piles. Furthermore, even though the average values compare preparation gob produced by coal washers, different kinds of washers were used and their products—though similar—were not identical. In addition, the averages compare severely weathered gob from surface channels with the mixture of severely weathered and less weathered gob from deep backhoe pit channels. Shallow and deep samples from a pile differ considerably in their heating values (see points 2 and 8, 3 and 9, and 5 and 10, fig. 7).

Dmmf heating values of the samples support the field evidence that the coal they contain has been severely oxidized by weathering. The highest and lowest heat values (5,545 and 12,697 Btu/lb) are 38 and 88 percent of the average Dmmf heating values for fresh Colchester (No. 2) Coal in Bureau, La Salle, Grundy, and Will Counties (14,490 Btu/lb). The average heating value for the preparation gobs (9,279 Btu/lb) is 64 percent of the average value for fresh Colchester Coal.

Conroy and others (1981, table 7.4.1.1) analyzed a preparation gob sample from the No. 3 Coal Corporation Site. The sample (B-2, 4) was a composite of four samples taken at depths between 16 and 37 feet from two holes drilled in the preparation gob pile. Its analysis yielded (on a dry basis) 4.03 percent sulfur, 69.7 percent ash, and 3,047 Btu/lb (12,644 Btu/lb Dmmf). These values are quite similar to those we obtained for Sample C-22098 from the same pile (fig. 7), but the Conroy sample is less oxidized than the surface channel sample, apparently because it was taken deeper in the pile.

Table 4. Forms of sulfur in four preparation gob samples

Sample no.	Location	Dry basis % Sulfur	% Pyritic Sulfur	% Sulfate Sulfur	% Organic Sulfur
R14802	Dalzell—Backhoe Pit 5	7.37	4.68	2.63	0.06
R14806	Ladd—Backhoe Pit 1	7.46	5.35	1.55	0.56
R14822	Central City—Backhoe Pit 3	5.97	0.20	5.57	0.20
R14827	C. W. and V. No. 1—Backhoe Pit	3.49	2.39	0.83	0.27

The high sulfate sulfur values in the four preparation gob samples (table 4) also indicate that the material is severely weathered. Ordinarily, fresh materials from the seam (coal, stony coal, and rock and mineral partings) contain very little sulfate sulfur. Gluskoter and Simon (1968) reported that the mean value of the sulfate sulfur in 361 Illinois coal samples was 0.08 percent. Eighteen analyses of fresh Colchester Coal samples on file from Grundy, La Salle, Will, and Woodford Counties report sulfate sulfur values ranging from 0.02 to 0.12 percent (dry basis).

Although the proportions of pyritic sulfur and organic sulfur in fresh preparation gob is not known, the decomposition of pyrite probably has produced most of the sulfate sulfur in the wastes. Pyrite reacts very readily with water and air, producing chemicals that react with calcite and clay minerals in the gob to form the sulfate minerals (gypsum, jarosite, melanterite, and others) that Hughes identified in these samples (ISGS, 1983, Part 2). The decrease in pyritic sulfur and corresponding increase in sulfate sulfur is most clearly shown by the analysis of the intensely rust-stained Central City sample, which shows that only one-thirtieth of its sulfur remains as pyritic sulfur.

The sample from the No. 3 Coal Corporation Terrace deposit (C-22097, table 3), which is not a preparation waste, has lower sulfur and ash values than the preparation wastes. Sieve analyses were not made on the sample from the terrace deposit because of the great range of its particle sizes.

Each waste material was generated by a specific, but somewhat variable, set of coal mining and/or preparation processes that determined to a great extent not only the characteristic composition of the waste but also its characteristic texture in place. Subsequently, weather and excavation modified this original texture. Sieving was used to analyze the textures of the waste samples, and help determine how the waste might be processed to recover coal.

Table 5 displays the ash analyses of preparation gob samples washed through a 48-mesh sieve to simulate roughly the initial washing (desliming) stage of a simple coal recovery process. The +48-mesh material is the presumed coal product; the −48-mesh material is rejected waste.

Table 5. Ash and combustibles in whole samples and wet-sieved, +48-mesh preparation gob samples

		Dry basis			
Whole sample (+48-mesh product)	Locations	(a) % +48-mesh product in whole sample	% ash in (b) whole sample and (c) product	(d) % ash rejected of total ash*	(e) % combustibles recovered of total combustibles**
C-22010 (C-22134)	Central City—Backhoe Pit 3	(53.5)	61.7 (54.6)	52.7	63.4
C-22012 (C-22336)	Ladd—Backhoe Pit 1	(45.9)	63.0 (40.0)	70.7	74.3
C-22098 (C-22331)	No. 3 Coal Corporation—Surface Channel	(40.9)	60.4 (33.6)	77.3	68.7
C-22100 (C-22332)	C. W. and V. No. 1—Backhoe Pit	(49.8)	53.9 (53.8)	50.3	49.9
C-22101 (C-22333)	Mark—Surface Channel	(16.6)	65.5 (35.6)	91.0	31.0
C-22102 (C-22334)	Dalzell—Surface Channel	(25.4)	62.1 (24.7)	89.9	50.4
C-22103 (C-22335)	Ladd—Surface Channel	(19.2)	67.2 (39.9)	88.5	35.1

*$d = 100 - \frac{ac}{b}$ **$e = \frac{a(100\text{-}c)}{100\text{-}b}$

+48-mesh product values in parentheses

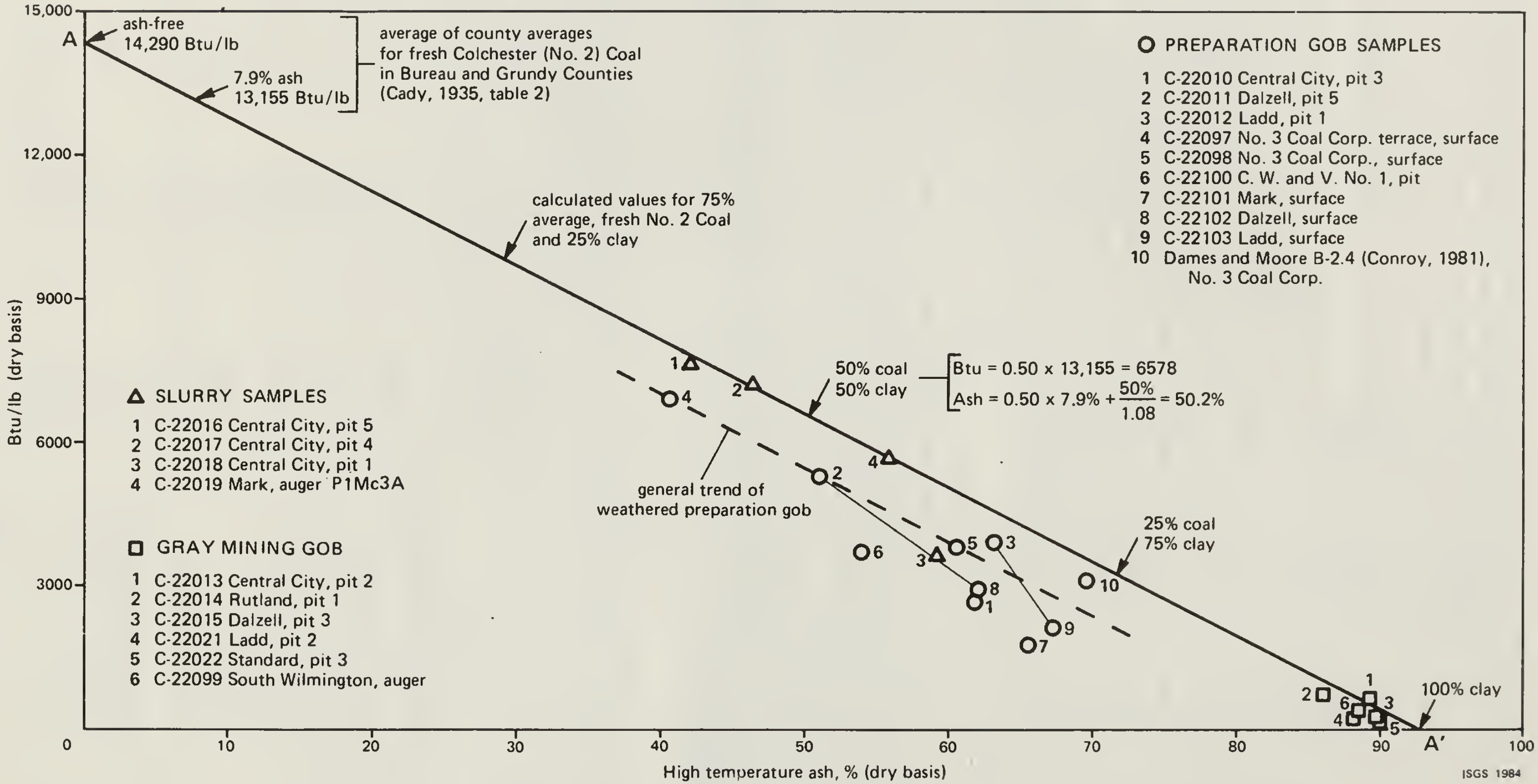

Figure 7. A comparison of heating and ash values (dry basis) of gray mining gob, preparation gob, and slurry samples.

Sample C-22012 (table 5) yielded 45.9 percent of the sample as coal product (+48-mesh) when washed through a 48-mesh sieve. The product contained 40 percent ash—a high value, although substantially less than that for the whole sample (63%). This simple desliming process rejected 70.7 percent of the ash in the whole sample and recovered 74.3 percent of the combustible matter, indicating that the material responded fairly well to this type of processing.

However, a simple desliming process alone does not produce a marketable product from this sample. A buyer considering a recovered coal product recognizes that its delivered ash, moisture, and sulfur contents are detriments to its use as a fuel; therefore, he calculates the value of the coal in the product and then discounts its value according to the amount of included impurities.

To produce a more salable product from Sample C-22012, either a better initial cleaning process or additional cleaning after screening will be required to lower the 40 percent ash content of the deslimed product. During second stage cleaning, for example, the +48-mesh product could first be crushed to break coal away from the mineral matter and then be washed again to remove the fines and the liberated mineral matter. Screening, the first stage of cleaning, rejected 54.1 percent of Sample C-22012 (table 5). If second stage crushing and washing were designed to reduce the ash content of the +48-mesh product further by 75 percent, for instance, then an additional 13.8 percent of the total material must be sent as ash to the waste impoundment: (1.00-0.707) x 63.0 x 0.75 = 13.8%. This calculated 67.9 percent total for rejected material will be increased by the normal inefficiencies of the recovery processes, and by the additional loss of part of the coal as fines.

Slurry

Table 6 shows the sulfur, ash, and heating values of the four slurry samples from the Central City and Mark sites. Typical variation across a slurry deposit is shown by the increase in sulfur and ash values and corresponding decrease in heating values from Central City Backhoe Pit 5 (farthest from the discharge outlet) to Pit 4 (between Pit 5 and Pit 1) to Pit 1 (closest to the outlet). The Mark sample was taken about halfway across the larger pond opposite the slurry discharge pipe.

The close agreement of the Dmmf Btu values for Samples C-22016, C-22017, and C-22019 with the average Dmmf Btu value for fresh coal in this area (14,490 Btu/lb) indicates that little oxidation and loss of volatiles has occurred in the coal (table 6, fig. 1). These samples were taken from low areas, and the sampled backhoe pits and auger hole were partly filled with groundwater. Water saturation and moist clay layers interlaminated with the coaly layers evidently keep air out of the materials at these localities, preventing their degradation. Conversely, Sample C-22018, which has only 71 percent of the average Dmmf heat value for fresh coal, was taken from a dry pit having a rusty, weathered slurry zone in its upper part, indicating that the material was exposed to greater oxidation.

The wet-sieve analyses of slurry samples (table 7) show the typical fine-grained nature of these materials. In general, only about 30 to 40 percent of a sample is coarser than

Table 6. Total sulfur, ash, and heating values of slurry samples

Sample no.	Location	Dry basis % Sulfur	Dry basis % Ash	Dry basis Btu/lb	Dmmf* Btu/lb
C-22016	Central City—Backhoe Pit 5	2.81	42.0	7593	14,033
C-22017	Central City—Backhoe Pit 4	5.27	46.1	7174	14,802
C-22018	Central City—Backhoe Pit 1	9.41	58.9	3685	10,311
C-22019	Mark—Auger P1M c-3A	2.39	55.7	5624	14,292

*Dry, mineral-matter-free basis

Table 7. Particle size analyses of wet-sieved slurry samples

	Central City G28CC			Mark P1M c		
	Pit 1	Pit 4	Pit 5	1A	1B	3A
	C-22018	C-22017	C-22016	C-21974	—	C-22019
Sieve mesh	+Σwt%	+Σwt%	+Σwt%	+Σwt%	+Σwt%	+Σwt%
+20	8.1	16.5	11.4	13.5	19.5	5.2
+30	15.2	25.6	17.5	21.1	27.4	7.4
+35	23.8	35.3	23.7	26.2	35.1	9.2
+48	31.7	42.8	29.6	32.1	41.1	11.1
0	100.0	100.0	100.0	100.0	100.0	100.0

*Calculations are based on the weights of air-dried samples

48-mesh size (or coarser than 0.0117-inch medium sand). Very little of a sample (5.2 to 19.5%) is coarser than 20-mesh (0.033-inch coarse sand).

The fact that the composition and texture of slurry deposits vary vertically as well as horizontally is demonstrated by the analyses of the two samples from Mark Auger Hole P1M c-1 (table 7). Sample 1A, which represents the upper 13 feet of the hole, is finer grained than Sample 1B, which represents the lower 8 feet of the hole. Note the horizontal variation in grain size shown by the three Mark samples. Sample 3A (the upper 11 feet of the 13-foot-deep Auger Hole 3) is much finer grained than samples A and B from Auger Hole 1 because it is about midway across the impoundment and Auger Hole 1 is nearer the washery discharge outlet.

Results of whole sample analyses and +48-mesh product analyses are compared in table 8. Wet-sieve desliming has reduced the ash in four of the six samples to acceptable product levels near 10 percent. Note in the same samples the correspondingly high percentages of rejected ash and recovered combustibles.

Two of the samples represent the types of slurry materials that a coal recovery operator probably would choose to avoid. The sample from Central City Backhoe Pit 1 is typical of slurry material found close to a slurry discharge outlet. The whole sample

Table 8. Ash and combustibles in whole samples and wet-sieved, +48-mesh slurry samples

		Dry basis			
Whole sample (+48-mesh product)	Locations	(a) % +48-mesh product in whole sample	% ash in (b) whole sample and (c) product	(d) % ash rejected of total ash*	(e) % combustibles recovered of total combustibles**
C-22018 (C-22140)	Central City—Backhoe Pit 1	(31.7)	58.9 (45.5)	75.6	42.1
C-22017 (C-22138)	Central City—Backhoe Pit 4	(42.8)	46.1 (27.4)	74.6	57.7
C-22016 (C-22136)	Central City—Backhoe Pit 5	(29.6)	42.0 (8.6)	93.8	46.6
C-21974 (C-22009)	Mark—Auger P1M c-1A	(32.1)	39.7 (11.0)	91.2	47.4
*** (C-22148)	Mark—Auger P1M c-1B	(41.1)	40.1 (15.7)	83.8	57.8
C-22019 (C-22142)	Mark—Auger P1M c-3A	(11.1)	55.7 (8.2)	98.4	23.0

$^*d = 100 - \frac{ac}{b}$ $^{**}e = \frac{a(100-c)}{100-b}$ ***Calculated from C-22149 and C-22150

'+48-mesh product values in parentheses

contains 58.9 percent ash and the +48-mesh product still contains 45.5 percent ash. The fact that this sample was taken from a pit located closer to the slurry discharge point than the other two Central City samples accounts for its high ash and sulfur content (table 6). The second sample, from Mark Auger Hole P1M c-3A, is like the very fine-grained, high-ash, high-clay slurry materials usually found farthest from a washery discharge outlet in a slurry impoundment.

Comparison of types of material and heating values

Our analytical data suggest several generalizations about the mine wastes.

- A preparation waste deposit is not homogeneous: the systems that formed and deposited the waste may have changed over time; the medium or conveyance that transported a waste segregated its particles to some extent by size and density; the air and water that penetrate a deposit decompose it over time, lowering its heat value and raising its ash values toward infiltrated surfaces.
- Gray mining gob samples can be distinguished from preparation gob and slurry samples on the basis of ash and heating values; differentiating between preparation gob and slurry requires additional information about their textures and such characteristics as bedding, color, and form of deposit.
- The sulfur and ash contents, heating values, textures, and processing behaviors of different mine wastes are directly related to the composition of the coal seam and to the mining and preparation processes that made and deposited them.

The points on the graph (fig. 7) are the plots of the heat and ash values of the waste samples listed in tables 2, 3, and 6. The points representing gray mining gob samples form a cluster well separated from the preparation gob and slurry points. Most preparation gob samples have more than 60 percent ash and all slurry samples have less than 60 percent ash, but the ranges of values for these two materials overlap. (Note again that sample C-22097, which has an unusually low ash content, is listed in this group for convenience but is not a preparation gob like the others.)

Line A-A′ of figure 7 represents the theoretical values of fresh mine wastes in the Historic Longwall District. It is constructed by plotting the calculated Btu and ash values of different mixtures of clay and average, fresh Colchester (No. 2) Coal. A comparison of the plot of a sample to the line shows whether the coal in it is relatively weathered or not. Slurry points 1, 2, and 4 plot on the line, indicating that coal in these samples is nearly unweathered. Preparation gob points 5, 7, 8, and 9 all represent surface channel samples, which are the most oxidized; all of them have Btu values significantly lower than the fresh coal Btu values coinciding with their ash values on line A-A′. The dashed line represents this general tendency of the preparation gob samples. Dalzell samples 2 and 8 and Ladd samples 3 and 9 (connected by lines in fig. 7) demonstrate that the Btu and ash values of preparation gob samples change with depth in the piles. Surface channel samples (8 and 9) are more weathered and have higher ash and lower Btu contents than do the samples taken from deeper in the piles in backhoe pits at the same sample locations.

POTENTIAL COAL RECOVERY FROM MINE WASTE: CONCLUSIONS

The physical, chemical, and washing characteristics of the mine wastes show that these materials have very different potentials for secondary recovery of coal.

Gray mining gob

- The gray mining gob contains so little coal that it is not feasible to attempt to recover coal from it.

Preparation gob

Our analyses (table 5) lead to several conclusions.

- Tests of all the preparation gob samples indicate that two stages of processing will probably be required to upgrade these inferior high-ash, low-combustible materials to marketable products. The additional cost of a second stage of processing and the expected low yield of final product would increase the cost and decrease the margin of profit involved in recovering coal.
- The preparation gobs probably do not contain enough coal to support profitable recovery operations at this time.
- Coal recovery from a preparation gob pile may not be feasible even if the recovery operation were to be partly funded as part of a site reclamation program. If a preparation gob pile were excavated by hydraulic mining, coal could be separated from the slurry stream, and the waste—reduced in bulk by the recovered coal—could be pumped into an impoundment that would be easier to reclaim than would the original pile. However, our analyses indicate that only small amounts of coal product would be removed by such an operation and that no large reduction in the preparation gob volume would result. Furthermore, the resulting pulp would probably be highly acidic, causing corrosion of the processing equipment and other problems.

Slurry

- Since completion of our report in 1983, reclamation at the Central City and Mark sites has buried the slurry deposits. Simple desliming and sizing operations could have recovered good coal products from parts of these deposits. However, the typical variability of texture and composition of the deposits indicates that the recovery method used would have to have been readily adaptable to variations in the material so that the quality of the products could have been kept consistent without costly, sophisticated controls.
- These slurry deposits probably could have supported coal recovery operations if there had been a sufficient volume of better grade materials and if local buyers could have been found for the coal products. To determine whether sufficient quantities of minable slurry were present, it would have been necessary to sample each deposit systematically, conduct coal analyses and washability tests, and map reserves. The high-ash and high-sulfur parts of a slurry deposit would probably have to be avoided for a coal recovery operation to be profitable.

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