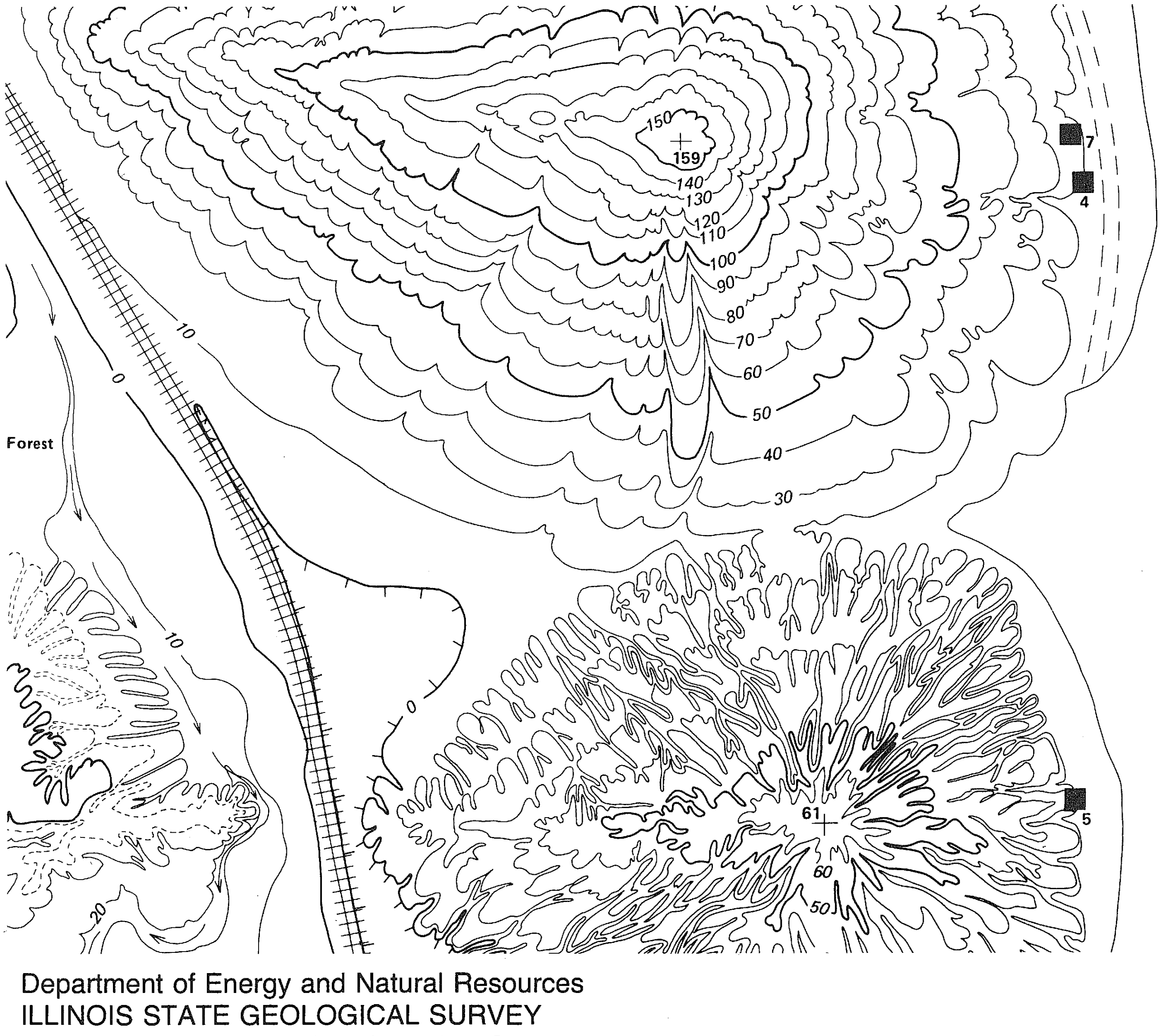
EGN 118

Characteristics and Potential Uses of Waste from the Historic Longwall Coal Mining District in North-Central Illinois

Susan Carol Bradford, Dwain Berggren, and Paul B. DuMontelle



Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
ENVIRONMENTAL GEOLOGY NOTES 118
1987

Graphic artists: Craig Ronto, Pamella Foster, and John Moss

Bradford, Susan Carol
Characteristics and potential uses of waste from the Historic Longwall Coal Mining District in north-central Illinois / Susan Carol Bradford, Dwain Berggren, and Paul DuMontelle. — Champaign, Ill. : Illinois State Geological Survey, 1987.
50 p. : illus., figs. ; 28 cm.

1. Coal mine waste. 2. Abandoned coal mines. I. Berggren, Dwain. II. DuMontelle, Paul. III. Abandoned Lands Reclamation Council. IV. Series.

Printed by authority of the State of Illinois/1987/1200

EGN 118

Characteristics and Potential Uses of Waste from the Historic Longwall Coal Mining District in North-Central Illinois

Susan Carol Bradford, Dwain Berggren, and Paul B. DuMontelle

ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief
Natural Resources Building
615 E. Peabody Drive
Champaign, Illinois 61820

FIGURES

Figures in the text are from Bradford, Berggren, and DuMontelle (1983) and figures in the appendix from Bradford (1983) unless otherwise noted.

ABSTRACT

The first large-scale industrial coal mining operation in Illinois (begun in the mid-1800s) produced more than 100 piles of waste—some almost 200 feet high, and many unstable. Most of these piles consist of shale, clay, and other debris resulting from mining operations; some consist of coal and clay separated from the coal during coal-washing operations. Problems associated with the piles include slumping, erosion of gob materials onto adjacent farmland and streams, and runoff. In this study, conducted for the Illinois Abandoned Lands Reclamation Council, gob materials from 16 representative sites were systematically sampled and tested, and six sites were studied in detail. Waste materials were classified on the basis of source material, mineral composition, geochemical properties, and color. Analyses of materials indicated that mining gob could be used for fired clay products, light-weight aggregate, landfill liners and levees, roads, and some foundations and fill, although considerable treatment might be required in some cases. Some coal could be recovered from preparation slurry deposits (from discharge ponds at coal washing plants), but coal cleaning would be required. U.S. EPA Extraction procedures performed on mine waste materials and leachates did not indicate toxic or corrosive hazards; however, the potential for formation of acid leachates should be a consideration in the use of waste materials or reclamation of a site. Geotechnical engineering studies showed that slopes of the piles would generally be stable if slope angles were reshaped to about 20 to 30 degrees. Current reclamation technology cannot prevent all the problems associated with the piles, but reclamation of the mine sites can temporarily control the problems and in some cases provide parks or landfills for local residents.

ACKNOWLEDGMENTS

This study was funded by the Abandoned Mined Lands Reclamation Council (AMLRC). This summary of the study results is based on the final report to the Council (ISGS, 1983) that includes sections referring to: mineralogy (R.E. Hughes), chemistry (J.K. Frost and J.D. Steele), geochemistry (I.G. Krapac and C.S. Smyth), evaluation of colliery waste for secondary recovery of coal (L.A. Khan, D. Berggren, and L.R. Camp), and engineering and hydrogeologic properties of the materials (W.J. Su and P.B. DuMontelle). R.E. Hughes contributed valuable information on the depositional environment and clay mineralogy of the Francis Creek Shale and participated in the initial appraisal of mineral analyses used to establish mappable units for the sampling program; J. Thomas provided information on the spontaneous combustion of coal and pyrite, and R.A. Bauer on mining methods and mine subsidence.

We also thank M.M. Killey, C.J. Stohr, and R.J. Krumm for their help in the field, and the following contract personnel (field, lab, technical and editorial assistants) for their helpful contributions: J.E. Crockett, J.M. Dunn, B.W. Fisher, S.F. Greb, J.K. Hines, D.M. Loffredo, M.A. Hehaia, T.A. Merwick, H.O. Minc, L.K. Radochanski, J.S. Rauh, and J.A. Stewart.

We are grateful to city and regional officials and local miners for their hospitality and information, and to property owners for allowing us to study their mine sites.

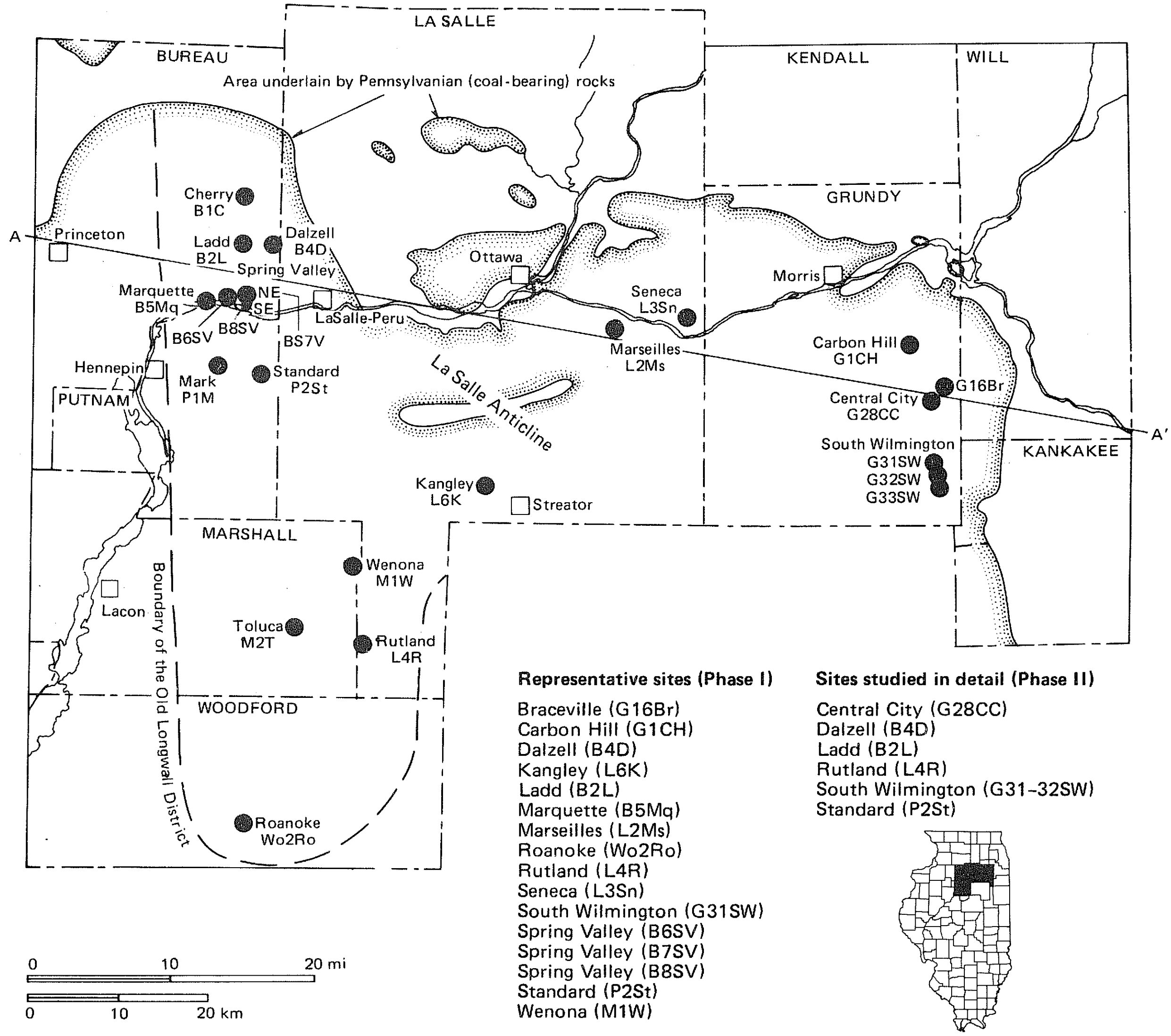


Figure 1 Sampled mine sites in the historic Longwall Mining District (modified from Bradford, Berggren, and DuMontelle, 1983).

INTRODUCTION

In north-central Illinois, between Bureau and Will counties, more than 100 piles of mine waste mark the sites of abandoned coal mines from the first large-scale industrial mining operations in the state. Some of these piles tower almost 200 feet above the flat landscape and cover as much as 25 acres, their gullied brick-red and gray surfaces almost barren of vegetation. Others, small and vegetated, are barely visible.

These piles of waste shale, clay, and coal are vestiges of mines operated in the historic Longwall District from the mid-to late-1800s into the 1950s; the mines were most active around the turn of the century.

To many residents of the towns that grew up around the mines the piles represent the labors of their fathers and grandfathers and the beginning of their families' lives in America; they consider the gob piles tributes to those who worked (and sometimes died) in the mines. But problems are associated with the piles, particularly the large ones. Slumps block railroad tracks and dam up streams, and sediments wash down from the piles. Some sediments settle onto farmland, making the land too clayey to plow; others fill in drainageways, causing adjacent lands to flood. These problems prompted some residents to request the Abandoned Mined Lands Reclamation Council to fund a project to minimize the problems. The Council contracted with the Illinois State Geological Survey to conduct a 7½-month study to (1) locate the sites and characterize the physical and chemical properties of the mine waste; (2) determine potential uses of the materials in the piles; (3) investigate methods of stabilizing and reclaiming the piles; and (4) determine if the materials posed any toxic or corrosive hazards. The Council also funded a parallel study by the Illinois Natural History Survey to determine what would be required to vegetate the piles.

During the first phase of our study we systematically sampled and analyzed materials from 16 representative sites (fig. 1). During the second phase we studied six sites in detail (fig. 1); most of the six sites were among the original 16. Throughout the study we collected single samples from any sites at which we found materials having exceptional characteristics; this brought the total number of sites sampled to 22.

HISTORIC LONGWALL SYSTEM OF MINING

Andros (1914) compared the layout of the mines in the historic Longwall District to a wheel (fig. 2). The center of the mine, where unmined coal or pack rock supported the hoisting and ventilation shafts, corresponded to the hub of the wheel; the haulageways, radiating out from the center to the working face where the coal was mined, to the spokes; and the working face (a constantly enlarging circle) to the rim. Mines of irregular shape developed when mining proceeded more quickly in certain directions to follow thicker coal, better mining conditions, or property lines.

The miners undercut (by hand) 8 to 12 inches of underclay from beneath the coal (fig. 3); if the underclay were more than about 18 inches thick, or if sandstone instead of clay occurred beneath the coal, they cut out the base of the coal itself (Andros, 1914). The miners braced the coal with sprags (short wooden posts) to prevent the coal from falling on them during the undercutting. If the coal did not fall when they knocked away the sprags, they would pry it down (Andros, 1914).

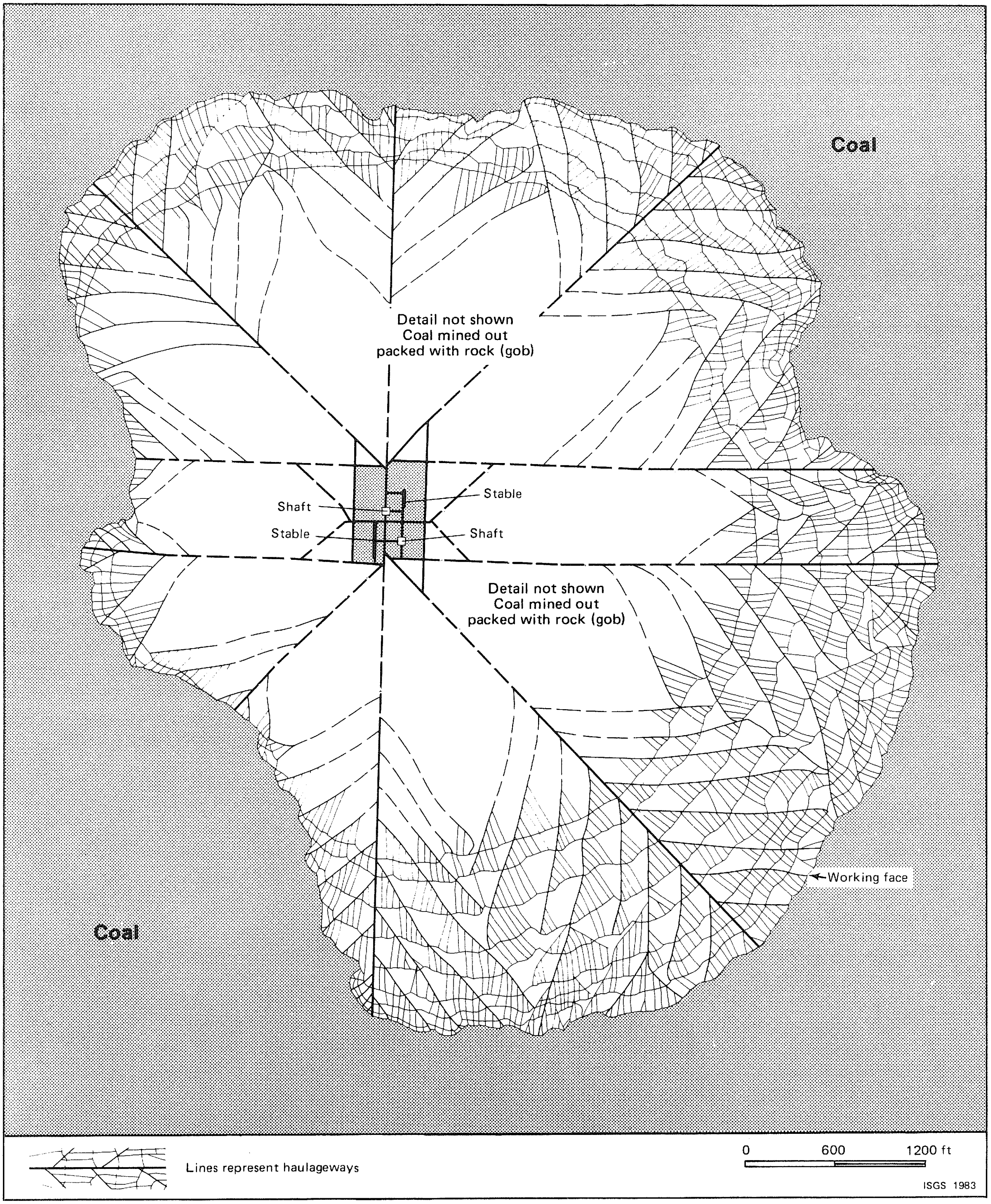


Figure 2 Plan view of a typical mine in the historic Longwall Mining District.

In the roadways, miners cut down ("brushed") about 2 feet of the shale immediately above the coal and secured the roof with timbers to provide sufficient height for mules and mine cars. This shale was used to build pack walls along each side of the roadways (Herbert and Rutledge, 1927). Miners filled the areas behind the pack walls to within about 2 to 5 feet of the working face with shale and other waste materials (the waste materials, as well as the areas behind the pack walls, were known as gob). The pack walls and the gob made a yielding support for the overlying strata. When a gob area was properly filled, the weight of the overlying strata on the working face would cause the coal to fall when the sprags were knocked away. If the gob area were packed too tightly, the roof strata would not exert enough pressure to allow the coal to fall easily; if it were not packed tightly enough, the roof would break in front of the working face (Andros, 1914; Herbert and Rutledge, 1927).

This method of mining resulted in subsidence of the ground, which usually ceased after a few years (appendix 1).

All the gob not needed for filling the gob areas was loaded into cars, conveyed to the surface, hauled up inclined tracks, and dumped (fig. 4). When the pile of dumped gob became level with the tracks, the tracks would be lengthened; if a pile became too large, the miners would begin a second pile. Most large mines produced at least two piles of mining gob. About 20 percent of all the material hoisted to the surface was gob—the rest was coal (Bement, 1929).

Some mines shipped run-of-mine coal only; others screened the coal into different sizes (Andros, 1917). In order to make their coal salable, some mining companies sent their coal to washeries for rescreening and sometimes washing to remove underclay that had become mixed with fine coal during mining (Bement, 1929). Some washeries were located at mine sites (as those near Mark, Dalzell, Ladd, Central City, and South Wilmington), but others were not associated with any mine site.

CLASSIFICATION OF MINE WASTE MATERIALS

Longwall coal mining operations in the District produced two general types of wastes: *mining gob,* consisting of discarded materials (shale, clay, dirty coal, and scraps of timber and other debris) hauled from the mines; and *preparation waste,* debris later separated from the coal during the cleaning (washing) process (figs. 5, 6). Mining gob and preparation waste are collectively known as *mine waste.* In the Geologic Study of Longwall Mine Sites in Northern Illinois (ISGS, 1983), mining gob was termed mine waste and mine waste was termed colliery waste. The stratigraphy and bedrock structure of the mine waste source materials are discussed in detail in appendix 2.

As we began our study, it became obvious that there were several distinct types of mine waste in the piles, and that a classification of these materials that was more precise than the commonly used "gob" and "slurry" would be helpful to those conducting recovery and reclamation work at the historic longwall sites. Accordingly, we classified the waste materials on the basis of source material, color, mineral composition, and geochemical properties.

Mining gob

Mining gob is by far the most abundant type of mine waste in the historic Longwall Mining District. (Gob piles in other parts of the state consist almost exclusively of preparation waste from coal not extracted by historic longwall mining methods.) Mining gob consists of gray gob, soft nongray gob, and clinker (fig. 7). The gob of many piles burned (especially those in the La Salle District), causing gray gob to alter to soft nongray gob and clinker. The cause of the spontaneous combustion in the piles is not fully understood, nor was it investigated as a part of this study.

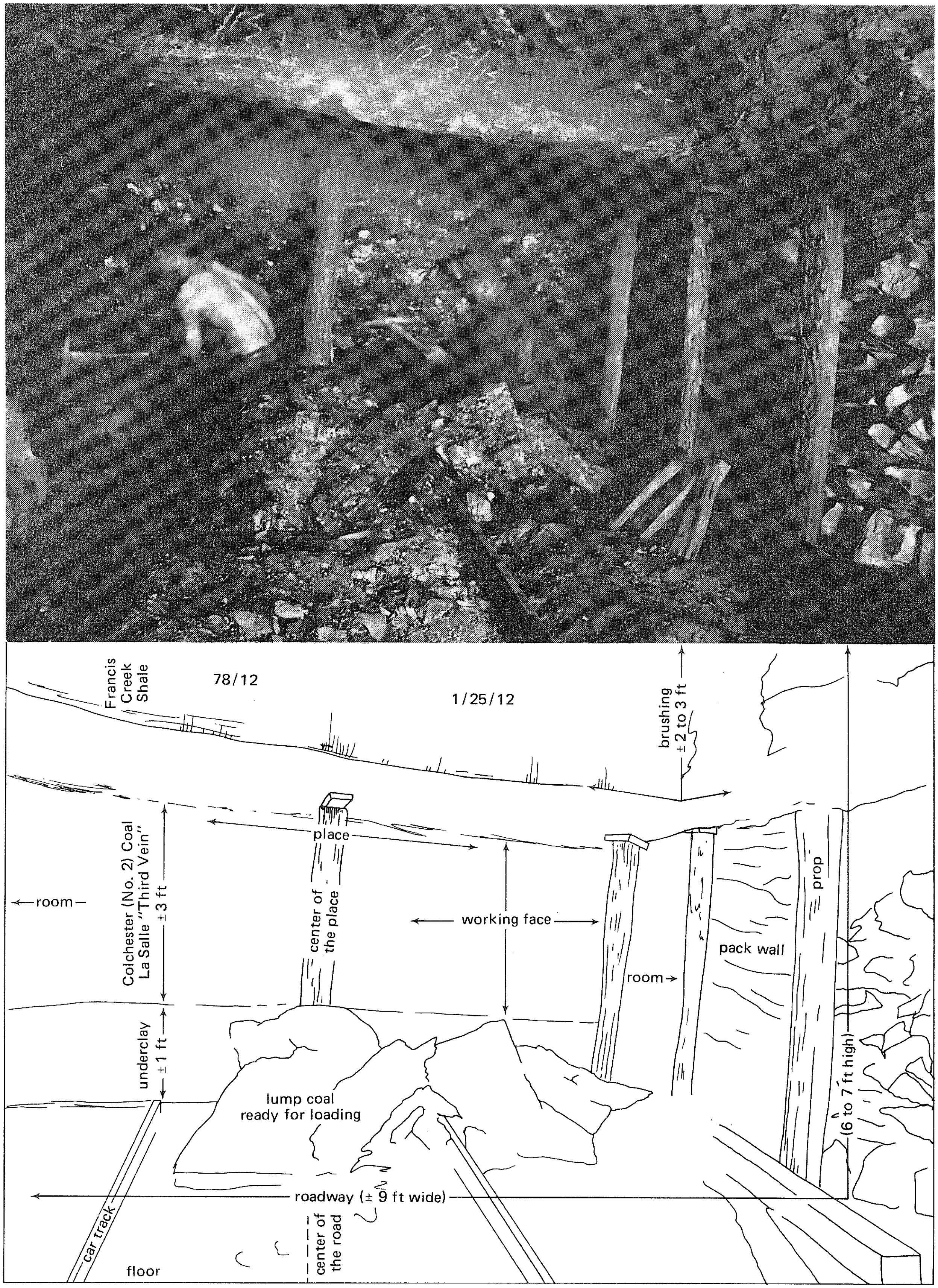
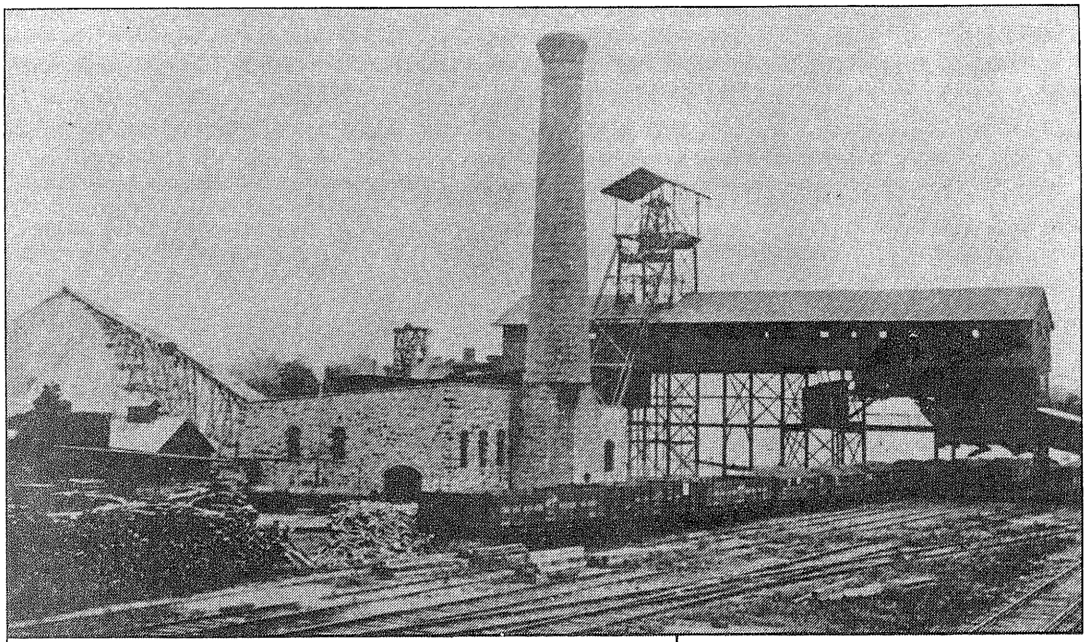


Figure 3 Miners at the face of a longwall mine are undercutting the coal seam by removing the underclay *(ISGS file photo 688; 1912 photograph).*



Bement (1929)

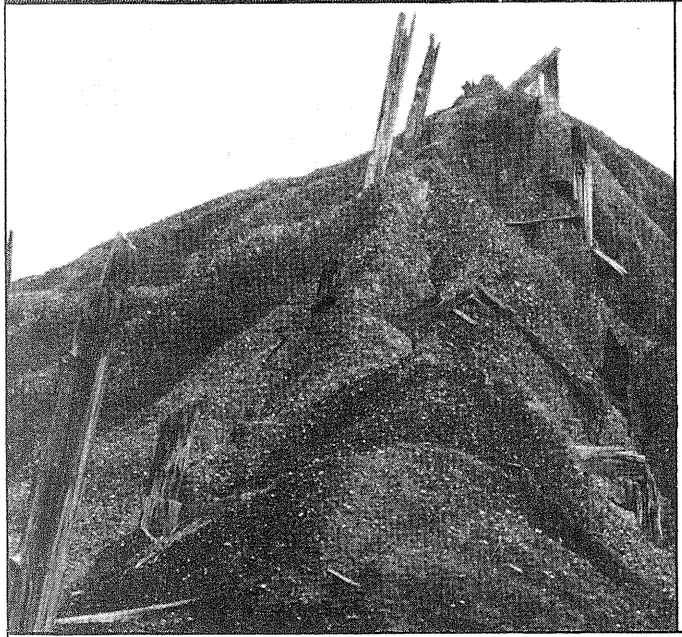
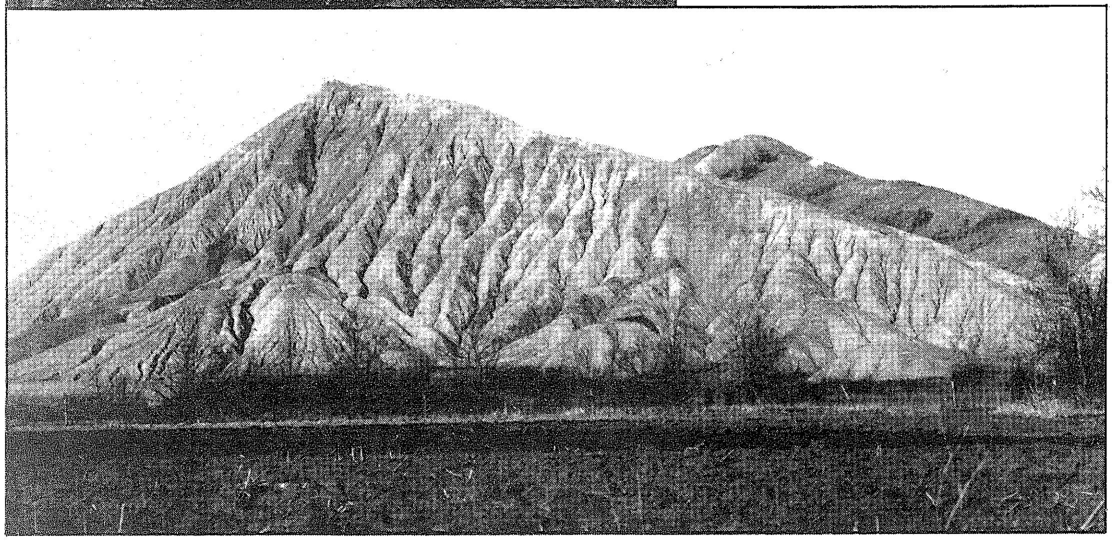


Figure 4 Top: Tipple and mine gob pile at Dalzell. Middle: Remains of a wooden trestle protrude from a pile of preparation gob at Dalzell. Bottom: Two piles at Standard showing typical skewed-cone shape of gob piles.



Gray gob Gray gob is any waste discarded during the mining operation that has not burned or become heavily oxidized. It consists mostly of Francis Creek Shale, but also contains small amounts of Mecca Quarry Shale, underclay, some pyrite concretions, and sandstone. Gray gob also contains ends of timbers, tracks, wooden supports, wheels from coal cars, and other debris. The Francis Creek Shale gives the pile its dominant characteristics and medium-gray color with faint yellowish to olive gray tints.

According to Hughes (1983), X-ray diffraction analyses reveal that the gray gob samples collected for the study have a uniform composition; they consist of minerals typically associated with the Pennsylvanian shales (illite, kaolinite, chlorite, quartz, and plagioclase feldspar), and gypsum and jarosite resulting from the oxidation of pyrite. Some samples contained vermiculite, presumably formed from the alteration of illite and chlorite by sulfuric acid. There were slightly more nonclay components in the gray gob at some sites in the east, probably because of high concentrations of silt and sand near the original source channels (Hughes, personal communication, 1985).

Gray gob covers all or most of the surfaces of many piles in the eastern part of the Longwall District; in the western part of the District gray gob is generally found at the bases of piles, where it has slumped or has been preserved. Siderite (iron carbonate) nodules tend to be concentrated on the surfaces of the piles; Mecca Quarry Shale tends to be concentrated in gullies.

Soft nongray gob Soft nongray gob is gray gob that was altered by low-to-moderate temperature oxidation. The zone of soft nongray gob between gray gob and clinker was narrow in places and broad in other places, depending upon the thermal gradient temperature, and other factors. The soft nongray gob is found on the surface of many piles in the La Salle District about midslope between gray gob at the bases of the piles and clinker at the tops. Soft nongray gob near clinker often contains hard, partly

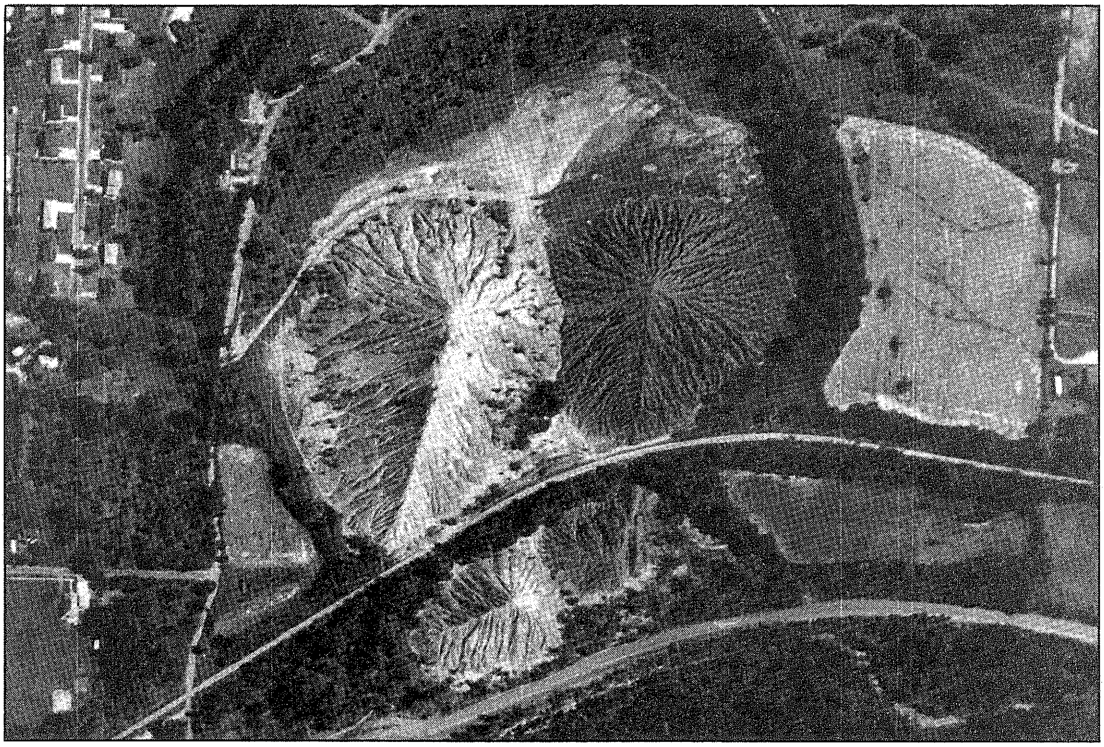


Figure 5 Four mine waste piles at Dalzell: the two darker piles are preparation gob, the two lighter piles, mining gob.

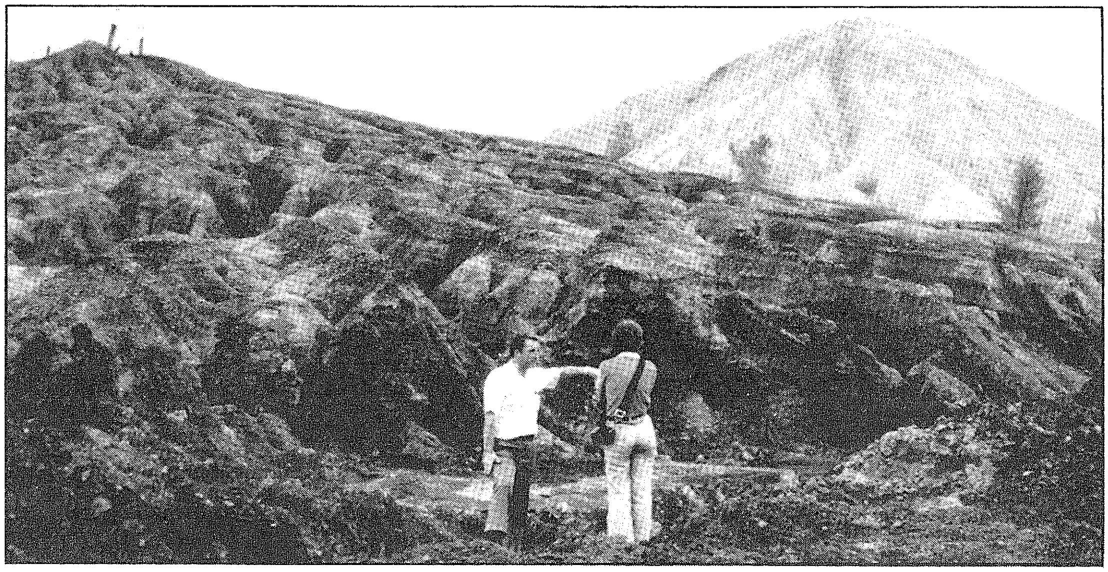


Figure 6 Preparation gob pile (in foreground) and mining gob pile behind it at Dalzell.

burned fragments that have sharp edges; most of these fragments break up easily in water. Soft nongray gob is typically shades of red, pink, orange, buff, yellow, and brown.

X-ray diffraction (Hughes, 1983) provided data that distinguished slightly burned soft nongray gob from that altered merely by oxidation. Depending upon the degree of alteration, soft nongray gob usually contains hematite and sulfate minerals in addition to those minerals found in gray gob. Most organic compounds have been removed (by oxidation) from the soft nongray gob, and some soluble minerals may also have been leached out (Hughes, 1983).

Clinker Clinker is gray gob that has burned to a hard, bricklike mass; it breaks into sharp fragments and does not readily slake. Clinker is predominantly red, but sometimes occurs as shades of orange, black, or buff. Unlike gray gob, which is remarkably homogenous (Frost and Steele, 1983), clinker has marked differences in composition,

Figure 7 Mining gob pile at Ladd. The lower, darkest part of the pile is the gray gob (unburned); the light patches on the sides are soft nongray gob (unburned and partly burned); the intermediate gray peak is clinker (burned). Borrowing has exposed the dark mass of fused clinker beside the man on the ridge.

depending on its location in the piles and the temperatures to which the piles heated. Hughes (1983) observed temperature-dependent changes in a series of samples collected from piles showing transitions from unburned to burned gob and in samples of unburned (gray) gob that were fired in laboratory furnaces. As the temperature increased, kaolinite, then chlorite, and then illite broke down; the quartz began to melt and mullite, cordierite, and cristobalite began to form. Hughes identified spinel and cordierite in some samples and also observed a number of sulfates (including complete and partial anhydrides of gypsum) and melanterite, jarosite, alunite, kaolinite, rozenite, and pickingerite. Well-crystallized sulfates sometimes grew overnight on the sides of pits excavated with backhoes. Some sulfates were so unstable that they changed forms in the laboratory in response to humidity changes.

Clinker found on the surfaces of piles tends to be exposed by erosion, and some piles may be burned throughout, as indicated by borings (Conroy et al., 1981). The burned areas may have been places where local concentrations of coal were close enough to the surface to undergo repeated cycles of wetting and drying; this could have raised the temperature of the coal several degrees, thereby accelerating the rate of oxidation and causing spontaneous combustion (Thomas, personal communication, 1982). The coal also must have been deep enough in the pile to prevent the heat from dissipating faster than it was produced.

Preparation waste

Preparation waste (preparation gob and preparation slurry) is found at sites where coal was washed (coal was not washed at every mine site). Coal from more than one mine may have been washed at some of these sites—therefore, preparation waste may be a composite of materials from more than one mine.

Because the specific gravity of impurities in coal (such as pyrite, siderite, calcite, and clay) is much higher than that of the coal itself, gravity methods were used in many washeries to separate the impurities from the coal. Stewart jigs were used in at least two sites (Ladd and Dalzell, B2L and B4D) where preparation waste is found (Link-Belt Machinery Company, 1905). At these sites, boxes with perforated bottoms were filled with unwashed coal and suspended with rods in tanks of water. When the boxes were agitated, water rising up through the perforated bottoms lifted the coal, which was then carried away by streams of water that flowed across the tops of the boxes. The coarse-grained debris (preparation gob) settled to the bottom of the boxes and was conveyed forward until it fell through hoppers to elevators. Fine-grained debris in water circulating through the coal during the cleaning process (preparation slurry) was discharged onto land and settled out in collecting ponds.

Preparation gob Preparation gob, like mining gob, was dumped in piles. These piles, usually dark gray, generally consist of poorly stratified coal and clay, and contain more coal than do the mining gob piles. X-ray analyses indicated that the noncoal fraction of the preparation gob contains illite, kaolinite, chlorite, gypsum, jarosite, quartz, feldspar, and pyrite (Hughes, 1983).

Preparation slurry When the water in the preparation slurry ponds evaporated, the slurry deposits remained as fairly level areas of stratified clay and shale. In some areas, erosion formed gullies and ridges in the slurry deposits.

X-ray diffraction analyses of a few samples of slurry reveal that the mineral composition and properties of the slurry tested are similar to those of preparation gob (Hughes, 1983); however, the composition of a sample within a pond differs according to the location of the sample relative to the discharge outlet. Cobb et al. (1979), and Khan, Berggren, and Camp (1983) noted that both large and small mineral particles having high specific gravities tended to be concentrated in samples taken close to the sources of the outlets.

Alluvium

Eroded materials from piles of mining gob and preparation gob are found as secondary deposits of alluvium that form aprons around the piles. (Some alluvium is probably colluvium that was deposited by sheetwash or creep.) Only alluvium from piles of mining gob was tested in the laboratory in this project. Field observations indicate that the alluvium consists mostly of soft nongray gob and clinker; X-ray diffraction analyses by Hughes (1983) confirm this.

POTENTIAL USES OF MINE WASTE MATERIALS AND SITES

Laboratory analyses and field investigations conducted during our ISGS study of the historic Longwall Mining District (ISGS, 1983) indicate that some types of mine waste have commercial potential and that some can be used safely as fill for small private or municipal projects near the sites. The findings, however, are based on generalizations from a study across the entire District. (Figure 8 shows locations of sampled mine sites; study procedures are discussed in appendix 3). When materials at a specific site are being considered for possible commercial use or for a purpose that might

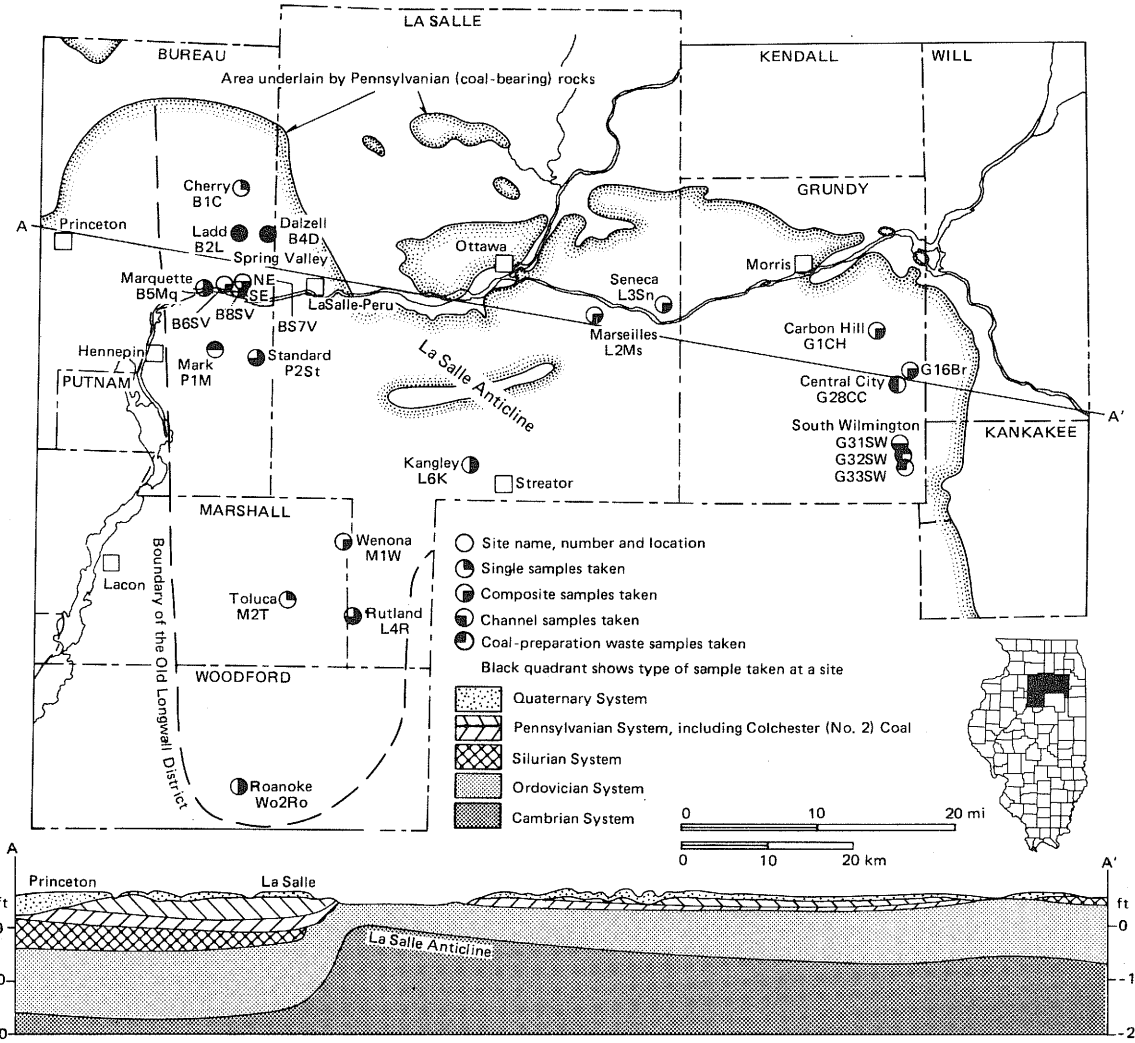


Figure 8 Locations of sampled mine sites, type of sampling, and cross section showing the La Salle Anticline.

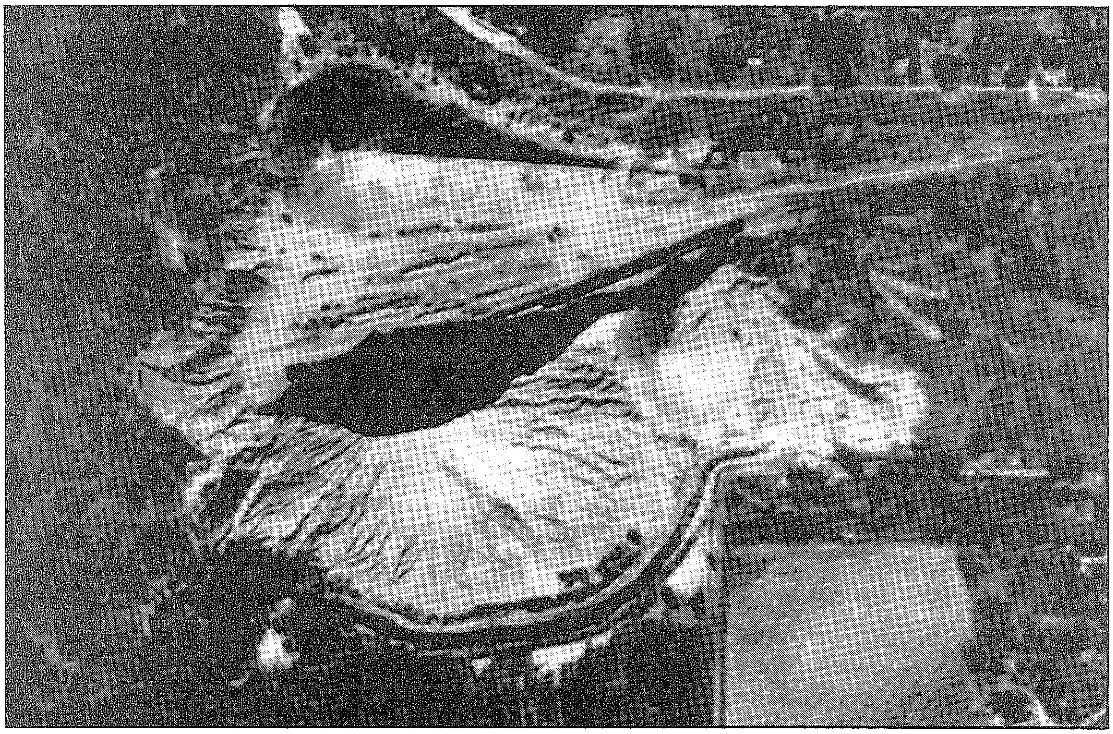


Figure 9 At the time this 1951 photograph was taken the larger pile of mine gob at the Spring Valley West site was being hauled away by train to supply shale and clay to a cement company. *(From USDA Agricultural Stabilization and Conservation Service)*

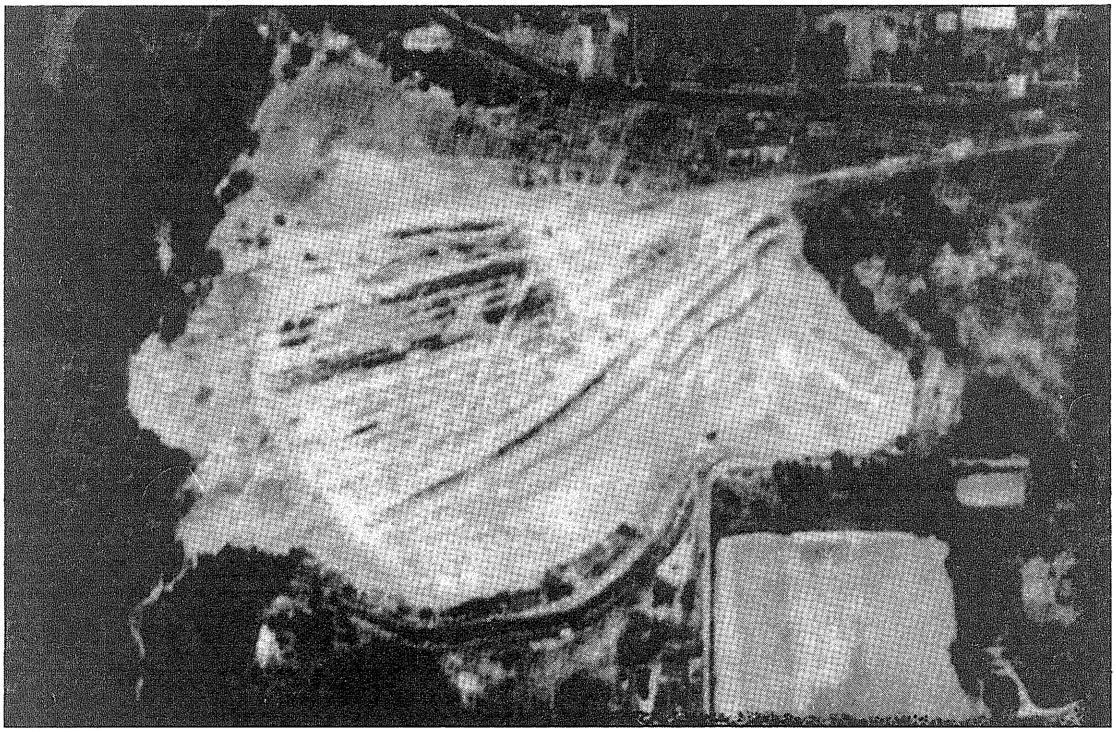


Figure 10 Same site in 1964; most of the pile is gone and the area is partly overgrown. *(From USDA Agricultural Stabilization and Conservation Service)*

involve risk, a detailed on-site study should be made to determine potential hazards and economic feasibility of the proposed use.

Materials from some sites, for example, from B8SV in Spring Valley (figs. 9, 10), have been successfully used in the past. Although we do not know how the materials were treated or used, a local city commissioner told us that the same treatment was unsuccessful when tried at another site in Spring Valley (B6SV).

Local, private uses for mine waste materials

Mining gob is being used successfully for various types of small-scale projects (fig. 11). Clinker, which compacts well and drains easily, is frequently used as road material for private lanes, trailer pads, and landscaping; gray gob is used for general fill and for landfill covers. Gray gob can probably be used without testing for filling low spots in a lawn or driveway. But untested material should not be used as fill around the foundation of a house; some clays in gray gob expand when wet and after many cycles of wetting and drying may exert sufficient pressures to crack foundation walls. Gray gob can also inhibit drainage around the house.

Commercial uses for mine waste materials

Mining gob Clayey mining gob has a number of uses; its commercial potential depends upon availability, amount of treatment required, and distance from the pile to point of use.

Fired clay products Bricks, sewer pipe, drain tile, flower pots, and pottery could be made from gray and soft nongray mining gob, which are similar in mineral composition to the clays generally used to make these products (Hughes, 1983). However, although mining gob clays are accessible and cheap, most require treatment before use: some screening is necessary to remove stones and scraps of timber and steel, the sulfur must be removed, and sand sometimes has to be added to the clay. The cost

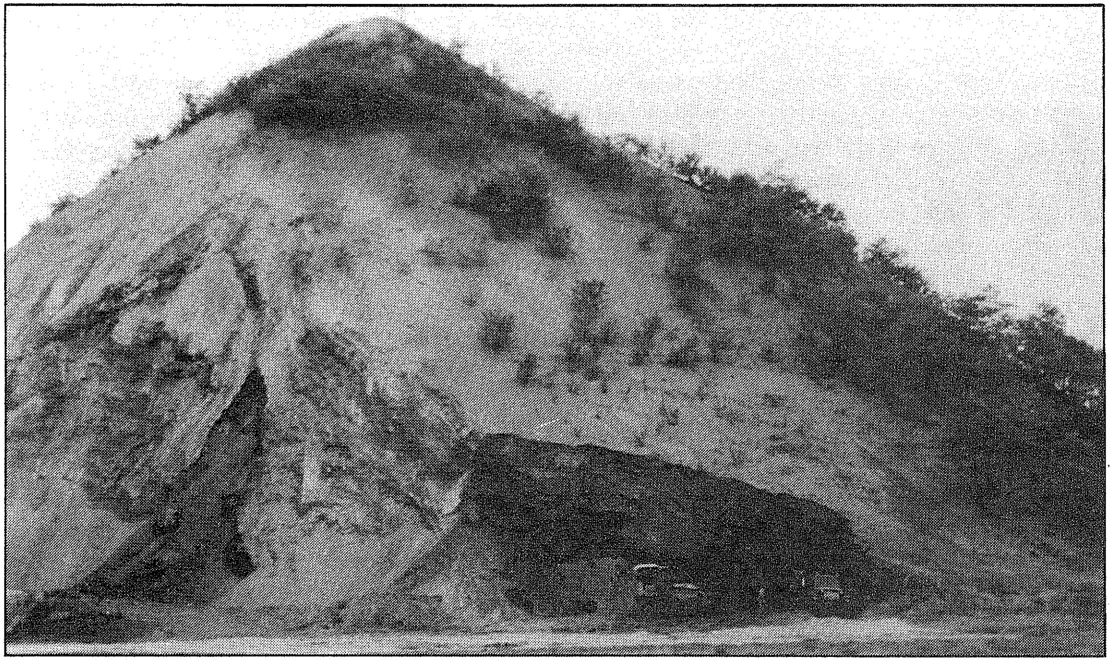


Figure 11 A small borrow operation at the Cherry site provides clinker for road metal, sub-base material, and clean fill. Note small slumps on slope at left.

of sulfur removal could be substantial enough to prevent some mining gob from being economically feasible to market for fired clay products.

Light-weight aggregate Hughes (1983) suggests that a light-weight aggregate could be produced by rapidly heating mining gob clay, but points out that its sulfur content would severely limit its uses. His analyses of gray gob indicates that the gob would generally be suitable for use in cement unless significant quantities of manganese and sulfate were present.

Landfill liners and levees Gray gob material having a high clay content can be compacted and used for liners and core materials for structures requiring very low hydraulic conductivities (Su and DuMontelle, 1983). Such material could probably meet or exceed standard construction specifications. Mineral analyses indicate that mining gob in the western part of the Longwall District contains a higher percentage of clay than does mining gob elsewhere in the District (Hughes, 1983). Clayey gob might actually be preferable to the commonly used bentonite for uses requiring material with low hydraulic conductivity: certain chemicals that might change the permeability of the bentonite are less likely to affect the permeability of the gob (Hughes, 1983).

Roads, foundations, and other structures Hard, properly sized clinker that does not weather excessively is found at several sites. Such clinker could be used to bind asphalt (using fine-sand sized materials), to provide clean backfill with good drainage, and to construct light-duty roads (Su and DuMontelle, 1983; Hughes, 1983).

Fill Gob can be used to fill low areas, cover undesirable materials, and support foundations for small buildings. The physical properties of the materials can be modified if necessary by mixing different types of gob to meet design specifications (Su and DuMontelle, 1983; Hughes, 1983).

Preparation waste Some usable coal could be recovered from preparation waste, but considerable processing would be required (Khan, Berggren, and Camp, 1983).

Preparation slurry A marketable product could be produced by washing parts of the slurry deposits remaining from washery operations at the two sites we tested (Central City, G28CC, and Mark, P1M); however, additional testing would be necessary to verify the quantity and locations of the better materials (Khan, Berggren, and Camp, 1983). The particle size and coal content of preparation slurry differs laterally (as well as vertically), depending on its distance from the source of inflow in the pond; thus, slurry in some areas of a site might be more desirable for coal recovery than slurry from other areas of the same site. (Both sites are now reclaimed.)

Preparation gob Washing preparation gob will probably not produce a desirable coal product. A wet-screening analysis of seven preparation gob samples was performed to simulate a simple beneficiation process by washing the fine fractions (mostly clay, silt, and fine sand—all high in ash) from the waste (Khan, Berggren, and Camp, 1983). Test results indicated that reprocessing the preparation gob by using a relatively inexpensive washing process would be impractical: only about a third of the gob would remain as product after screening and washing, and this product would contain too much ash to be desirable; meanwhile, the unused waste (now in the form of slurry) would still have to be disposed of in impoundment sites.

Uses for mine waste sites

Landmarks and memorials Large gob piles are landmarks treasured by many communities as relics of an important era in the industrial history of the state. The historic longwall mines were major forces in the communities that grew up around the mines (many of the villages, such as Mark, Dalzell, and Coal City, were founded along with the mines), and to many residents of these communities the mine sites are tributes to the men who worked in the mines. In the decades since the historic longwall mines closed a great deal of information has been lost. During our field work we encountered only a few of the thousands of people who worked in the mines—an indication that first-hand information about the operation of the mines and construction of the piles may be very difficult to obtain. Reclamation of the old mine sites could involve the collection and commemoration of industrial, community, and personal histories related to this era of coal mining.

Recreation areas A typical large mine site—with its towering piles of waste and overgrown areas—is a dramatic contrast to the flat fields that surround it and could provide an interesting environment for parks and other recreational facilities. Any pile more than 50 feet high offers an unparalleled view of the land around it. From the highest mining gob pile at Mark (about 180 feet high) at least 10 other longwall mines can be seen. The most distant is at Toluca, about 20 miles to the southeast (fig. 12). A reclaimed mine site can be a haven for small animals. Wild fruits and nuts, flowers, fossils, and mine artifacts could attract casual strollers and collectors. Gullies and steep ridges could serve as local playgrounds and dirt-bike courses. Planners could construct ponds and plant groundcover, shrubs, and trees to make the sites more attractive. The gob pile at Wenona (fig. 13) is an example of what can be done to transform a waste pile into a parklike area: a path leads through black locust trees and grasses to a leveled area on top that is ideal for picnics.

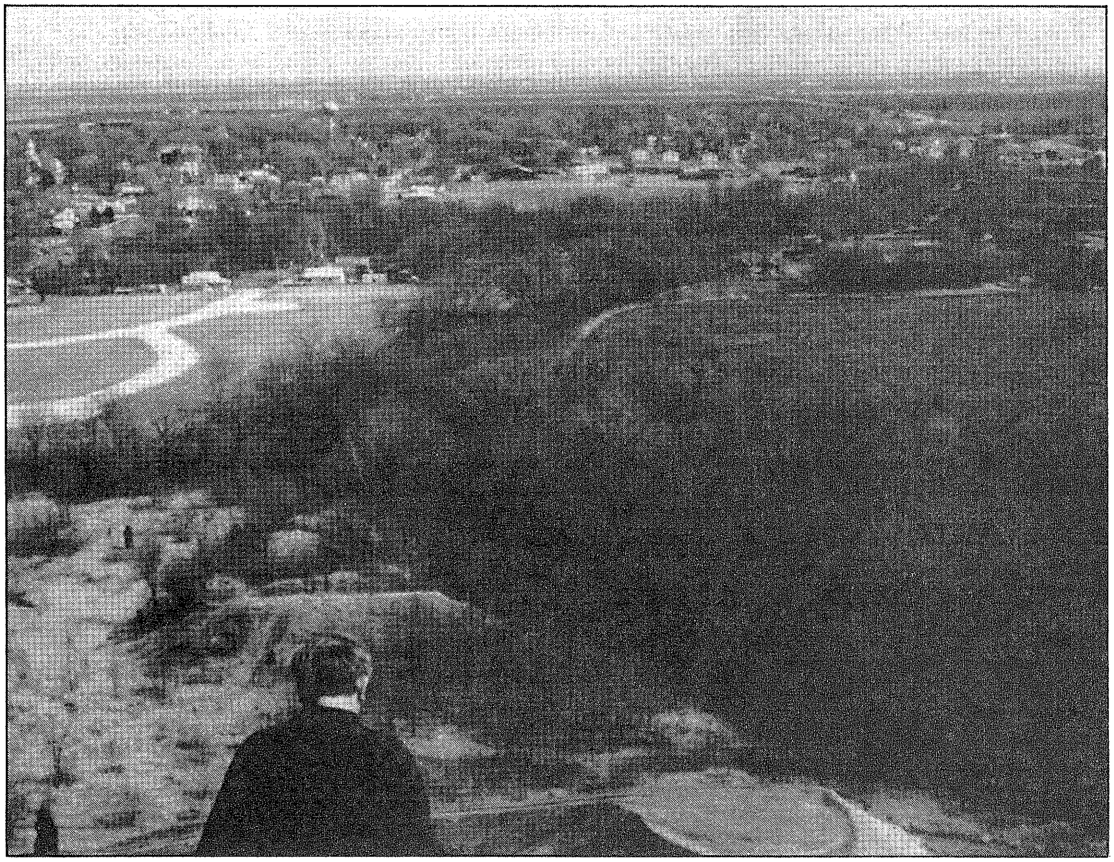


Figure 12 View from the top of the gob pile at the Mark site.

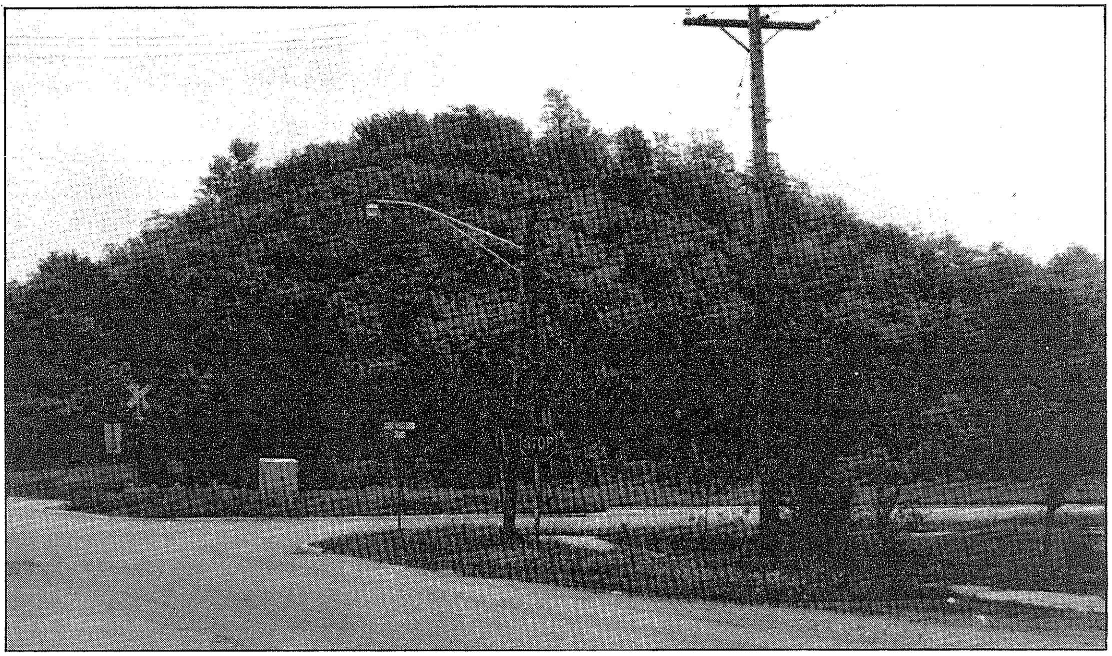


Figure 13 The U.S. Army reshaped and planted this gob pile in 1940 to use as a radar site. The site has since been made into a park.

Landfills and other uses Some communities are using mine waste sites as landfills, sewage lagoons, parking for off-road recreational vehicles, and other purposes so that prime farmland need not be used for this purpose.

Although a few large sites have been almost cleared (figs. 9, 10), allowing the land to be used for other purposes, the prospect of clearing most large sites is not promising. Even if some materials can be recovered for specific uses, much of a pile might remain (fig. 11). These remaining materials would need to be disposed elsewhere, probably at considerable expense.

EVALUATING MINE WASTE POTENTIAL

In determining the feasibility of using mine waste at a site (or sites) for a specific product or purpose, the following factors should be considered.

Availability of desired components

The nature and quantity of materials at a site should be verified by a drilling and sampling program. Although useful components were observed in samples tested for this study (ISGS, 1983), our sampling methods were designed to allow us to make generalizations about average compositions of each type of material at a site. Twenty-two sites were chosen to represent the characteristics of more than 100 sites (fig. 1). The mineral composition of gray gob samples from across the District were remarkably similar (Frost and Steele, 1983); however, the composition of a particular type of material could vary within a site, and greater variations are likely between sites. Assuming that the treatment and proposed use of the gray gob at the two sites in Spring Valley (B6SV and B8SV) previously mentioned were the same, variations in composition of the gob between the sites probably accounted for the success of operations at B8SV and lack of success at B6SV.

Large quantities of material are available at some sites. The total volume of all types of materials at each of the six sites studied in detail ranged from 100,000 to more than 1 million cubic yards, as determined with a planimeter and our topographic maps

(Su and DuMontelle, 1983). The approximate volume of materials (cu yds) in the six gob piles studied in detail has been calculated as follows: Central City, 100,000; Dalzell, 560,000; Ladd, city-owned, 160,000; Ladd, company-owned, 1,000,000; Rutland, 120,000; Standard, 450,000; and South Wilmington, 120,000. These volumes are based on the amount of materials above the present ground surface; the estimates would be slightly larger if all materials above the original ground surface were considered.

Workability of materials

Engineering and hydrogeologic properties of mine waste determine its usefulness for construction purposes. Tests commonly used in the construction industry were used to investigate how the gob materials would react under construction conditions (Su and DuMontelle, 1983). Atterberg limits tests, which show how materials behave at different water contents, indicated that mine waste material may have limited use because of its high water-holding capacity. This characteristic is typical of materials having high clay contents; particle size tests confirmed the presence of large amounts of clay in the samples tested. Laboratory compaction tests (designed to simulate field conditions for placement and compaction of sub-base materials for construction projects) indicate that even under the best of site conditions, compacted gob materials will be somewhat light and therefore may not be ideal fill for large structures requiring materials with higher strengths. Mining gob has been used successfully as fill for small structures and some roads.

Marketability of proposed product

Materials in mine gob piles may have a distinct market advantage over roughly comparable raw materials traditionally used for the same purposes, if they are close to points of use. The eastern part of the historic Longwall District is near Chicago, for instance, and many waste piles are adjacent to railroads. The materials in most piles are close to the surface, so little or no overburden would have to be removed to recover any type of mining gob. However, these economic advantages could be outweighed by high costs of special treatment that may be required.

The demand for gob materials is hard to predict. Other materials may already dominate the market (for instance, fly ash is now commonly used for light-weight aggregate). The clay industry in Illinois has been declining over the years because of competition from southern states, so at present the market for any types of clay, including gob clays, is limited. And although gob clays might provide a good source of clay suitable for making cement, cement company personnel are likely to be more concerned with locating their plants near high-quality limestone than near inexpensive clay resources.

PROBLEMS ASSOCIATED WITH MINE WASTE SITES

A number of problems—such as failing or unstable slopes, erosion, toxic or acidic leachates, and unmarked mine shaft openings—exist or could occur in the future at some mine sites.

Slope failure or instability

Slopes of large gob piles can fail, causing slumps that may block adjacent roads, railroads, or buildings, dam nearby streams, and enlarge the area affected by the pile (fig. 14). The slopes of the gob piles have changed over the years and are continuing to change as slumping and surface erosion lower slope angles to more stable configurations. Slumping occurs naturally on gob piles, but can also be triggered by excavation of materials from the foot of a slope (fig. 11). Overhangs resulting from such operations can create serious hazards.

High water tables near the bases of slopes can also cause unstable conditions that may endanger nearby facilities. Observations of monitoring wells drilled at three gob pile sites and of springs, seeps, mud flows, slumps, and swampy areas at the sites indicate that groundwater near the bases of slopes is at or near the surface. The high water table makes the land unsuitable for construction not only because the ground is soft and soggy, but because changes in the water content of clays near the surface can result in shrinking and swelling, causing cracks in roads and buildings and offsetting railroad tracks.

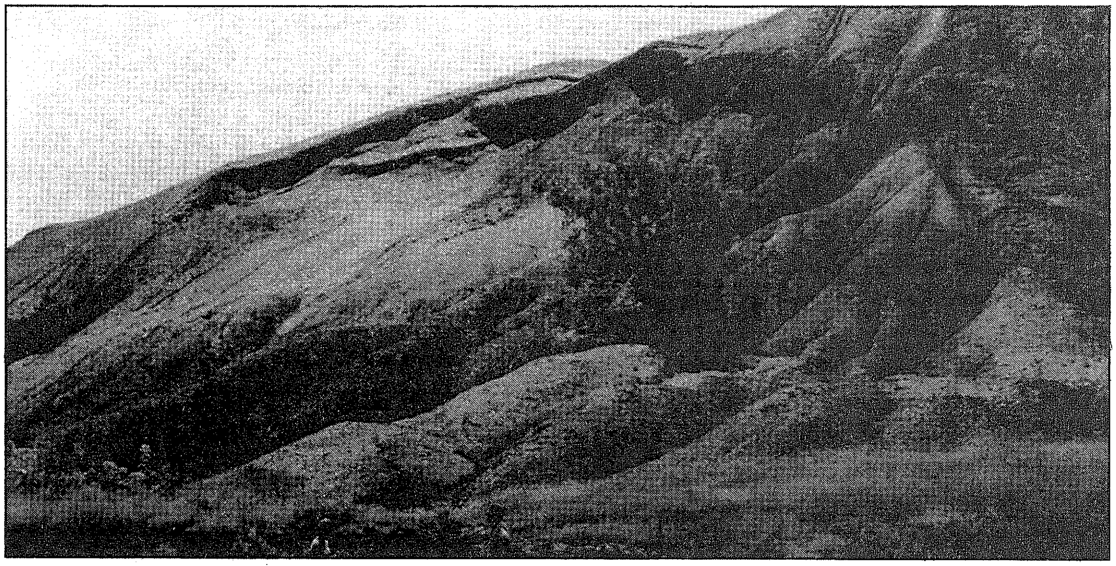


Figure 14 In 1982 a large landslide (slump) occurred on the western pile at Standard after heavy summer rains.

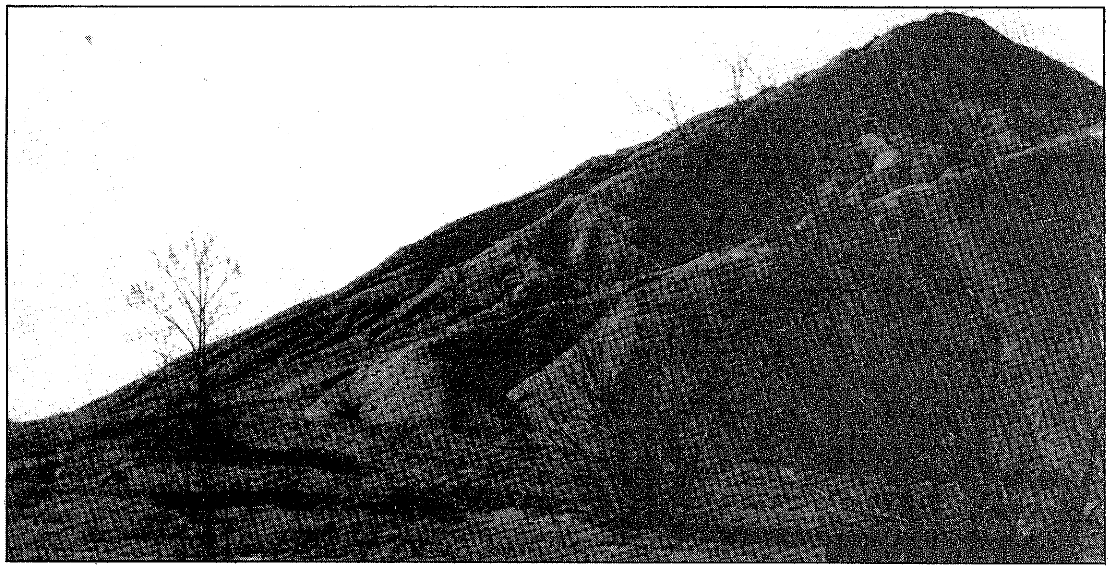


Figure 15 Large volumes of muddy sediments washing down from gob piles at Standard have partly buried a car that was abandoned years ago.

Erosion

Because there is often little or no vegetation to hold down materials on the slopes, wind and water can easily erode materials and carry them onto adjacent lands (often good farmland) and into streams (fig. 15).

The Illinois Natural History Survey found that soft nongray gob can support some types of vegetation if the slope is not too steep and is protected from erosion (Grunwald and Szafoni, 1983). Gob is far from ideal for farm crops, however. Some farmers have found that their crops could grow through a thin veneer of mining gob that had washed onto their land, but as the deposits became thicker, the affected land became less productive. Some farmers reported that the clayey mining gob clogged their farm machinery.

As sediments from gob piles fill in streams, flooding occurs on lands that depend upon the streams for drainage (fig. 16). Fields become too wet to farm, basements may flood, and septic tanks may overflow. Periodic dredging of the streams helps to restore drainage, but only temporarily if the piles are left to erode.

Leachates

U.S. EPA Extraction Procedure (EP) performed on samples of mine waste from 18 historic longwall sites indicated that extracts generated by this procedure did not contain selected constituent concentrations in sufficient amounts or with pH values acidic enough (pH $\leqslant 2$) to be classified as hazardous on the basis of U.S. EPA criteria for toxicity or corrosivity. Because our sampling was limited and directed towards generalizations, the possibility exists that effluents from some piles may be more toxic or have lower pH values than our tested samples. Observations in the field indicate that undesirable constituent concentrations in the leachates do exist. Red leachate springs were observed at several sites (indicating acidic, iron-containing water), as well as salt deposits in alluvium of some mining gob piles (fig. 17). The alluvium of preparation gob does not support vegetation.

The chemical characteristic of extracts generated from different types of mine waste are noted in the following paragraphs.

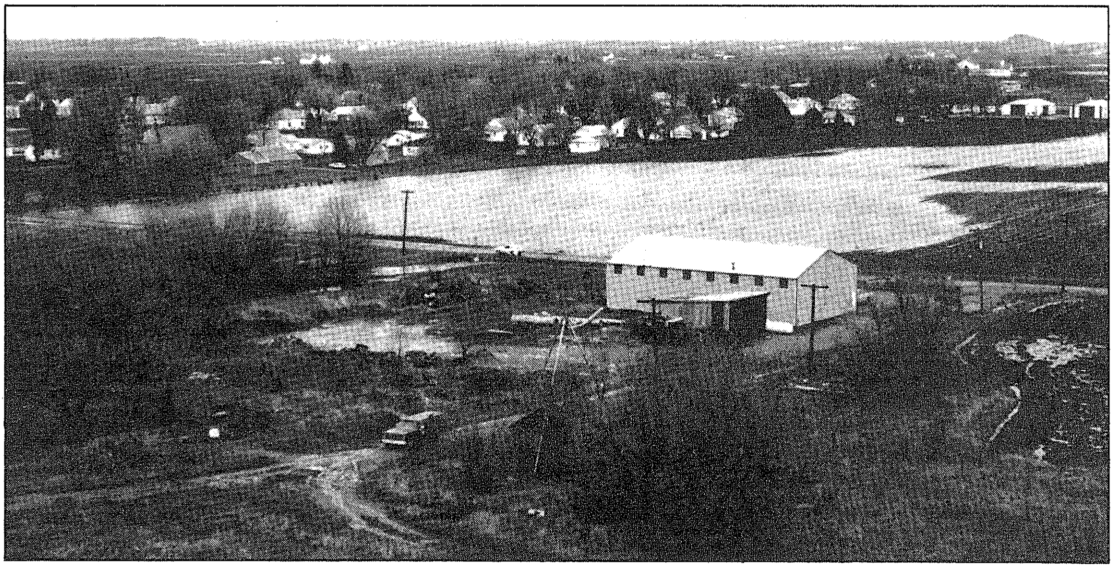


Figure 16 Mud from piles of mine gob at Standard filled a drainage ditch, causing repeated flooding of a nearby field; septic tanks adjacent to this ponded field overflowed (photo taken in spring of 1982).

Mining gob Most of the gob piles in the historic Longwall District consist of mining gob, which contains little coal and limited amounts of acid- and salt-producing minerals. On the basis of mean pH determinations from the EP extraction method (Krapac and Smyth, 1983), gray gob, which is only partly oxidized, is the most acidic mining gob material (pH ≃ 3.94). Soft nongray gob, which is more heavily oxidized or partly burned, has an intermediate value (pH 4.32), and clinker, which has burned the most, is the least acidic (pH 4.75). For comparison, household vinegar has a pH of approximately 4.8 and rain water (without SO_2 pollutants) is approximately 5.8.

We observed little difference in acidity between samples from the surface and samples from up to about 20 feet into the piles. Although we did not sample the deep interiors of most piles, we would not expect the acidity to vary greatly because the materials in the mining gob piles were coarse grained and mixed with water and air when they were dumped onto the piles.

Alluvium Two samples of alluvium from the mining gob were tested by the EP extraction method. The mean pH of the extracts generated by the alluvial material (4.99) indicated values slightly less acidic than those of clinker (4.75). When the samples were tested by a saturated paste method, they yielded a mean pH of 4.97, less acidic than soft nongray (burned) gob (4.19) and more acidic than clinker (6.01) (Krapac and Smyth, 1983). These results were expected, because alluvium from piles of mining gob consists largely of clinker and soft nongray gob.

Preparation waste The waste from the coal-washing process (preparation gob and slurry) contains concentrations of coal impurities such as pyrite that can react with oxygen to form acidic leachates. As expected, EP extracts from preparation gob were relatively acidic (mean pH 3.67); extracts from preparation slurry were not very acidic (mean pH 5.10)—even less so than mining gob (Krapac and Smyth, 1983). A possible explanation for the high pH values in the slurry extracts may be that there is a greater amount of acid-neutralizing minerals such as calcite and dolomite which contain calcium carbonate, in the slurry samples than in the preparation gob samples (Ainsworth, personal communication, 1983; Krapac and Smyth, 1983). Another factor may be that because of the particle composition of the slurry and the disposal

Figure 17 White iron sulfate salts found on alluvium where seep water has evaporated next to a gob pile at Standard. Rain and snowmelt soaking into the pile dissolved minerals in the gob and carried them to the base of the pile.

method, oxidation of the pyrite material (and thus production of acid) may be inhibited. Because the slurry is saturated when deposited and because there is a preponderance of clay, infiltration of air (oxygen) into the slurry deposits is limited, and the amount and rate of pyrite oxidation is decreased.

Samples from the interiors of the preparation gob piles produced less acidic extracts than did samples from the surfaces, indicating that they had not oxidized as much as had the surface materials. The materials in preparation gob piles are finer grained than those in mining gob piles; deposited while still wet from the coal-cleaning process, they compacted under their own weight, impeding penetration of air into the piles. Concentrations of iron-oxidizing bacteria and the physical breakdown of waste particles by wetting-drying and freezing-thawing cycles also control the differences in acidity observed at the surfaces and interiors of the piles. The mean pH (determined by EP shake methods) of composite samples of the surficial preparation gob was 2.4; the preparation gob from deeper in the piles, collected as channel samples, showed a mean pH of 4.3 (Krapac and Smyth, 1983).

Potential for acid formation in mine waste The potential for acid formation in mining gob and preparation gob decreases as acid-forming minerals continue to oxidize. Preparation slurry has a potential for acid production because it contains iron sulfide minerals. If acidic water is introduced into slurry, it could react with the calcium carbonate materials; upon neutralization of the calcium carbonate minerals, acidity conditions could then develop. The preparation slurry may then become as acidic as preparation gob, if not more so. If acidic material (even mining gob) is placed on top of preparation slurry, any water seeping through the gob would become acidic and could react with the calcium carbonate in the slurry.

Unprotected mine shaft openings

Openings to mine shafts are dangerous and difficult to close off permanently. Mine shafts in the Longwall District were vertical openings connecting the plant on the surface with the underground mine. Most sites contain two shafts: a coal-hoisting and an escape shaft. Shafts in the Wilmington (eastern) District are generally 50 to 200 feet deep, and shafts in the La Salle (western) District are about 350 to 500 feet deep.

Open shafts without safe covers are obvious hazards; however, even open shafts having substantial covers are a long-term concern because collapse of their linings can create openings in the covers and the ground around them. Some shafts thought to be filled may actually be only partly filled; in some shafts a platform was built partway down (or material may have become lodged partway down), and only the section of the shaft above the platform or lodged material was filled. Even shafts that have been completely filled sometimes sink because people have dumped garbage, construction debris, and other municipal wastes into the shafts; these materials can settle into a low-density, loose material and decay, causing voids and allowing increased water infiltration. Shaft fillings can also sink if the fill slides into open entries at the bottom of the shaft. For example, at the Mark site, a partly filled shaft opened suddenly in an area where earthmoving equipment had been working over it. Sites that have already been completely reclaimed may pose an even greater risk because people may be unaware of mining activity in the area. This is especially important in the Wilmington area where the coal was shallow, and numerous small, local mines operated. Waste piles at these mines are so small that little scarring of the land may be visible after reclamation.

Objectionable uses of sites

Neighbors may object to some of the uses made of a mine waste site. Shooting and hunting are common at many sites. Regulated landfilling at a mine waste site may spare prime land for farming, but unregulated dumping can be hazardous and unsightly. Use of the sites for recreational vehicles isolates the riders from the hazards of traffic and offers interesting terrain, but the noise can become a nuisance, and constant use can cause erosion and compaction that can kill vegetation on the slopes.

MINIMIZING MINE WASTE SITE PROBLEMS

Although it may be next to impossible to eliminate completely all the problems existing at a large mine waste site, many problems can be minimized by regrading the piles, controlling erosion and drainage, monitoring movement and quality of groundwater, and locating and marking hazardous mine shaft openings.

Regrading piles

Lowering the angles of the slopes and reshaping the piles can help stabilize the piles, control groundwater levels, and inhibit slumping and acid runoff. Changes in slope, vegetation, land use, periodic wet or dry climatic conditions, as well as other factors, can change local water table conditions. Because it is nearly impossible to predict the effects of all these factors, development of a design for long-term stability at a mine waste site is very difficult. Evaluation of the physical properties of mine waste (fig. 18) indicated that slopes should be stable if slope angles were about 20 to 30 degrees (Su and DuMontelle, 1983). Reshaping the slopes to these angles or lower would increase stability by inhibiting slumping, thus protecting the piles and the adjacent areas. But lowering the slopes might also result in a higher water table, which would decrease slope stability in a few years as the water table establishes a new position; additional slumping could then occur. Monitoring water table conditions at the sites could forewarn managers when water tables were rising. Action could then be taken, such as changing vegetation and installing drainage, to prevent serious problems from developing.

A series of wells was drilled in the slopes of three mining gob piles in the historic Longwall District. Water levels were too deep to be observed in these wells, and therefore the true elevation of the water table could not be determined in the piles. Water

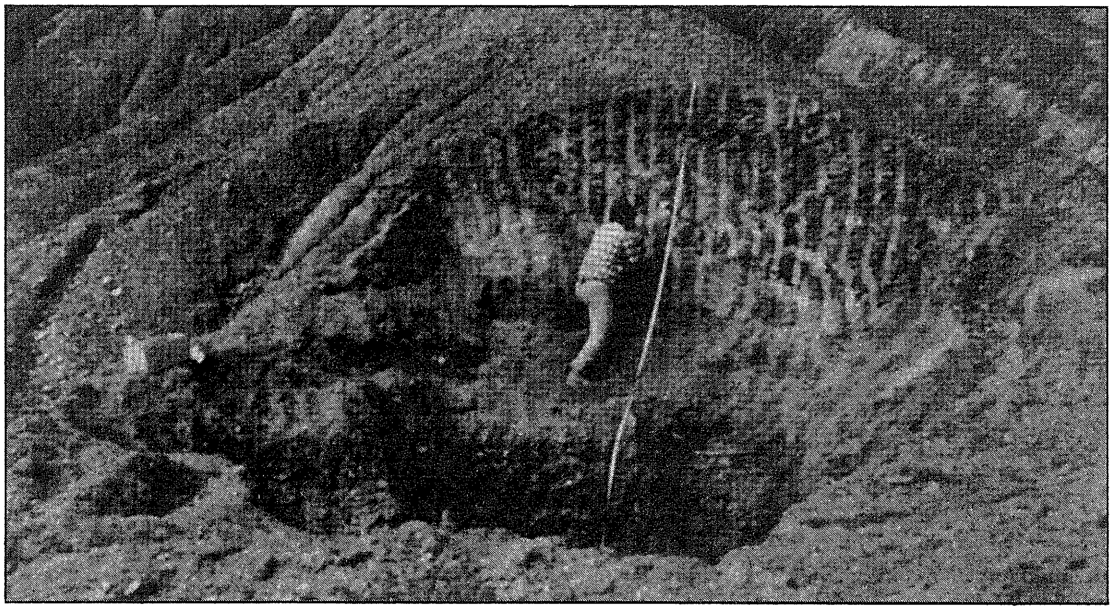


Figure 18 Samples were collected from backhoe pits for tests to determine the physical properties of the waste materials. Test results indicate what slope angle would be required to ensure stability.

levels beneath preparation gob piles in southern Illinois, however, were depressed below the level of the original land surface. Removing the top of the mining gob piles to lower the slopes might expose more clinker (coarse-grained permeable materials) and loosen masses of fine-grained materials, thereby increasing infiltration and raising the water table.

Lowering the slopes at a waste site generally involves removing materials from the tops of the piles and placing them in the gullies in the sides of the piles. Mine waste dumped many years ago has had time to settle and is usually quite dense; gullies filled with improperly compacted materials will allow acidic water to seep out along the original surfaces of the gullies and lead to future instability of the slopes. The loose, displaced material will also settle, causing depressions on the surface that will eventually become new gullies. Even careful design and control of compaction during construction may not eliminate the long-term problem of acidic seeps emerging from the bases of regraded piles.

Covering preparation gob with mining gob (which is less acid-forming) can prevent the exposure of preparation gob to weathering processes, but it may be necessary to separate the underlying acidic materials from the less acidic materials with a blanket of impermeable materials to prevent capillary movement of acidic waters bearing salts upward into the better soils (Krapac and Smyth, 1983). New slopes can also be designed to control groundwater flow.

Any design for covering preparation slurry with mining gob should ensure that no significant amount of water can pass through the mining gob and interact with the preparation slurry. Water from mining gob can still be acidic and can upset the balance of minerals in the slurry.

Care must be taken during regrading to protect less weathered materials from exposure. Exposed gob may burn spontaneously (parts of many piles have done so already). Spontaneous burning could be inhibited by disturbing the materials as little as possible and quickly compacting any materials newly exposed.

Controlling drainage and erosion

Installing drainage systems and constructing sediment ponds and wetland areas can help control high water tables at the bases of slopes. If slopes are regraded to low angles, access trails developed along these slopes would have to be drained to maintain stability. Some slopes could be left steeper than others, however, and catchment ponds or sediment basins could be constructed at the bases of the piles and at other parts of the piles to allow water plants to flourish and improve water quality before the water leaves the site. (Such a design would require less grading and would be less expensive than a design requiring all slopes to be graded low enough to ensure that the slopes would be dry.)

Establishing plantings on the piles will help stabilize slopes and prevent formation of intermittent streams and sheetwash that carry gob materials and dissolved chemicals offsite. The Illinois Natural History Survey made a study of which plants grow best in soft nongray gob (Grunwald and Szafani, 1983). Deep, well-developed root systems might help further stabilize slopes already lowered to a relatively stable configuration, but we noted some small trees and large bushes planted on unstable slopes that had moved downslope along with slump blocks.

Monitoring groundwater movement and quality

Regrading slopes, covering materials, and planting new vegetation can change the infiltration rates of water from rain and snow melt, resulting in significant changes over time in the position of the water table. Although engineering designs are usually conservative, unexpected conditions can and do develop at complex sites. Even after reclamation efforts have been completed, observation wells should be installed to monitor the movement and chemical quality of groundwater until a balance of conditions is achieved at a site. Such a program could also evaluate the engineering design to help ensure that future site reclamation programs are adequately but not wastefully planned.

Locating and marking mine shafts

Shafts at each mine site should be located and permanently marked so that experts can ensure that they have been properly filled and sealed and can inspect them regularly. It is usually difficult to find the shafts at sites in the study area because shaft structures are no longer visible. Some mine maps showing locations of shafts are available at the Illinois Department of Mines and Minerals, and open shafts should be reported to the Abandoned Mined Lands Reclamation Council. Although the Council is not a regulatory agency, it does monitor potentially hazardous shafts and provide for their reclamation. High priority should be given to locating and permanently marking shafts before reclamation work begins. Reclamation should include examining fillings, and constructing permanent covers.

Setting up permanent file of mine records

A local, permanent file should be set up and maintained. Each file might include (1) maps of surface and underground works and histories of the mine and its operations; (2) records of tests conducted on waste materials and uses of materials; (3) descriptions of any reclamation work and any problems associated with mining or reclamation at the site, such as slumping or subsidence; and (4) a long-term plan for permanent reclamation.

Reclamation of a large waste site will require a long-term effort, and will not be achieved during a single season of construction. Even if a site is extensively reclaimed by a well-financed project, it will require some maintenance for decades and may require reconstruction if a different use is later made of the site or its materials. Voluntary and locally funded reclamation projects, necessarily piecemeal in nature, should be well documented and coordinated with long-term planning in mind. Although current reclamation technology cannot prevent the occurrence of problems associated with the mine waste piles, it can at least control them temporarily.

SELECTED BIBLIOGRAPHY

Ainsworth, C. A., 1979, Pyrite forms and oxidation rates in Missouri shales: Master's thesis, University of Missouri, Columbia, MO, 144 p.

American Public Health Association, 1975, Standard methods for the examination of water and waste-water: 14th edition, American Public Health Association, Washington, DC.

American Society for Testing and Materials, 1977, Gaseous fuels; coal and coke; atmospheric analysis: American Society for Testing and Materials, Annual book of ASTM standards, part 26, Philadelphia, PA, 494 p.

American Society for Testing and Materials, 1982, Soil; rock; building stone peats: American Society for Testing and Materials, Annual book of ASTM standards, part 19, Philadelphia, PA, 710 p.

American Society for Testing and Materials, 1982, Gaseous fuels; coal and coke; atmospheric analysis: American Society for Testing and Materials, Annual book of ASTM standards, part 26, Philadelphia, PA, 992 p.

Anderson, D., K. W. Brown, and J. Green, 1982, Effect of organic fluids on the permeability of clay soil liners: Proceedings of the Eighth Environmental Protection Agency Research Symposium on the Land Disposal of Hazardous Waste, p. 179-190.

Andros, S. O., 1914, Coal mining practice in District I (Longwall): Illinois State Geological Survey, Mining Investigation Bulletin 5, 42 p.

Auchmuty, R. L., 1931, Subsidence and ground movement in a limestone mine caused by longwall mining in a coal bed below, *in* Transactions of the American Institute of Mining and Metalurgical Engineers, Inc., Coal Division: Institute at the Office of the Secretary, New York, N.Y., p. 27-50.

Barthauer, G. L., Z. V. Kosowski, and J. P. Ramsey, 1971, Hydrology and related experiments: Control of mine drainage from coal mine mineral wastes, Phase 1, U. S. Environmental Protection Agency, EPA 14010DD4, 148 p.

Bement, A., 1929, Illinois coal: a nontechnical account of its occurrence, production, and preparation: Illinois State Geological Survey, Bulletin 56, 123 p.

Berggren, D., and C. S. Hunt, 1978, A guide to the geology of the Middle Illinois Valley —Putnam, Marshall, and Peoria Counties, Illinois: Illinois State Geological Survey, Field Trip Guide Leaflet 1978C, 31 p.

Bradford, S. C., 1983, Mining methods, geology, and sampling procedures used to study colliery waste from the historic Longwall Mining District, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Bradford, S. C., D. Berggren, and P. B. DuMontelle, 1983, Colliery waste: issues caused by features at historic longwall mining sites, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Busch, R. A., R. R. Backer, and L. A. Atkins, 1974, Physical property data on coal waste embankment materials: Bureau of Mines, Report of Investigations 1964, 142 p.

Butler, P. E., 1974, Utilization of coal mine refuse in highway embankment construction: Proceedings of the First Symposium on Mine and Preparation Plant Refuse Disposal, National Coal Association-Bituminous Coal Research, Inc., Louisville, KY, p. 237-255.

Cady, G. H., 1915, Coal resources of District I (Longwall): Illinois State Geological Survey, Mining Investigation Bulletin 10, 149 p.

Cady, G. H., 1935, Classification and selection of Illinois coals: Illinois State Geological Survey, Bulletin 62, 354 p.

Cady, G. H., 1948, Analyses of Illinois coals: Illinois State Geological Survey, Supplement to Bulletin 62, 77 p.

Carter, R. P., 1978, Land reclamation program annual report, July 1976—October 1977: Land Reclamation Program ANL/LRP-2, Argonne National Lab, Argonne, IL, 163 p.

Caruccio, F. T., 1975, Estimating the acid potential of coal mine refuse, M. J. Chadwick and G. T. Goodwin [eds.], The Ecology of Resource Degradation and Renewal: Blackwell Scientific Publications Ltd., Oxford, p. 197-205.

Coalgate, J. L., 1975, A study of coal-associated wastes resulting from the mining, processing, and utilization of coal: Literature survey—coal-associated wastes (1900–1972): Interim Report No. 2 to U. S. Energy Research and Development Administration FE-1218-T-1, Aug. 1, Coal Research Bureau, West Virginia University, 120 p.

Cobb, J. C., J. M. Masters, C. G. Treworgy, and R. J. Helfinstine, 1979, Abundance and recovery of sphalerite and fine coal from mine wastes in Illinois: Illinois State Geological Survey, Illinois Minerals Note 71, 11 p.

Cobb, J. C., J. D. Steele, C. G. Treworgy, and J. F. Ashby, 1980, The abundance of zinc and cadmium in sphalerite-bearing coals in Illinois: Illinois State Geological Survey, Illinois Minerals Note 74, 28 p.

Collins, R. J., and R. H. Miller, 1977, Availability of mining wastes and their potential for use as highway material; Executive Summary: Report to U. S. Department of Transportation, Federal Highway Administration, Valley Forge Laboratories, Inc., FHWA-RD-78-28, NTIS, PB 287511/OWP, 40 p.

Commission of the European Communities, 1977, Utilization of colliery spoil in civil engineering applications: Coal Research Report EUR 5736e, National Coal Board, London, 41 p.

Conroy, P. J., I. Khosla, T. Preber, K. J. O'Reilly, 1981, A study of the properties of mine waste in the Midwestern coal fields: Final Report to U. S. Department of Energy Office of Procurement Operation PR 531, Washington, DC, Dames and Moore, Park Ridge, IL, 157 p.

Crossmore, E. Y., 1976, Utilization of wash water sludge: Proceedings of the Second Symposium on Coal Preparation Preprints, National Coal Association-Bituminous Coal Research, Inc., Louisville, KY, p. 132-141.

Dannen, G., and V. Stalmann, 1969, Washery discard in dike and embankment construction: Gluckauf, v. 105, no. 26, p. 1336-1343.

Fookes, P. G., W. R. Dearman, and J. A. Franklin, 1971, Some engineering aspects of rock weathering with field samples from Dartmoor and elsewhere: Quarterly Journal of Engineering Geology, v. 4, no. 3, p. 139-186.

Franklin, J. A., 1970, Observations and tests for engineering description and mapping of rocks: Proceedings from the Second Congress International Society of Rock Mechanics, Belgrade, VI, paper 1-3.

Frost, J. F., and J. D. Steele, 1983, Chemical composition of colliery waste from the historic Longwall Mining District, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Furman, N. H. [ed.], 1962, Standard methods of chemical analysis: Sixth Edition, D. Van Nostrand Company, Inc., Princeton, NJ, v. 1, p. 1008-1011.

Gleason, V. E., 1981, Bibliography on disposal of mine and cleaning plant refuse: Coal and the environment abstract series; Report to the U. S. Environmental Protection Agency, Office of Research and Development, Industrial Environmental Research Laboratory, EPA 600/7-81-107, Bituminous Coal Research, Inc., Monroeville, PA, 282 p.

Gluskoter, H. J., and J. A. Simon, 1968, Sulfur in Illinois coals: Illinois State Geological Survey, Circular 432, 28 p.

Gluskoter, H. J., and M. E. Hopkins, 1970, Distribution of sulfur in Illinois coals, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation —western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 89-95.

Gluskoter, H. J., R. R. Ruch, W. G. Miller, R. A. Cahill, G. B. Dreher, and J. K. Kuhn, 1977, Trace elements in coal: occurrence and distribution: Illinois State Geological Survey, Circular 499, 154 p.

Good, D. M., V. T. Ricca, K. S. Shumate, 1970, The relation of refuse pile hydrology to acid production: Proceedings of the Third Symposium on Coal Mine Drainage Research, Pittsburgh, PA, p. 145-151.

Gore, J., J. R. Nawrot, S. M. Jenkusky, and J. R. D'Antuono, 1979, Environmental and economic aspects of refuse disposal from Illinois underground mining: Final report to the U. S. Department of Energy, Carbondale Mining Technical Center, Carbondale, IL, 75 p.

Grim, R. E., W. F. Bradley, and W. A. White, 1957, Petrology of the Paleozoic shales of Illinois: Illinois State Geological Survey, Report of Investigations 203, 35 p.

Grunwald, C., and D. Szafoni, 1983, Revegetation study of longwall mine wastes in northern Illinois: Illinois Natural History Survey contract report for the Abandoned Mined Lands Reclamation Council, 174 p.

Haynes, R. J., 1976, Some properties of coal spoil bank and refuse materials resulting from the surface mining of coal in Illinois: Ph.D. thesis, Southern Illinois University, Carbondale, Illinois, 147 p.

Hebley, H. F., 1956, The control of gob pile fires: Journal of Air Pollution, Control Association, v. 6, no. 1, p. 29-31.

Herbert, C. A., and J. J. Rutledge, 1927, Subsidence due to coal mining in Illinois: U. S. Bureau of Mines Bulletin 238, p. 2-29.

Herzog, B. L., K. Cartwright, T. M. Johnson, and H.J.H. Harris, 1982, A study of trench covers to minimize infiltration at waste disposal sites, Task I Report review of present practices and annotated bibliography: Report to the U. S. Nuclear Regulatory Commission Division of Waste Management, Technical Report No. NUREG/CR-2478, v. 1: Illinois State Geological Survey, Contract/Grant No. 1981-5, 245 p.

Hoek, E., and J. W. Bray, 1981, Rock slope engineering: The Institute of Mining and Metallurgy, London, p. 358.

Hopkins, M. E., and R. B. Nance, 1970, Sulfur content of the Colchester (No. 2) Coal Member at the Banner Mine, Peoria and Fulton Counties, Illinois, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 96-98.

Hughes, R. E., 1970, Clay minerals associated with the Colchester (No. 2) Coal of the Illinois Basin, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 84-88.

Hughes, R. E., 1983, Mineralogy and potential economic uses of colliery waste from the historic Longwall Mining District, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Hursh, R. K., J. E. Lamar, and R. E. Grim, 1944, Illinois clays and shales as mortar mix: Illinois State Geological Survey, Report of Investigations 100, 55 p.

Illinois Department of Transportation, 1979, Standard specifications for road and bridge construction, adopted October 1, 813 p.

Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Jacobson, R. J., 1985, Coal resources of Grundy, La Salle, and Livingston Counties: Illinois State Geological Survey, Circular 536.

Jarrell-Ash Division, 1978, Jarrell-Ash Plasma Atom Comp Direct-Reading Spectrometer System: Fisher Scientific Company,Bulletin no. 434A, 17 p.

Jastrow, J. D., C. A. Zimmerman, A. J. Dvorak, and R. R. Hinchman (Argonne National Laboratories), 1981, Plant growth and trace element uptake on acidic coal refuse amended with lime: Journal of Environmental Quality, v. 10, no. 2, p. 154-160.

Johnson, R. G., and E. S. Richardson, Jr., 1970, Fauna of the Francis Creek Shale in the Wilmington area, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 53-60.

Khan, L. A., D. Berggren, and L. R. Camp, 1983, An evaluation of colliery waste from the historic Longwall Mining District, north-central Illinois, for secondary recovery of coal, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Krapac, I. G., and C. A. Smyth, 1983, Geochemical evaluation of colliery waste from the historic Longwall Mining District, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

Lamar, J. E., J. S. Machin, W. H. Voskuil, and H. B. Willman, 1956, Preliminary report on Portland cement materials in Illinois: Illinois State Geological Survey, Report of Investigations 195, 34 p.

Lamar, J. E., and R. D. Harvey, 1966, Geology of cement raw materials in Illinois: Proceedings of the Second Forum on Geology of Industrial Minerals, A Symposium on Geology of Cement Raw Materials, p. 45–71.

Lambe, T. W., 1951, Soil testing for engineers: John Wiley and Sons, New York, p. 165.

Link-Belt Machinery Company, 1905, Washing bituminous coal: Link-Belt Engineering Co. Special Booklet No. 42, 40 p.

National Coal Association-Bituminous Coal Research Inc., 1977, Proceedings of the Fifth Symposium on Surface Mining and Reclamation: National Coal Association, Monroeville, PA, 325 p.

Nawrot, J. R., R. J. Haynes, P. L. Pursell, R. D'Antuono, R. L. Sullivan, and W. D. Klimstra, 1977, Illinois lands affected by underground mining for coal: Illinois Institute for Environmental Quality Document 77/11, 195 p.

Nawrot, J. R., P. L. Pursell, W. D. Klimstra, and B. N. Jacobson, 1977, Problem sites: lands affected by underground mining for coal in Illinois: Illinois Institute for Environmental Quality Document 77/38, 556 p.

Nawrot, J. R. and W. D. Klimstra, 1977, Illinois mined land inventories: their implementation and utilization: Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL, 7 p.

Nawrot, J. R., W. D. Klimstra, S. M. Jenkusky, and T. J. Hickmann, 1980, Illinois state reclamation plan for abandoned mined lands/resource document: Illinois Abandoned Mined Lands Reclamation Council, 254 p.

Nawrot, J. R., W. D. Klimstra, and K. Sather, 1982, Reclamation and revegetation potential of Illinois historic longwall mining refuse, *in* 1982 Symposium on Surface Mining, Hydrology, Sedimentology and Reclamation, University of Kentucky, p. 129–138.

Odom, I. E., 1963, Clay mineralogy and clay mineral orientation of shales and claystones overlying coal seams in Illinois: Ph.D. dissertation, University of Illinois, Champaign, IL, 143 p.

Odom, I. E., and W. E. Parham, 1968, Petrography of Pennsylvanian underclays in Illinois and their application to some mineral industries: Illinois State Geological Survey, Circular 429, 36 p.

Peppers, R. A., and H. W. Pfefferkorn, 1970, A comparison of the floras of the Colchester (No. 2) Coal and Francis Creek Shale, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois, Illinois State Geological Survey, Field Guidebook Series 8, p. 61-74.

Portland Cement Association, 1973, Portland Cement Association soil primer: Portland Cement Association, Skokie, IL, 39 p.

Ramsey, J. P., 1970, Control of acid pollution from coal refuse piles and slurry lagoons: Symposium on Coal Mine Drainage Research, v. 3, p. 138–144.

Rees, O. W., 1966, Chemistry, uses, and limitations of coal analyses: Illinois State Geological Survey, Report of Investigations 220, 55 p.

Risser, H. E., and R. L. Major, 1968, History of Illinois mineral industries: Illinois State Geological Survey, Educational Series 10, 30 p.

Ruch, R. R., S. J. Russell, R. Malhotra, J. D. Steele, S. B. Bhagwat, G. B. Dreher, R. A. Cahill, J. K. Frost, R. D. Harvey, and J. F. Ashby, 1979, Determination of valuable metals in liquefaction process residues: Final Report to the U. S. Department of Energy, FE-8004-42, Illinois State Geological Survey, 187 p.

Savage, T. E., 1927, Significant breaks and overlaps in the Pennsylvanian rocks of Illinois: American Journal of Science, v. 14, p. 309.

Scott, P. B., 1973, Sealing of coal refuse piles: U. S. Environmental Protection Agency, Advanced Waste Treatment Laboratory, Crown, WV, 15 p.

Shabika, C. W., 1970, Depositional environments in the Francis Creek Shale, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 43-52.

Shan, N. S., S. K. Saxena, J. S. Rao, K. C. Singhal, and D. E. Lourie, 1981, Compaction criteria for coal waste embankments: U. S. Bureau of Mines, OFR 98-82, 200 p.

Smith, W. H., 1970, Lithology and distribution of the Francis Creek Shale in Illinois, *in* Smith et al., 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois: Illinois State Geological Survey, Field Guidebook Series 8, p. 34-42.

Smith, W. H., R. B. Nance, M. E. Hopkins, R. G. Johnson, and C. W. Shabika, 1970, Depositional environments in parts of the Carbondale Formation—western and northern Illinois, Francis Creek Shale and associated strata and Mazon Creek biota: Illinois State Geological Survey Guidebook Series 8, prepared for annual Coal Geology Division field trip Geological Society of America, Nov. 9-10, 125 p.

Sobek, A. A., W. A. Schuler, J. R. Freeman, and R. M. Smith, 1978, Field and laboratory methods applicable to overburdens and minesoils: Environmental Protection Technology Series, EPA-600/2-78-054, Industrial Environmental Research Laboratory, Cincinnati, OH, p. 72-78.

Stevens, T., 1978, Coal 'waste' may be good: Southern Illinoisan, Oct. 7, p. 3.

Stewart, B. M., and L. A. Atkins, 1982, Engineering properties of combined coarse and fine coal wastes: U. S. Bureau of Mines Report R.I. 8623, 18 p.

Stull, R. T., and R. K. Hursh, 1917, Tests on clay materials available in Illinois coal mines: Illinois State Geological Survey, Bulletin 18, 130 p.

Su, W. J., and P. B. DuMontelle, 1983, Engineering geological properties of colliery waste from the historic Longwall Mining District, north-central Illinois, *in* Illinois State Geological Survey, 1983, Geologic study of longwall mine sites in northern Illinois: Abandoned Mined Lands Reclamation Council contract report, 288 p.

United States Environmental Protection Agency, 1980a, Federal Register, 5-19-80, v. 45, no. 98, Superintendent of Documents, Washington, DC, p. 33063-33285.

United States Environmental Protection Agency, 1980b, Inductively coupled plasma-atomic emission spectrometric method for trace element analysis of water and wastes—method 100.7: U. S. EPA Environmental Monitoring and Support Laboratory, Cincinnati, OH.

University of Kentucky, 1979, 1980, 1981, 1982, Proceedings of annual Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation: Lexington, KY: Office of Engineering Services Publications, University of Kentucky.

Wahler and Associates (Palo Alto, California), 1981, Engineering property changes and environmental effects on coal mine wastes due to slaking: Report to U. S. Bureau of Mines Report OFR 13-82 (NTIS PB 82-163965), 281 p.

Wanless, H. R., 1957, Geology and mineral resources of the Beardstown, Glasford, Havana, and Vermont Quadrangles: Illinois State Geological Survey, Bulletin 82, p. 89.

Weaver, C. E., and L. D. Pollard, 1973, The chemistry of clay minerals: Elsevier Scientific Publishing Company, Amsterdam, London, New York, 213 p.

White, W. A., 1959, Chemical and spectrochemical analyses of Illinois clay materials: Illinois State Geological Survey, Circular 282, 55 p.

Willman, H. B., E. Atherton, T. C. Buschbach, C. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, J. A. Simon, 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95, 261 p.

Young, L. E., 1916, Surface subsidence in Illinois resulting from coal mining: Illinois State Geological Survey, Mining Investigation Bulletin 17, 112 p.

Zangerl, R., and E. S. Richardson, Jr., 1963, Paleoecological history of two Pennsylvanian black shales: Fieldiana: Geology Memoirs, v. 4, Chicago Natural History Museum, p. 25.

APPENDIX 1. Subsidence

Land overlying historic longwall mines subsided (sagged) during and after mining (fig. 19) as the weight of mine roofs gradually compressed pack walls and gob. Auchmuty (1931) and his colleagues monitored subsidence above a mine at Ogelsby (La Salle County) working the Colchester (No. 2) Coal where it was 3.5 feet thick at a depth of 560 to 595 feet. From data obtained at 145 surface monuments monitored between February 1915 and March 1918, they determined that subsidence occurred over a period of 3 years and 1 month. Herbert and Rutledge (1927) and their colleagues monitored two buildings 426 feet above the same coal seam (where it was also 3.5 ft thick) at an undisclosed location near the Illinois River. From surveys conducted

Figure 19 At this house near Coal City, a sag developed over a longwall mine 125 feet underground (Young, 1916). The entire house dropped, but the porch dropped 9 inches more than the rest of the house. Sags in the historic Longwall District stopped developing long ago.

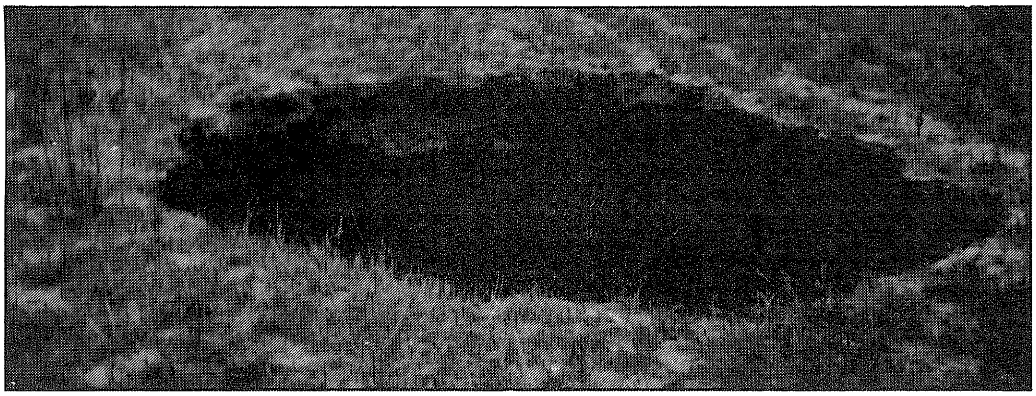


Figure 20 This pit in southern Illinois is similar to the kind that might occur today in the historic Longwall Mining District; however, only rarely are conditions favorable for the development of pits (Young, 1916).

between September 1916 and October 1920 they determined that subsidence practically ceased after 3 years and 4 months. Young (1916) determined that the depth of the sags was about 39 to 55 percent of the original mining height (usually about 4 to 4.5 ft). Subsided lands usually had to be drained artificially, and sagging roads were sometimes brought up to grade with gob and ashes (Young, 1916).

Most historic longwall mines operated at the turn of the century, and associated sags stopped developing long ago. Steep-sided holes (pits) may still develop from roof falls in haulageways of very shallow mines where conditions are favorable for the fall to propagate to the surface (fig. 20). Some pits have developed recently in southwestern Will County where the mines are 40 to 50 feet deep and only half the overburden thickness is bedrock. Many haulageways are probably no longer open, however, and the overburden above most mines is thick and solid enough to prevent roof falls from reaching the surface and causing subsidence. Homeowners in the area might still consider insurance against mine subsidence, however, as a precaution (Bauer, personal communication, 1982).

APPENDIX II. Stratigraphy and bedrock structure of mine waste source materials

STRATIGRAPHY

The principal coal mined by longwall methods in north-central Illinois was the Colchester (No. 2) Coal, a member of the Carbondale Formation of the Kewanee Group of the Pennsylvanian System (fig. 21). Some underlying underclay and the Francis Creek or Mecca Quarry Shale Members above the coal were also usually removed to mine the coal more efficiently.

Underclay

Beneath the Colchester Coal is an unnamed underclay. Cady (1915) noted that in the western part of the historic Longwall District the clay is thin and even absent in places, while in the middle and eastern part of the District the clay may be as thick as 20 or 25 feet. Cady's observations from two mines in Bureau County (western part of the District) describe the underclay as averaging 6 to 8 inches in thickness and consisting of light gray, micaceous sandstone grading into clay, or dark gray shale or clay with plant impressions and varying amounts of sand. At another mine in the county he describes the underclay as clay 3 to 5 feet thick that heaves (squeezes). In La Salle County (near the middle of the District), Cady describes at one mine a clay of unknown thickness that varies in quantity or sand, hardness, and tendency to heave; at another mine he describes a dark, hard, clay at least 20 feet thick with scattered ironstone concretions. In Grundy County (eastern part of the District), Cady describes the underclay at one mine as about 7 feet thick, uniform in character, and heaving somewhat. At another mine he describes that clay as 3 feet thick, fairly uniform in character, dark gray with considerable carbon and a small amount of root remains near the top and lighter gray towards the bottom. The clay was observed to heave considerably.

Odom and Parham (1968) observed that this clay contained an increased amount of kaolinite and decreased amount of pyrite towards the northern and eastern edge of the District. Because the kaolinite is poorly crystallized and similar to that developed in soils, Hughes (1970, and personal communication, 1983) associates clays of this type with the alteration of illite, chlorite, and feldspar due to long or intense weathering; ongoing research by Hughes should provide further insight into the distribution and significance of these clays.

Colchester (No. 2) Coal Member

One of the most widespread coals in the United States, the Colchester is a bright-banded coal averaging about 3 to 3½ feet thick in the historic Longwall District. The sulfur content of the coal varies, but sometimes decreases where the overlying deposits of Francis Creek Shale thicken, as in the eastern part of the Longwall District. However, widespread areas of high-sulfur coal are also known to occur where the shale is thick (Gluskoter and Hopkins, 1970).

Francis Creek Shale Member

Named for exposures along Francis Creek in Fulton County, Illinois and first referenced by Savage (1927), the Francis Creek is a medium-gray shale with a few sandstone beds in the upper part. Its thickness ranges from up to 15 feet in the western part of the Longwall District to more than 80 feet near the eastern edge (Smith, 1970).

Shale less than 30 feet thick is medium light gray, fine grained, and well laminated; it contains siderite nodules that are generally unfossiliferous. Shale more than 30 feet thick contains siltstone, sandstone, and fossiliferous nodules, which may suggest deposition in distributary channels and bays or in interdistributary bays. Shabika

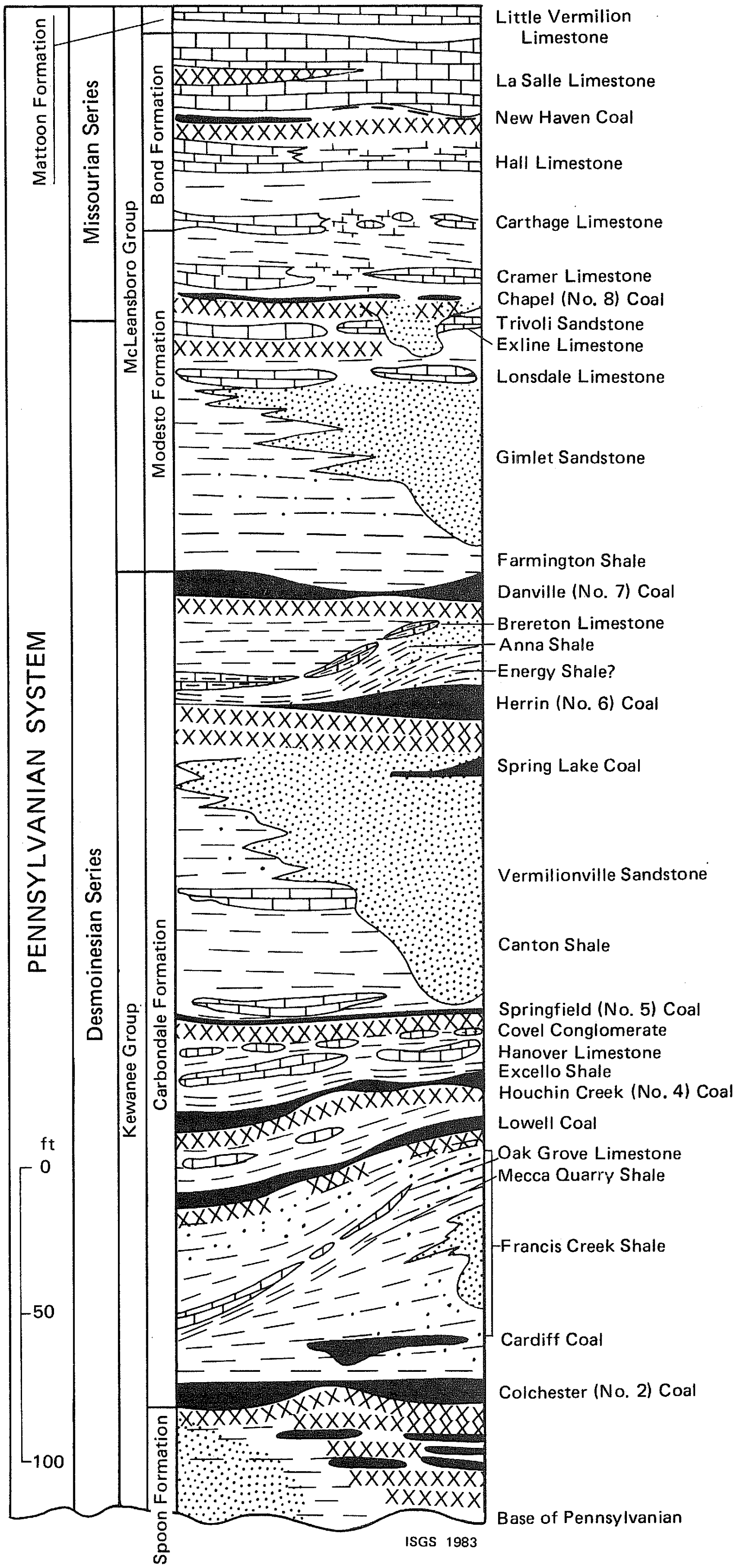


Figure 21 Generalized section of the Pennsylvanian System in the La Salle area (from Jacobson, 1985).

(1970) discussed the deposition of these thick shales in detail. Some siderite nodules contain compressions and fossils of plants and vertebrate and invertebrate animals; flora of the Francis Creek Shale are the most abundant and diversified flora of their age known in North America (Peppers and Pfefferkorn, 1970).

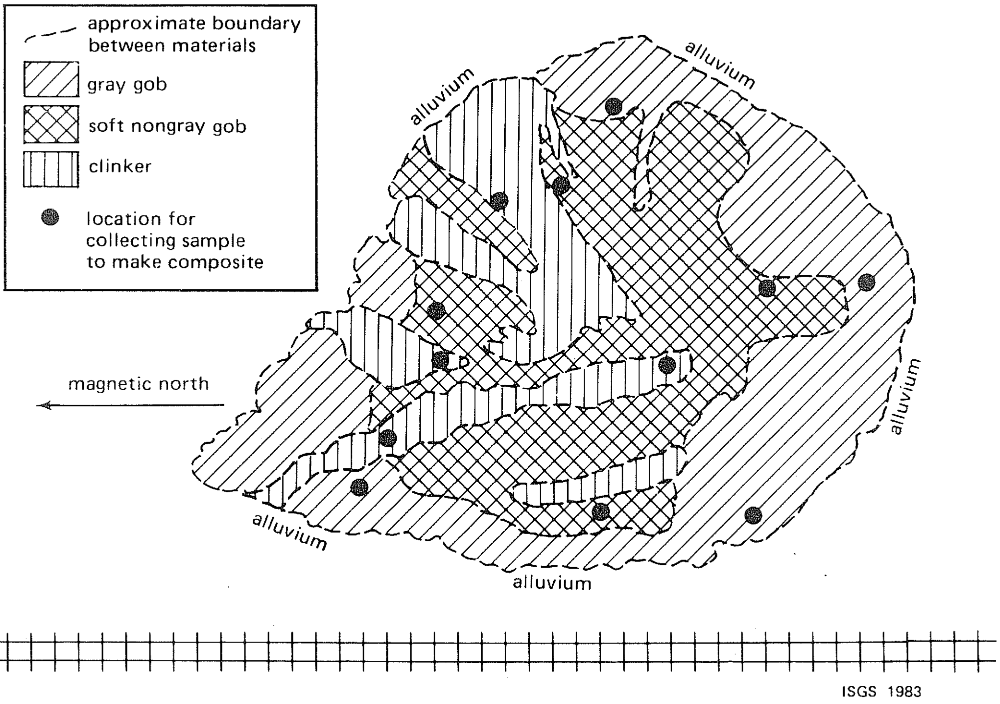
Mecca Quarry Shale Member

Named for a quarry in Mecca, Park County, Indiana and originally referenced by Zangerl and Richardson (1963), this pyritic shale is hard, black, carbonaceous, and fissile. Usually 1 to 2 feet thick, it contains numerous small phosphatic lenses that give it a pimply bedding plane surface. It generally occurs above the Francis Creek Shale, and is usually not found where the Francis Creek is more than 30 feet thick (Smith, 1970), as in the eastern part of the Longwall District. In some areas of the District (in the Dalzell mine, for example), the Mecca Quarry directly overlies the Colchester (No. 2) Coal (Herbert and Rutledge, 1927).

BEDROCK STRUCTURE

The bedrock structure in the historic Longwall District was deformed by forces that produced the La Salle Anticline (fig. 8). The anticline trends approximately north-south through the county of La Salle and southward, dividing the historic Longwall District into the La Salle (Third-Vein) District on the western flank of the anticline, and the Wilmington District on the eastern flank of the anticline.

In the steeper western flank of the anticline, mines in the Colchester (No. 2) Coal could reach 300 to 450 feet deep, whereas on the shallower eastern flank of the anticline the same coal was often mined at depths of less than 200 feet. Mines operated in the La Salle District tended to be larger than those in the Wilmington District where the cost of sinking a shaft was not so great, and this size difference is reflected in the larger sizes of many piles of mining gob in the west.



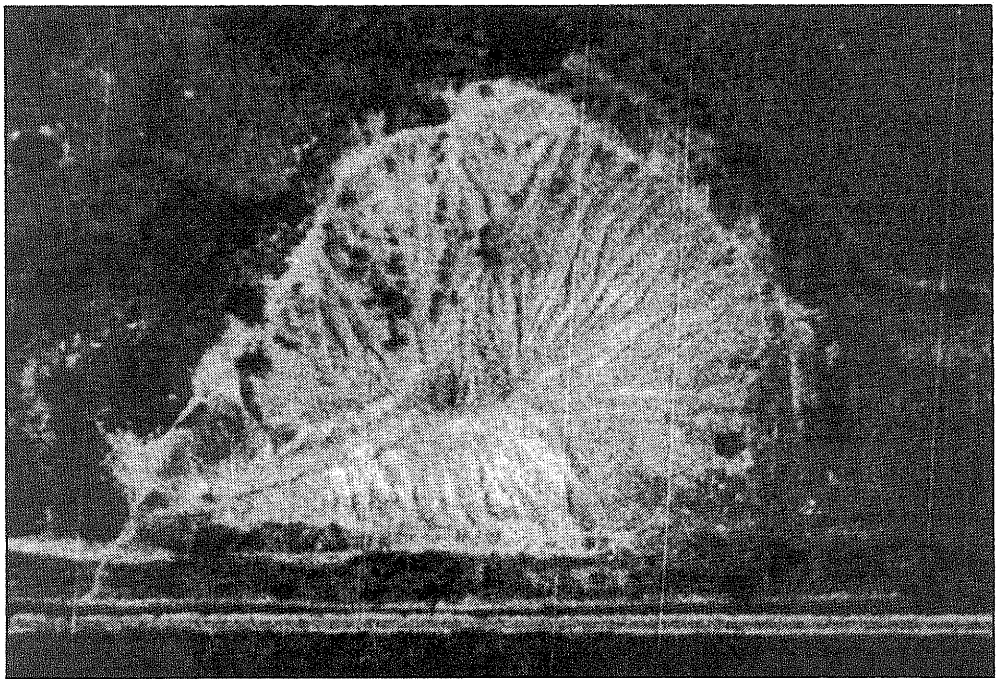


Figure 22 Field map (above) and aerial photograph (below) of the Rutland site (L4R). Gray gob, soft nongray gob, and clinker were mapped at the surface of this pile.
(From USDA Agricultural Stabilization and Conservation Service)

APPENDIX III. Study procedures

To characterize the materials in the more than 100 mine waste sites in the historic Longwall District during the short contract period, we set up a two-phase system of mapping, sampling, and analyses.

MAPPING EXPOSED MATERIALS

We began Phase I with a study of 343 Agricultural Stabilization and Conservation Service (ASCS) aerial photographs made over the study area between 1939 and 1974 to note how the piles had changed over time. Following an initial field investigation. we chose 16 representative sites on the basis of location, size, apparent variations in materials, and accessibility (fig. 1). The sites were selected in conjunction with the Illinois Natural History Survey, which was conducting a parallel study on vegetation of the gob pile sites.

We mapped the materials exposed on the piles on mylar overlays superimposed on enlargements made from aerial photographs (fig. 22). Photographs from the most recent ASCS flights over the project area did not arrive in time for mapping during the first phase.

In Phase II, topographic maps were made of the six sites studied in detail by surveying them with transit and with plane table and alidade methods (appendix IV). The maps were used to delineate site features and calculate volumes of materials in the piles, and to aid the Abandoned Mined Lands Reclamation Council in planning site work.

SAMPLING SURFACE AND NEAR-SURFACE MATERIALS

During Phase I, we observed problems and hazards, and systematically sampled the materials at the 16 sites (fig. 1). In addition to this systematic sampling, we also collected samples from various sites in the District where we found good examples of specific phenomena, such as unusual clinker, large crystals of sulfate-containing minerals, or zones showing a clear transition from unburned to burned gob.

We then chose six sites to study in detail for Phase II (fig. 1). Preliminary analyses of the 16 sites had indicated that the gray gob samples from across the District had similar mineralogy and that the mineralogy of the soft nongray gob and clinker depended upon the degree to which the gray gob had oxidized or burned (Hughes, 1983). Because the six sites did not have to be chosen on the basis of significant mineralogical differences, we made our selection on the basis of community interest, areal distribution, size, and problems caused by the piles.

Composite samples

At each of the 16 sites examined in Phase I of our study we attempted to obtain samples that would represent an average composition of each type material at each site. Each type material was sampled at four locations on a pile and then mixed to make composite samples for analysis. (If three types of material were found on a pile, each of the three—sampled at four locations—would yield three composites from 12 locations.) We did not mix different types of materials. The four locations for sampling each type material were approximately evenly spaced across the pile; the spacing was determined from our maps (fig. 22). If there were more than one pile at a site, we usually sampled the piles as if they were a single pile so that the samples would represent average compositions of materials at a site.

Because gray gob was the least altered type of mining gob, we obtained samples from the surfaces of the piles and at depth to determine significant differences due to surficial weathering. One composite sample was collected approximately 1 inch (2.5 cm) below the surface of each pile, a second from auger holes 2 to 3 feet (0.6 to

0.9 m) deep. We were not always able to obtain samples of gray gob as deep as 3 feet because gray gob sometimes occurred as a thin layer (<3 ft) over soft nongray gob.

Composite samples of soft nongray gob and clinker were collected from 12 to 18 inches (30 to 46 cm) below the surface to avoid surficial alterations and contaminants.

Composite samples of preparation gob were obtained by scraping off the weathered crust of the piles and collecting channel samples along gullies.

Channel samples

At the six sites studied in detail in Phase II we excavated pits with backhoes and collected channel samples so that we could study materials as deep as possible in the piles and observe contacts between different materials and structural features such as slip planes (figs. 1, 8). Channel samples were compared to composite samples from the same piles to determine the homogeneity of the piles (Krapac and Smyth, 1983).

Most pits were 15 to 20 feet (4.5 to 6.1 m) deep. Pits dug into alluvial and preparation slurry materials were about 5 to 10 feet (1.5 to 3.1 m) deep, lay low in the terrain, and usually filled quickly with groundwater. These pits almost always penetrated the soil of the original ground surface.

Single samples

We collected single samples by various methods, depending on the planned analysis. Some single samples were taken from the 16 sites from Phase I and some from eight additional sites where we found good examples of specific phenomena (fig. 8).

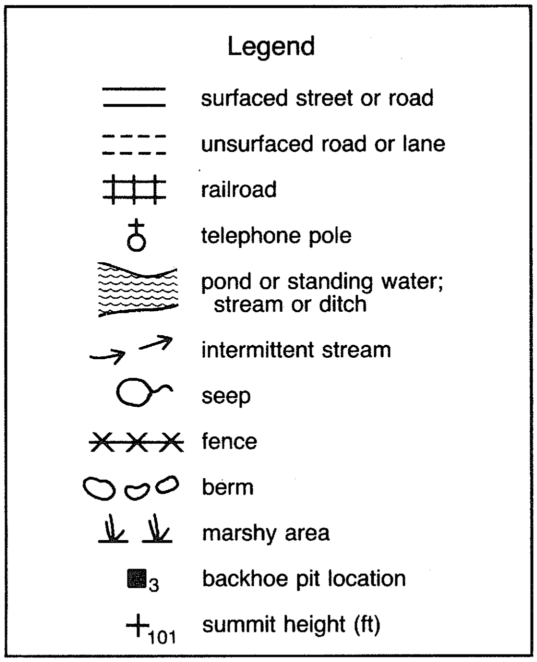
ANALYZING SAMPLES

Composite, channel, and single samples were analyzed for mineralogic, chemical, and geochemical properties, as well as for their potential for secondary coal recovery. Additional samples were collected and used to determine physical characteristics of the piles. Testing procedures and interpretations are discussed in detail in the report to the Abandoned Mined Lands Reclamation Council (ISGS, 1983).

APPENDIX IV. Mine site maps

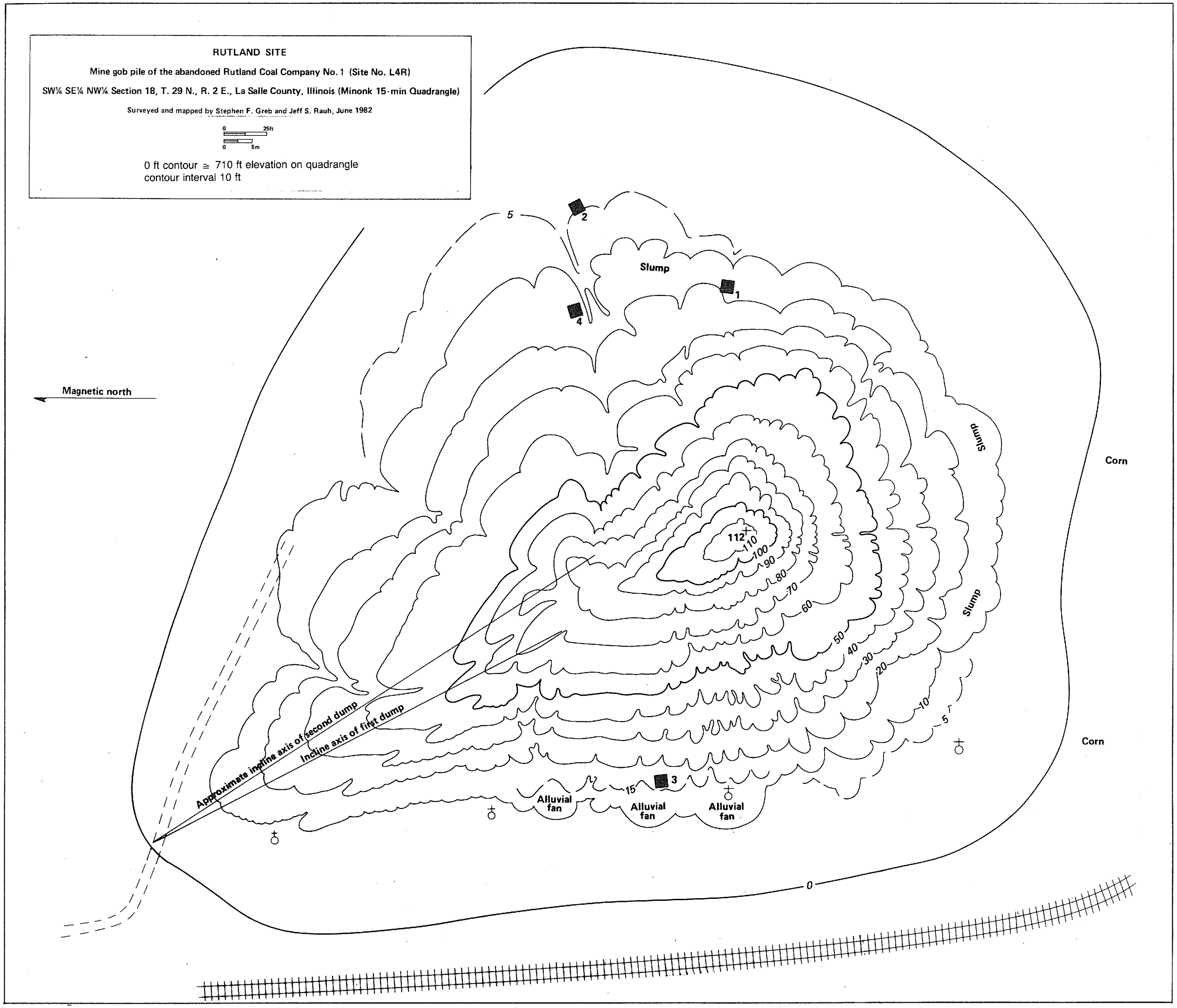
We are grateful to the property owners of the six mine sites studied in detail for allowing us to conduct our studies and bring heavy equipment onto their property: Phillip Allison, Frank Corsini, Donald Francois, Michael Joyce, Ladd Construction Company, Dean McKinney, Frank Piccinelli, Mayor Anton Rupe, and the townspeople of Dalzell. We thank David Owen, North Central Illinois Council of Governments, for his continuous support, and Mayor Terry Lindenmeyer, John Micheli, Jr., and Joe Barra for the extensive information they provided on sites at Standard, Dalzell, and Ladd.

We also thank Mayor James V. Cinotto and the Village of Spring Valley for hosting three public meetings during the course of the study, and to the following for giving us permission to study their mine sites and providing helpful information: Aldo and John Balestri, Charles Bartoli, Joe Bazzoni, Dean and Arthur Beckman, Mayor Louis Bernabei, Don Bevington, Mickey Byrne, Mayor Fritz Campbell, Carol DeSerf, Bruno Gambiani, Marcell Giocobozzi, Walter Hamlin, John and B.H. Huschen, Richard McCormick, John Marincic, Mayor Gerald Mennie, Angelo Nanni, Joe O'Berta, Eugene Paulsen, Dan Pelphry, Peter Ruffati, Earle Ryan, Lyle Siderly, John Valesano, Mayor Harry Volant, and Iola Yeno.



These topographic maps, produced by alidade and stadia traverse methods,
are intended only for geological and other environmental studies.
They should not be used for property location or detailed construction planning.

Funded by the Illinois Mined Lands Reclamation Council
Project No. AML-CGd*F-8237



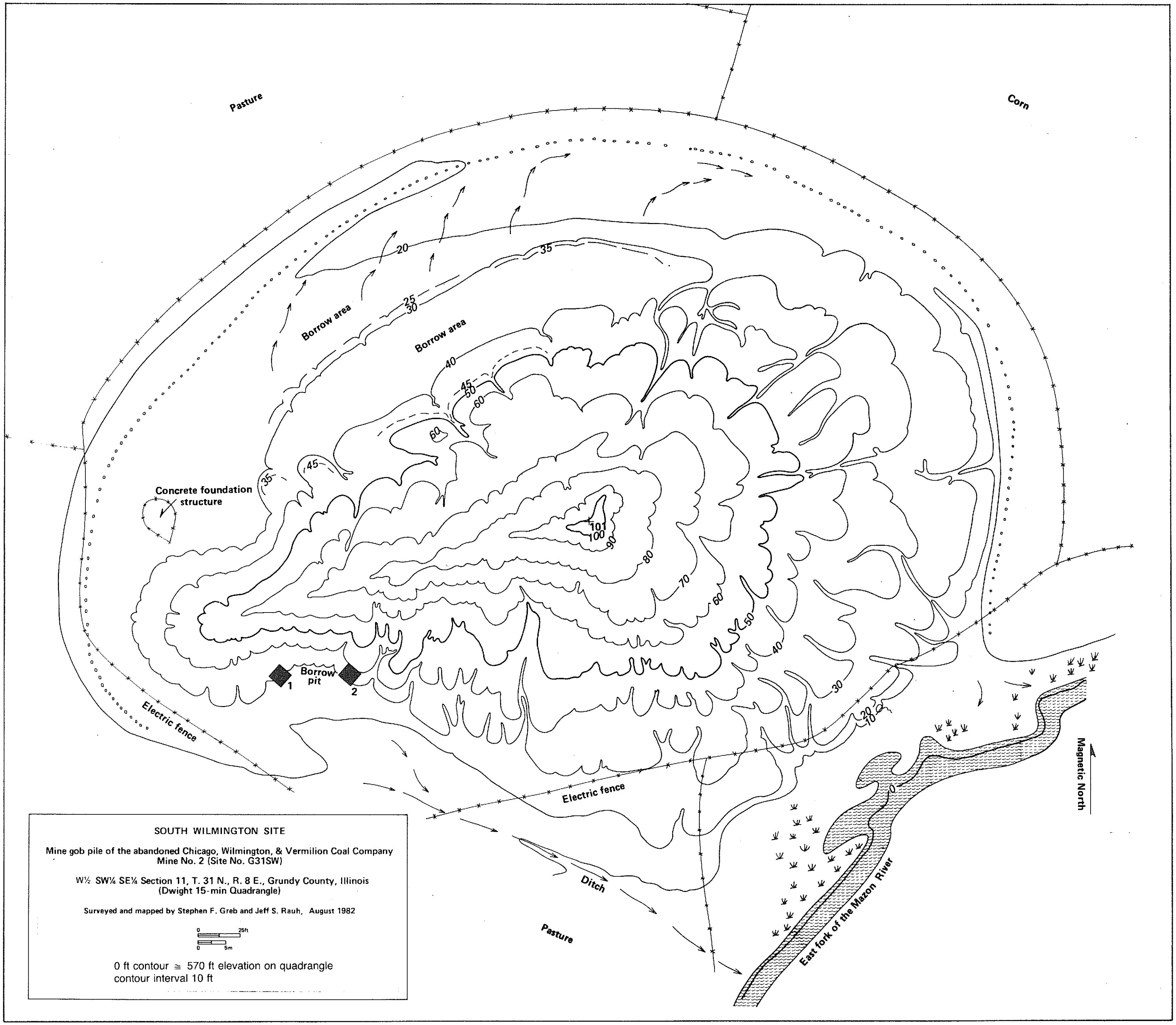
RUTLAND SITE

Mine gob pile of the abandoned Rutland Coal Company No. 1 (Site No. L4R)

SW¼ SE¼ NW¼ Section 18, T. 29 N., R. 2 E., La Salle County, Illinois (Minonk 15-min Quadrangle)

Surveyed and mapped by Stephen F. Greb and Jeff S. Rauh, June 1982

0 ft contour ≅ 710 ft elevation on quadrangle
contour interval 10 ft



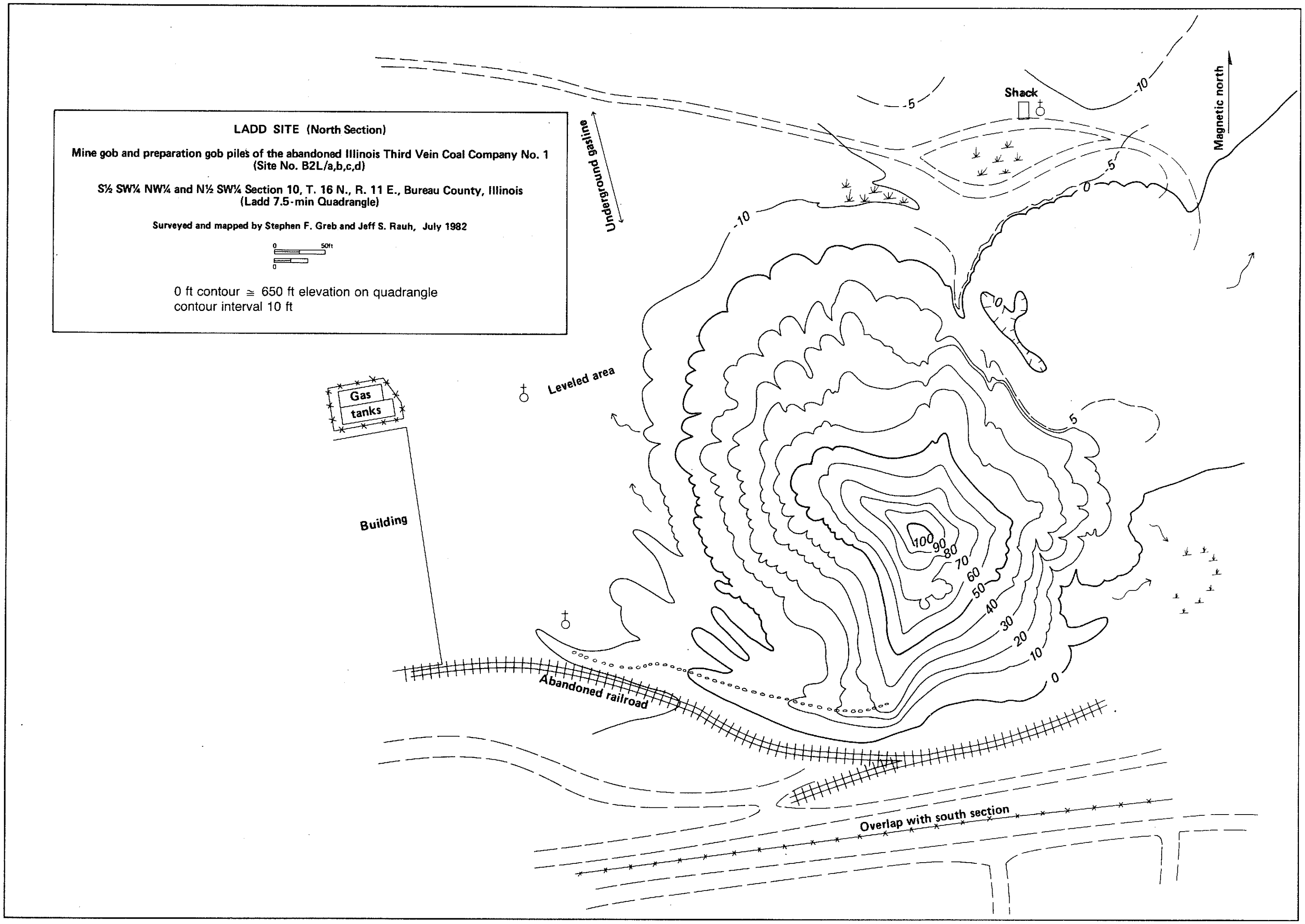
SOUTH WILMINGTON SITE

Mine gob pile of the abandoned Chicago, Wilmington, & Vermilion Coal Company Mine No. 2 (Site No. G31SW)

W½ SW¼ SE¼ Section 11, T. 31 N., R. 8 E., Grundy County, Illinois (Dwight 15-min Quadrangle)

Surveyed and mapped by Stephen F. Greb and Jeff S. Rauh, August 1982

0 ft contour ≅ 570 ft elevation on quadrangle
contour interval 10 ft



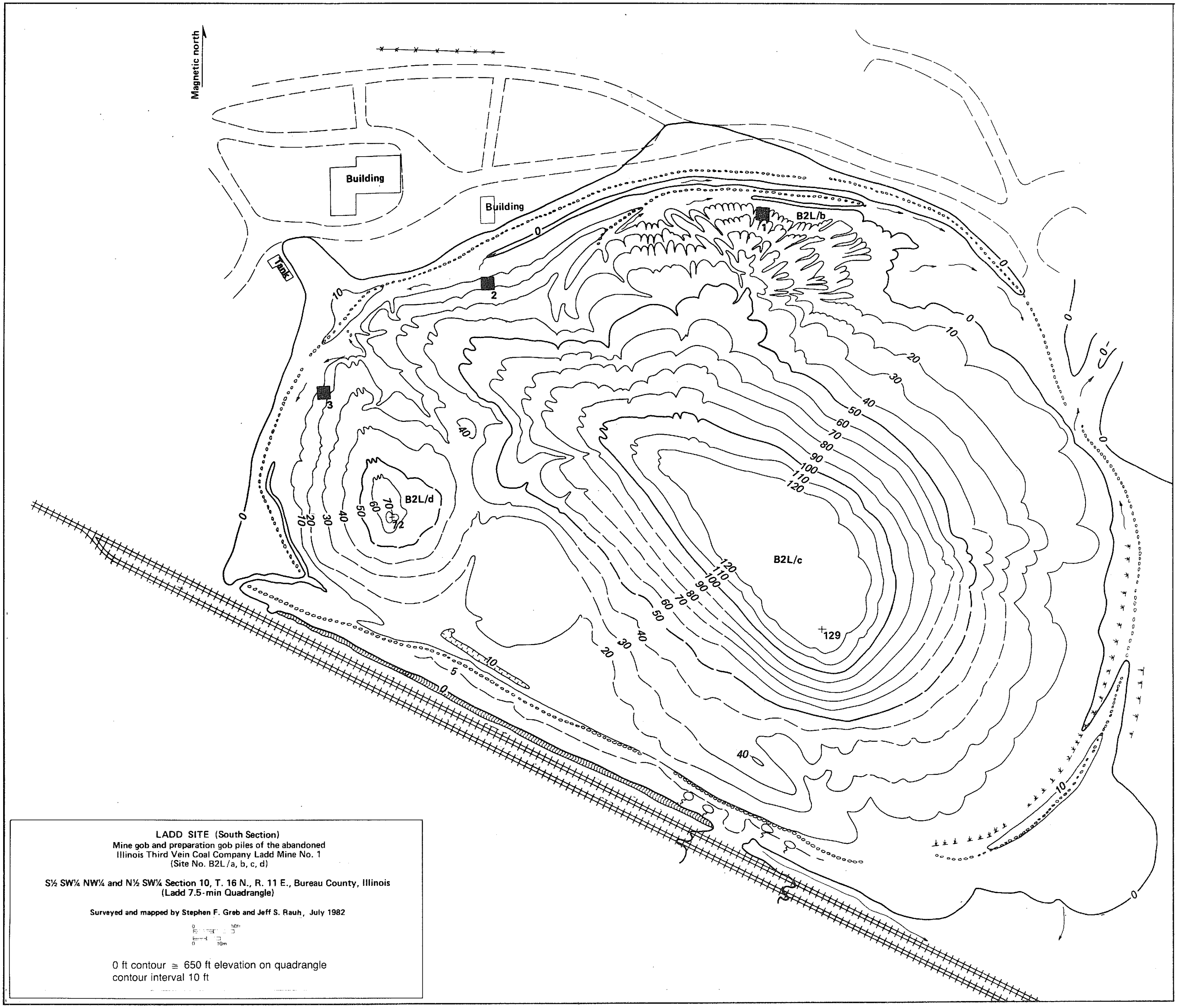
LADD SITE (North Section)

Mine gob and preparation gob piles of the abandoned Illinois Third Vein Coal Company No. 1
(Site No. B2L/a,b,c,d)

S½ SW¼ NW¼ and N½ SW¼ Section 10, T. 16 N., R. 11 E., Bureau County, Illinois
(Ladd 7.5-min Quadrangle)

Surveyed and mapped by Stephen F. Greb and Jeff S. Rauh, July 1982

0 ft contour ≅ 650 ft elevation on quadrangle
contour interval 10 ft

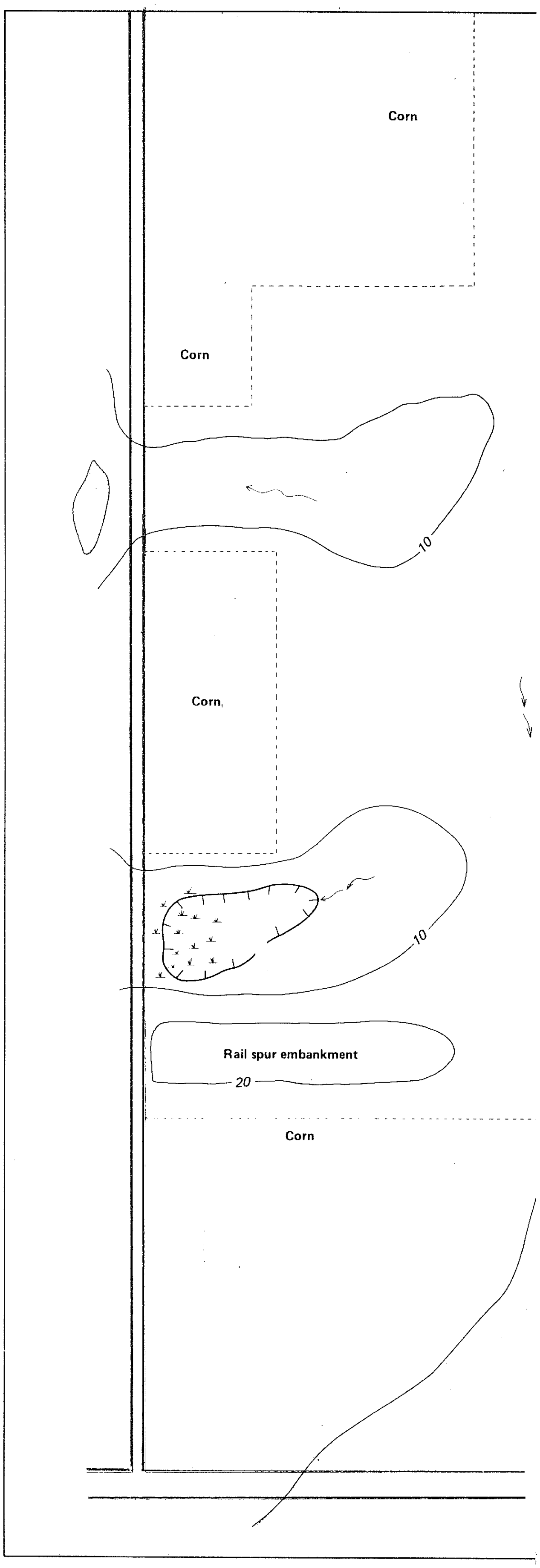


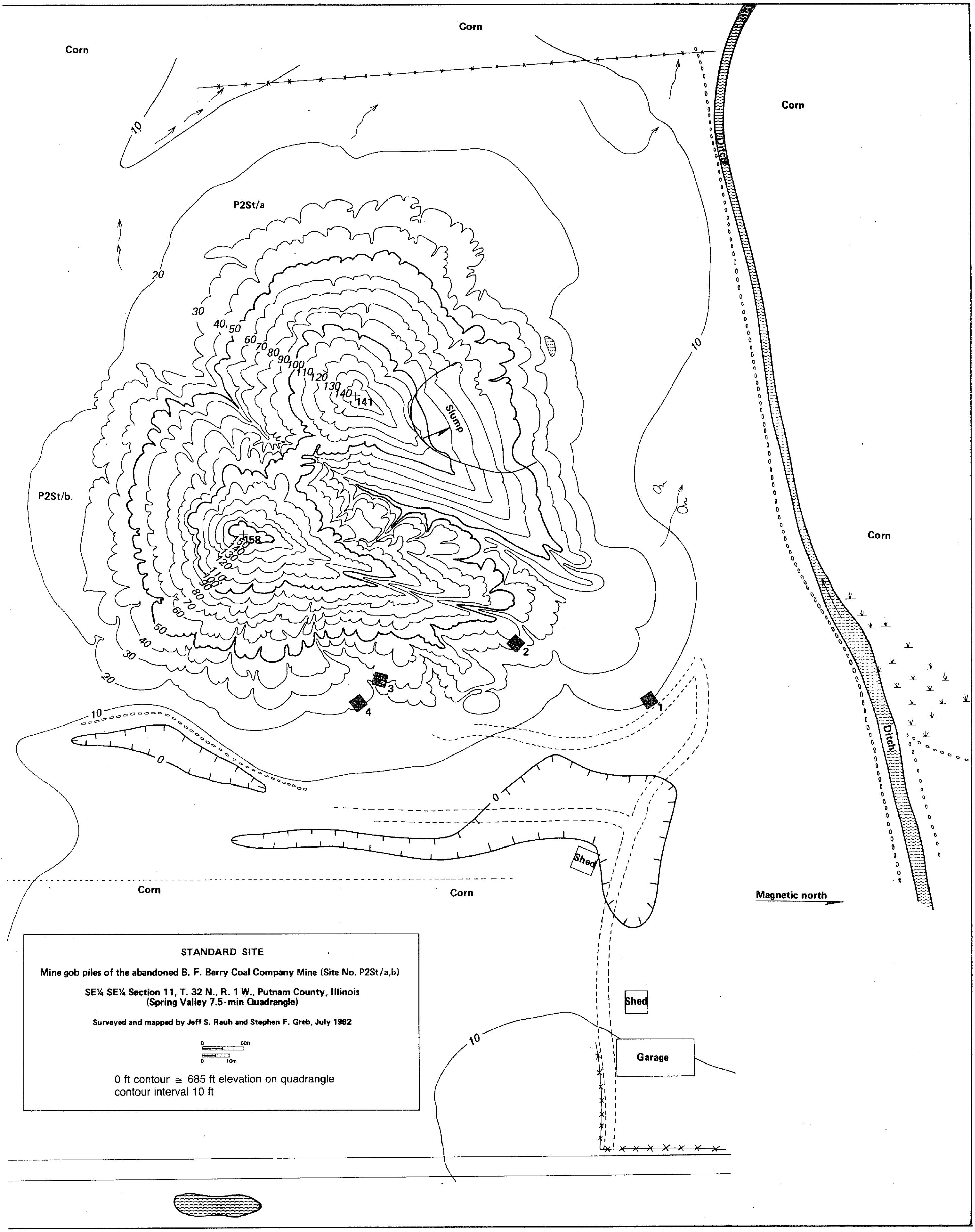
LADD SITE (South Section)
Mine gob and preparation gob piles of the abandoned
Illinois Third Vein Coal Company Ladd Mine No. 1
(Site No. B2L/a, b, c, d)

S½ SW¼ NW¼ and N½ SW¼ Section 10, T. 16 N., R. 11 E., Bureau County, Illinois
(Ladd 7.5-min Quadrangle)

Surveyed and mapped by Stephen F. Greb and Jeff S. Rauh, July 1982

0 ft contour ≅ 650 ft elevation on quadrangle
contour interval 10 ft


Corn
Corn
10
Corn
10
Rail spur embankment
20
Corn



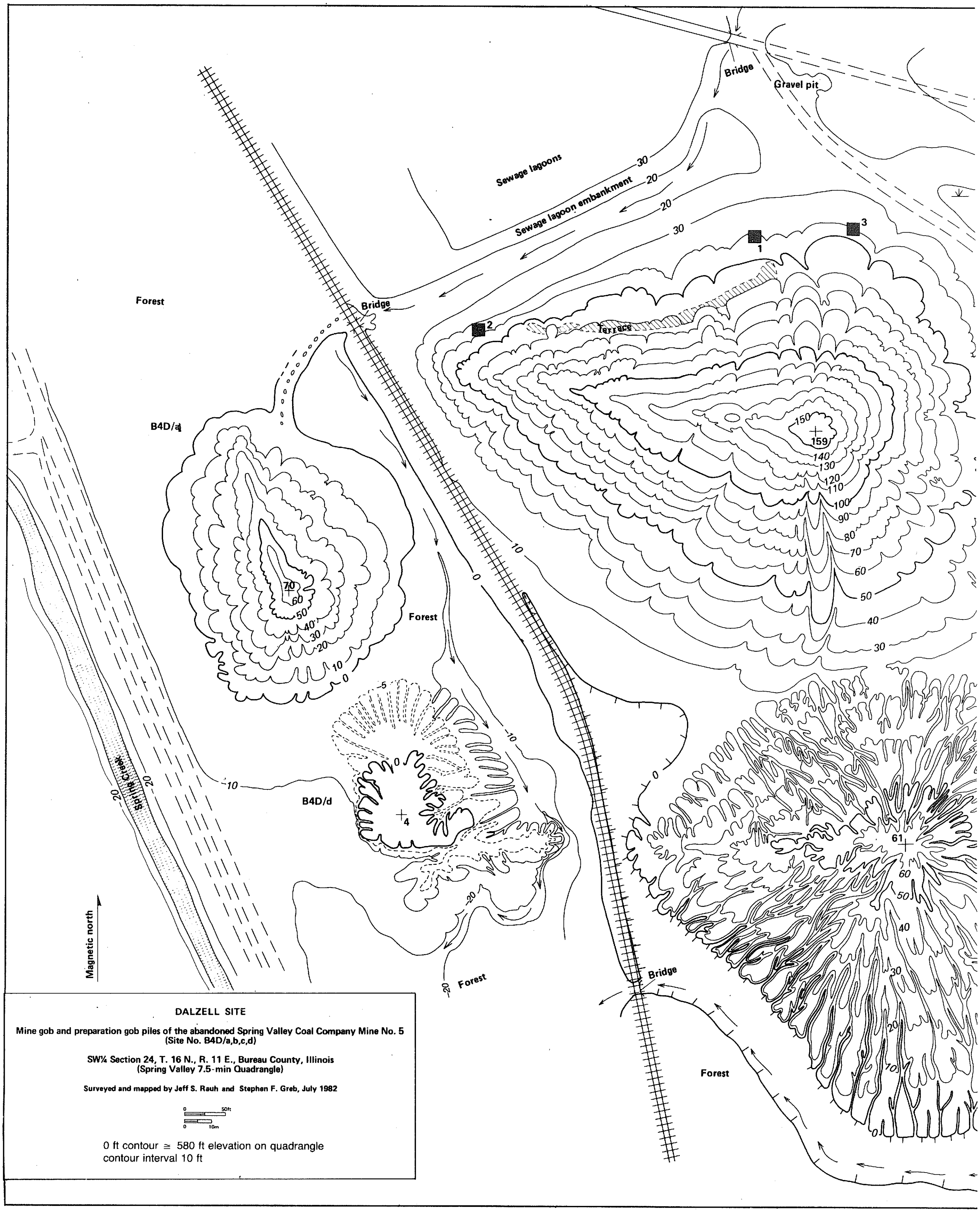
STANDARD SITE

Mine gob piles of the abandoned B. F. Berry Coal Company Mine (Site No. P2St/a,b)

SE¼ SE¼ Section 11, T. 32 N., R. 1 W., Putnam County, Illinois
(Spring Valley 7.5-min Quadrangle)

Surveyed and mapped by Jeff S. Rauh and Stephen F. Greb, July 1982

0 ft contour ≅ 685 ft elevation on quadrangle
contour interval 10 ft



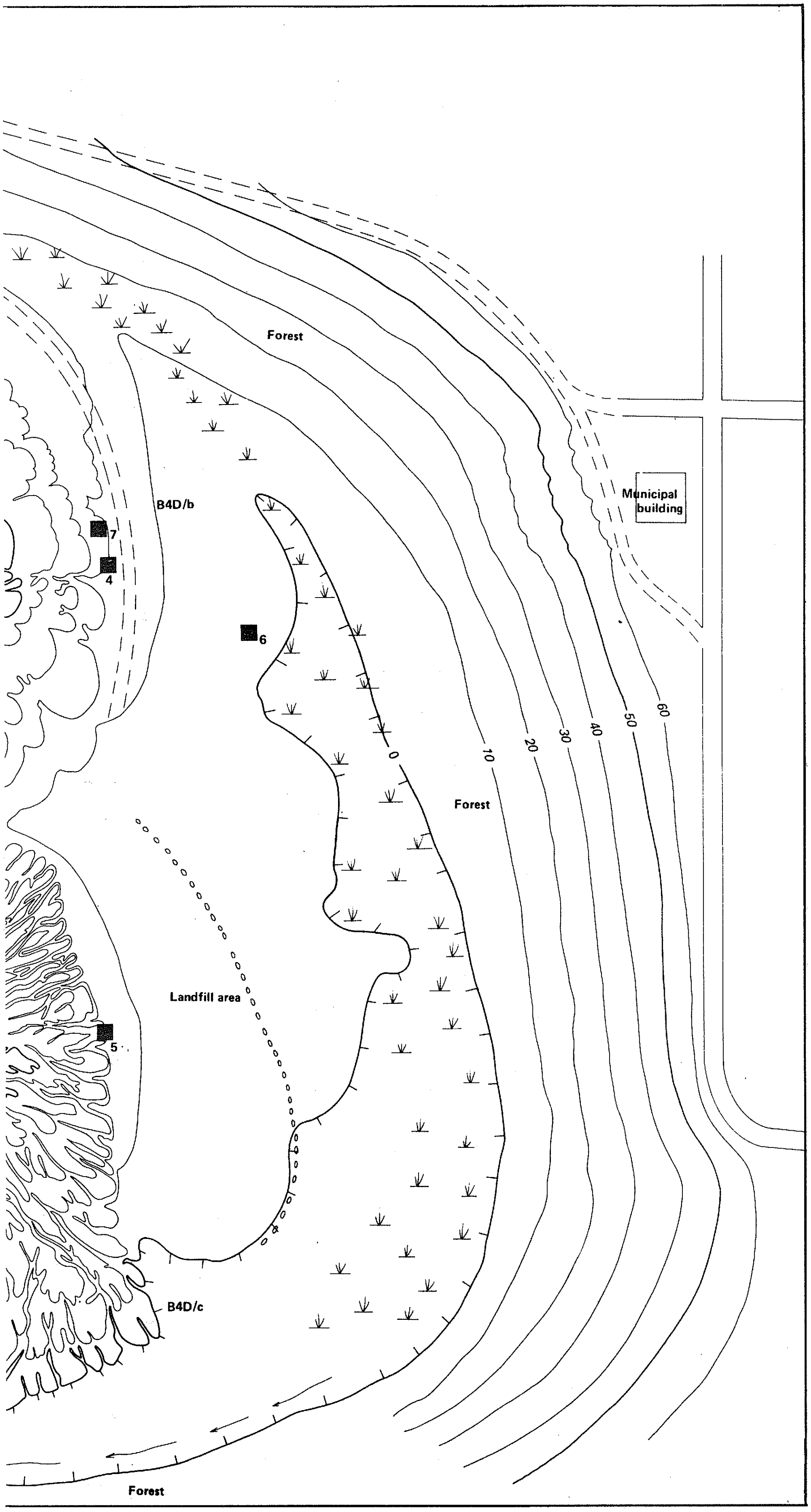
DALZELL SITE

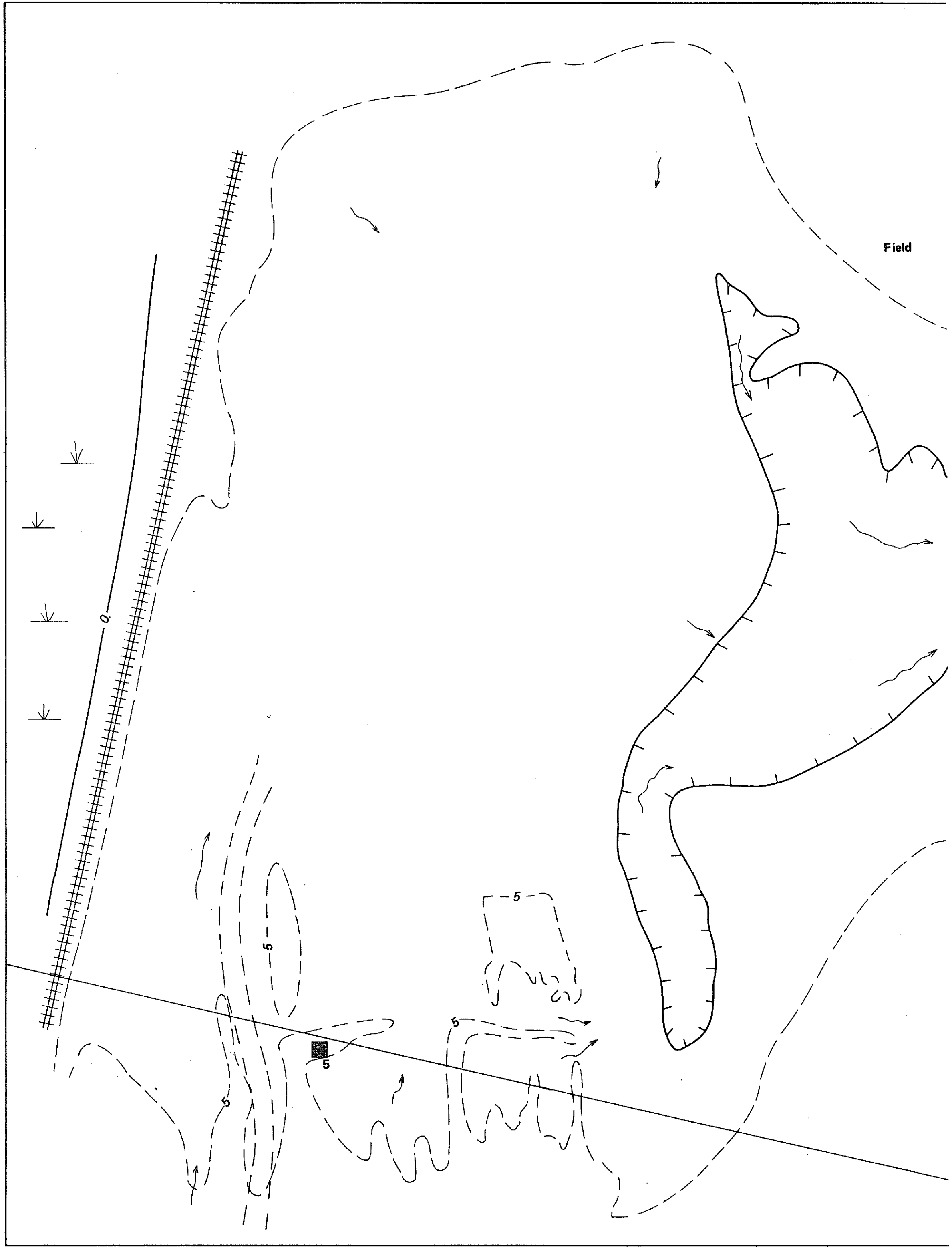
Mine gob and preparation gob piles of the abandoned Spring Valley Coal Company Mine No. 5
(Site No. B4D/a,b,c,d)

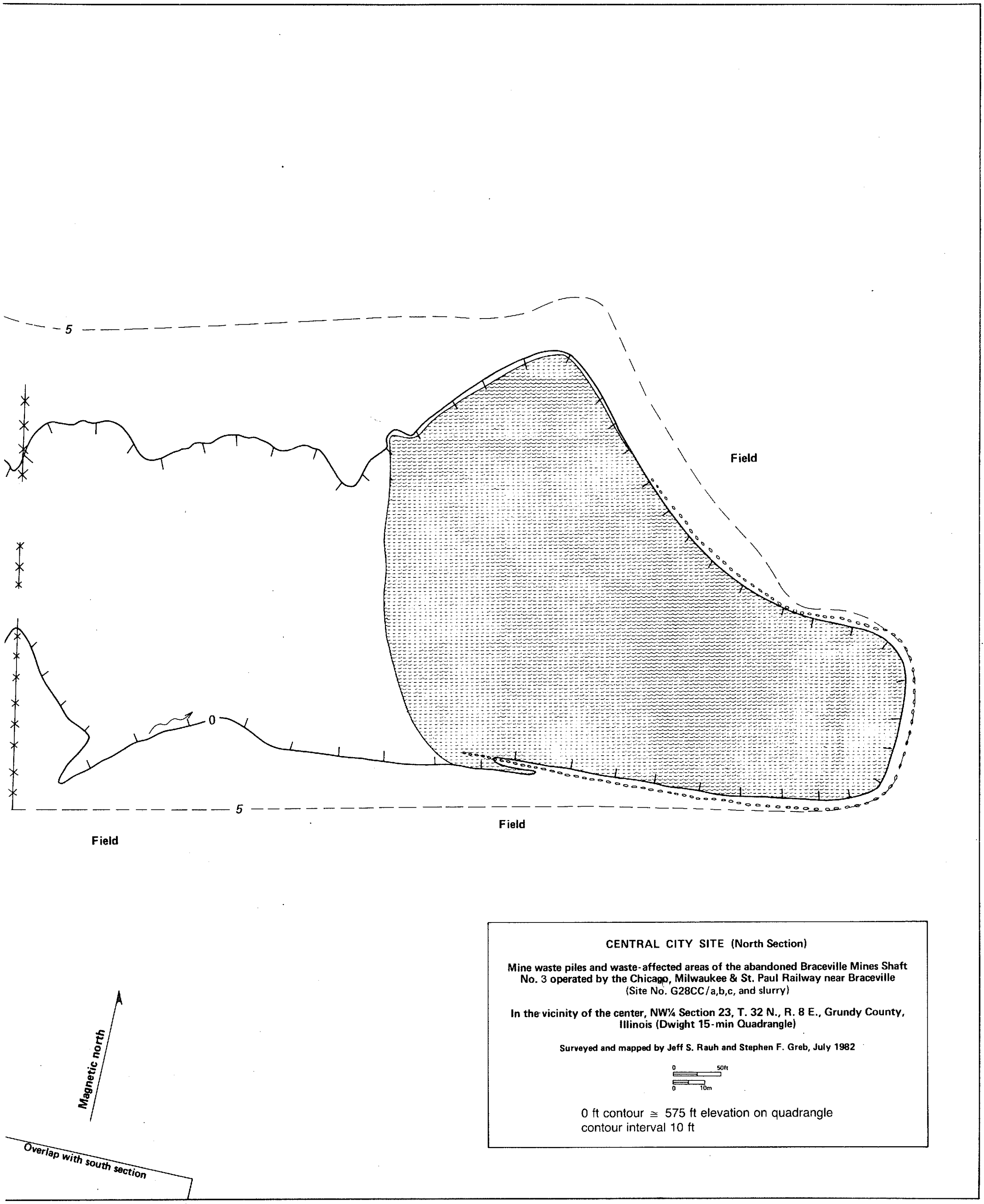
SW¼ Section 24, T. 16 N., R. 11 E., Bureau County, Illinois
(Spring Valley 7.5-min Quadrangle)

Surveyed and mapped by Jeff S. Rauh and Stephen F. Greb, July 1982

0 ft contour ≅ 580 ft elevation on quadrangle
contour interval 10 ft


Forest
Municipal building
B4D/b
7
4
6
0
10
20
30
40
50
60
Forest
Landfill area
5
B4D/c
Forest


Field
0
5
5
5
5
5



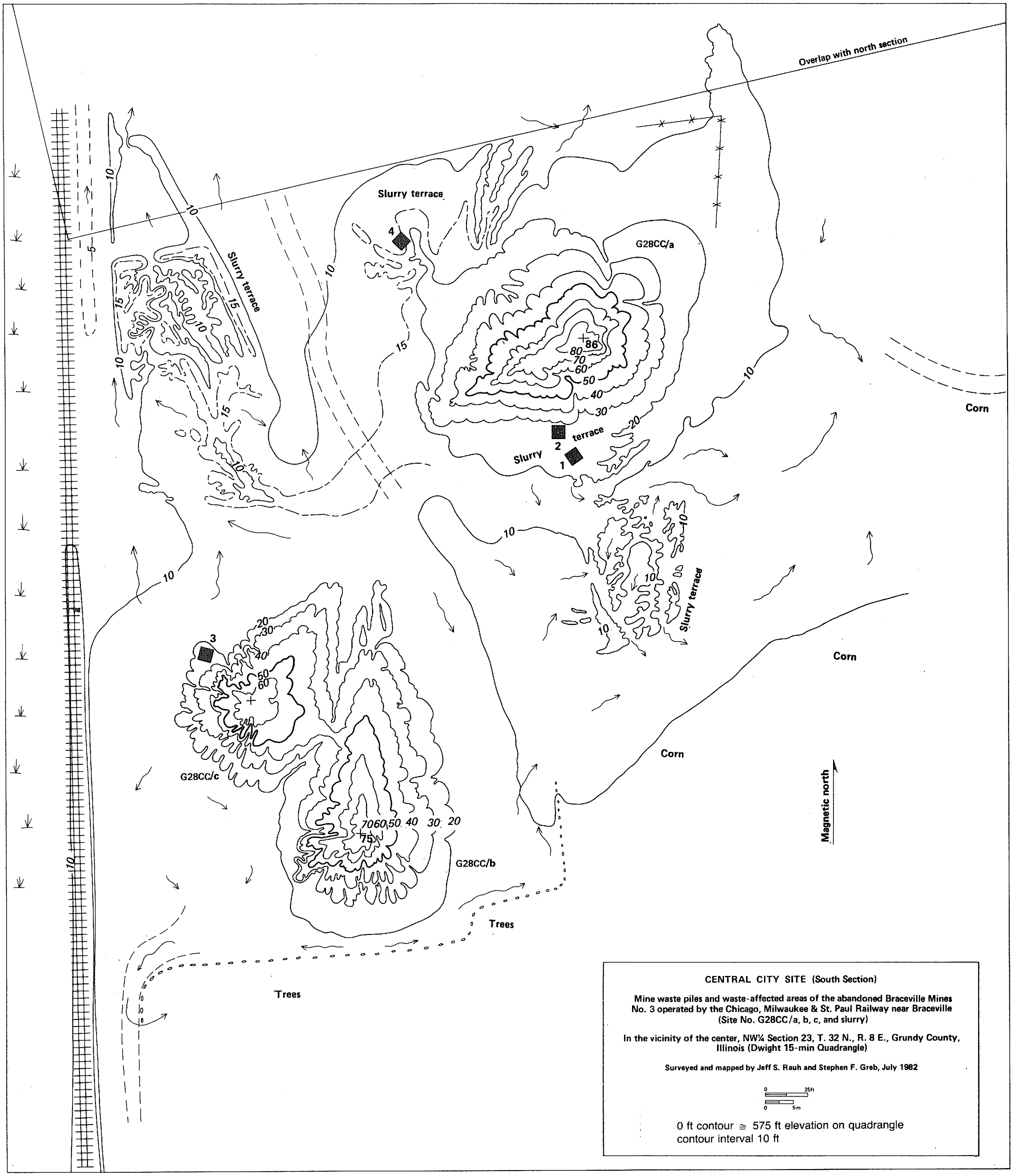
CENTRAL CITY SITE (North Section)

Mine waste piles and waste-affected areas of the abandoned Braceville Mines Shaft No. 3 operated by the Chicago, Milwaukee & St. Paul Railway near Braceville (Site No. G28CC/a,b,c, and slurry)

In the vicinity of the center, NW¼ Section 23, T. 32 N., R. 8 E., Grundy County, Illinois (Dwight 15-min Quadrangle)

Surveyed and mapped by Jeff S. Rauh and Stephen F. Greb, July 1982

0 ft contour ≅ 575 ft elevation on quadrangle
contour interval 10 ft



CENTRAL CITY SITE (South Section)

Mine waste piles and waste-affected areas of the abandoned Braceville Mines No. 3 operated by the Chicago, Milwaukee & St. Paul Railway near Braceville (Site No. G28CC/a, b, c, and slurry)

In the vicinity of the center, NW¼ Section 23, T. 32 N., R. 8 E., Grundy County, Illinois (Dwight 15-min Quadrangle)

Surveyed and mapped by Jeff S. Rauh and Stephen F. Greb, July 1982

0 ft contour ≅ 575 ft elevation on quadrangle
contour interval 10 ft