Underground Mines in the Survant Coal Member (Pennsylvanian) of Indiana

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INTRODUCTION

In Indiana more than 200 million tons of Survant coal (referred to historically as Coal IV) has been produced by underground mining. From the early 1900's until World War II, a period when underground mining dominated Indiana's coal industry, production from the Survant Coal Member (Linton Formation, Pennsylvanian) was second only to that from the Springfield Coal Member (Petersburg Formation). Since World War II, production from the Survant coal has declined to insignificant levels. Surface mining now dominates the state’s coal industry, and other coals, such as the Seelyville, Hymera, and Danville Coal Members (Staunton, Dugger, and Dugger Formations), have surpassed the Survant coal in importance.

The purpose of this report is to summarize publicly available information in the files of the Indiana Geological Survey regarding geologic conditions encountered during past underground mining in the Survant coal. It is intended for those persons with little or no familiarity with the Survant who may be considering or may be involved in exploration or development plans for underground mines in that coal. The report is based chiefly on information from mine maps and from geologic and mining literature. Drilling records were also a source of information. There has not been much underground mining in the Survant coal since the 1940's (fig. 1), so few exposures of the coalbed and its associated strata are available for study. Instead, attention is focused on geologic conditions encountered within now-abandoned mines and conditions that limited mining.

Much of this report has been taken from my reports on coal mining in Vigo and Sullivan Counties, Ind. (Harper, 1985, 1988). But this report contains additional maps and information about mining in the Survant coal in Knox, Greene, Clay, and Vermillion Counties. The maps of mining districts in this report are more detailed than those in the county reports. These maps provide evidence that underground mining of the Survant coal in most places was limited by geologic conditions, particularly split coal and thin (less than 4.5 feet) coal. Each mining district in the Survant coal has been developed in a geologically distinct area with its own conditions and surrounded by areas with geologic conditions different enough to prevent successful underground mining on a large scale even under favorable economic conditions. This is in contrast with some other commercially important coalbeds in Indiana in which underground mining may have been limited or halted by changing economic conditions, so that those geologic conditions that were previously adequate to sustain mining were rendered submarginal.

This report attempts only to describe geologic problems encountered in underground mines of the Survant coal, and no attempt is made to hypothesize geologic controls on the distribution of these problems or to produce a predictive model of their occurrence. The geology of the Survant coal has long been recognized to differ significantly from the other major commercial coalbeds of Indiana. A statement by Weller and others (1958, p. 443) that the Survant coal is "*** peculiar, not adequately understood, and require[s] further study" remains true today.

This is intended to be the first in a series of reports. Subsequent reports will deal with underground mines in the Hymera Coal Member (Dugger Formation), the Seelyville Coal Member (Staunton Formation), and the Springfield Coal Member (Petersburg Formation).

DISTRIBUTION OF MINES

Because of the good quality of the Survant coal, exploration in this coalbed in Indiana was apparently intense in the early 1900's, and because of favorable mining conditions where the coalbed was thick, development was rapid and complete. Values of fixed carbon and volatile matter are typically about 43 percent and 34 percent (Wier, 1973). The heat value of this coal averages about 12,500 Btu per
Figure 1. Graph showing annual production of Survant coal from underground mines of Indiana from 1900 to 1983. There are no data for 1916. Data from Indiana Inspector of Mines, Indiana Department of Mines and Mining, Indiana Bureau of Mines and Mining, and Indiana Coal Association (1955).

pound (ash-free basis), and the mean percentage of sulfur (as-received basis) is about 1.8 percent (Wier, 1973). In terms of sulfur and ash content, the Survant coal is clearly superior to other commercially important coals, such as Seelyville, Springfield, Hymera, and Danville. About the time of World War I, when mining of the Survant coal reached its peak, the Survant was in demand for domestic coal (because it was clean burning), for gas production, and for use in the steel and ceramic industries. In 1920 it was observed of the Survant coal in Vigo County (Baker, 1920, p. 1245): "*** there is now no longer much opportunity for development." Today the demand for coal for household fuel and gas production is negligible, but utilities and other industrial consumers requiring low-sulfur coal still use the Survant when it is available.

In Indiana the Survant coal has been mined underground in four areas (fig. 2). The two most important areas are northwest of Terre Haute in Vigo and Vermillion Counties and between Sullivan and Linton in Sullivan, Greene, and Clay Counties. A few small mines were developed east of Terre Haute in Vigo County, and a single mine was developed in northeastern Knox County.

Mine maps and drilling records indicate that in most of these areas the most extensive deposits of thick (greater than 4.5 feet) coal were thoroughly mined out. In some places mining even extended into areas where the coal was less than 3 feet thick. Across much of the area where the Survant coal was thick (greater than 4.5 feet) other geologic conditions, such as strong roof and floor, only moderate inflows of gas and water, gentle gradients, and only a few seam discontinuities, were favorable for mining. But along the margins of the thick-coal areas, discontinuities, such as horsebacks, roof rolls, and faults, were common. These were associated in many places

Figure 2 (on facing page). Map of west-central Indiana showing the locations of underground mines in the Survant coal and areas where the Survant coal is more than 3 feet thick. The thickness is total coal thickness; in some places the seam may contain significant rock partings that impair minability. The only active underground mine (as of 1985) is indicated by the arrow. Mined areas are from original mine maps and from Powell (1968), Wier (1951), and Hutchison and Hasenmueller (1988). Cropline is from Powell (1968), Friedman (1989), Hutchison (1958), Wier (1951, 1952b), and Wier and Powell (1967). Thickness contours were compiled from mine maps, geophysical logs, and drilling records and from Harper (1985, 1988).
UNDERGROUND MINES IN THE SURVANT COAL MEMBER

EXPLANATION

- Underground mined area
- Net coal > 3 ft thick
- Net coal < 3 ft thick
- Active underground coal mine

Legend:
- Dark area: Underground mined area
- Striped area: Net coal > 3 ft thick
- Light area: Net coal < 3 ft thick
- Diamond symbol: Active underground coal mine

Map showing the distribution of underground mines, net coal thickness, and active underground coal mines in the Survant Coal Member.
with rock partings in the coal that thickened greatly across a short distance. Mining was terminated in many places where the rock partings exceeded 1 foot in thickness; steep gradients were also common along the margins of the mining districts.

After 1918 production of the Survant coal from underground mines declined exponentially (fig. 1). This steady decline was virtually unaffected by economic booms, improvements in the technology of underground mining, or government regulations promoting the use of low-sulfur coal. The reserves discovered and leased during the early 1900's and suitable for conventional midwestern underground mining were exhausted by the early 1950's.

**MINES NORTHWEST OF TERRE HAUTE**

The Survant coal was mined northwest of Terre Haute in at least 24 separate operations (fig. 3). Many of the mines lie immediately adjacent to each other and therefore form a single large undermined area that is 1.8 to 3.6 miles wide and 12.7 miles long. A few small scattered mines are north of this main area of mining. Maps of 16 of these mines containing thickness notations and other notations about geologic conditions are in the files of the Indiana Geological Survey. The mining literature also contains descriptions of conditions encountered in some of the mines.

Mining in the Survant coal began in this area in 1902. Mine development peaked during 1910-24, and most operations were abandoned by 1933. The Saxton Mine was the largest, longest lived, and last major underground mine in the Survant in the area; it reached its maximum annual output of 860,000 tons in 1944 and closed in 1954. More than 114 million tons of coal was produced from the entire district during its lifetime.

In the northeast this mining district is bounded by the subcrop of the Survant coal along the west slope of the preglacial valley of the Wabash River (fig. 4). This preglacial valley is filled with thick (as much as 125 feet) unconsolidated water-bearing sediments. In the southern half of the mining district some mines actually pass under the Wabash River itself. Underground mining commenced west of the river, and it was 1917 before any mine successfully tunneled under the river to the area underlying the eastern flood plain. Installation of shafts through the thick unconsolidated water-bearing deposits was difficult and costly, and it was 1922 before a circular concrete-lined shaft was successfully emplaced in the floodplain deposits. At some points lithified overburden was only 30 feet thick and was overlain by 170 feet of unconsolidated sediments. For the northeastern part of the Saxton Mine directly underlying the Wabash River and its eastern flood plain, many mine-map notations indicate "bad roof" that repeatedly threatened to flood the mine with water from the unconsolidated sediments.

Mines that never broke through into unconsolidated sediments were generally dry. Gas emissions seldom presented serious problems. Regarding gas emissions in the Black Betty Mine, Baker (1920, p. 1248) said that "some gas is encountered in development, this being chiefly apparent immediately after the shooting of the coal * * * . Some gas is generated when the roof falls in the worked-out panels." Places where gas was emitted under pressure from holes or fissures ("feeders") were also common.

Mines in this district range in depth from 180 to 340 feet below the surface. This range is primarily a result of topography rather than variation in the elevation of the coalbed. The average downward gradient of the Survant coal in this area is only about 30 feet per mile to the west, but there are several small (less than 1 square mile) shallow (less than 40 feet closure) domes and basins. In some mines the coalbed was practically level. But in a few places around the periphery of the mined area steep grades were encountered. The maximum grades reported were in the Saxton Mine; at some places in that mine grades were 14 percent (740 feet per mile) across short distances, and as much as 9 feet of roof rock and 6 feet of bottom rock were removed to obtain acceptable grades for haulage. Steep grades are indicated by mine-map notations in two areas of the southern part of the Saxton Mine map (fig 4). Gradients as steep as 150 feet per mile may also exist just east of the Submarine Mine, which lies northeast of the Saxton Mine (fig. 3).

Thickness of the Survant coal typically ranges from 4 to 5.5 feet in mined-out areas, and in more than half of the mined areas the coal ranges from 5 to 5.5 feet in thickness (fig. 4). Drilling data indicate that east of the Submarine Mine, where gradients

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**Figure 3 (on facing page).** Map showing underground mines in the Survant coal northwest of Terre Haute, their locations relative to the Wabash River, and locations of datum points giving coal thickness. Some mine maps show data from exploration holes outside the mined area. Mine maps are on file at the Indiana Geological Survey.
steepen, the thickness of the Survant abruptly decreases to less than 2 feet within a distance of less than 750 feet. This thinning may be related to the subcrop of the coalbed. Exploratory drilling east of the Jackson Hill No. 5 Mine (fig. 3) indicated that coal just east of the Wabash River was absent or that the solid overburden was too thin for mining. On the west side of the mined-out area, exceptionally thick unsplit coal (greater than 6 feet) was found in the southwest corner of the Universal No. 4 Mine (fig. 3), just east of the area where the coal began to split (fig. 4).

A rock parting within the Survant coal abruptly thickens to the west of the mining district (fig. 4). The net thickness of the Survant gradually decreases westward, and neither bench of coal is more than 3.9 feet thick. Mining to the northwest was also limited by thin coal, although a few small scattered mines were developed north of the main mining area where the coal was between 3 and 4 feet thick. The coal in several mines was described as having a thin rock parting about 20 to 30 inches from the bottom of the seam. The thickness of this parting ranged from one-fourth to three-eighths of an inch in the Fayette No. 4 Mine (Coal Age, 1939, p. 44), from 1 to 2 inches in the Saxton Mine (Richart, 1944, p. 99), and from 2 to 11 inches in the southwest corner of the Universal No. 4 Mine (figs. 3 and 4). This thin parting was commonly referred to as the blue band (not to be confused with a more famous clay parting of the same name in the Herrin [No. 6] Coal Member of Illinois) and was in some places accompanied by one or two other thin, hard layers of rock or "bone" (clay-rich coal or carbonaceous shale within coal). In the Fayette No. 4 Mine this parting was described as thickening and changing into a white shale to the west. Mining was discontinued where the rock parting reached about a foot in thickness. Drilling data indicate that the parting thickens to as much as 15 feet in a distance of 0.8 mile and may thicken to as much as 28 feet farther west (Friedman, 1989). Wier (1952a) showed the limit of minable coal (greater than 14 inches) in Vigo County lying about 2 miles west of the westernmost mine boundaries.

Although notations indicating bad top appear on the mine maps of the Submarine No. 2, Crown Hill No. 4, Miami No. 8, Dering No. 6, Saxton, Wabash, and Speedwell Mines (fig. 4), roof conditions were generally considered fair to excellent in this field. The immediate roof was usually described as a gray shale or a gray slate ranging in thickness from 4 feet at the Binkley No. 10 Mine (Coal Age, 1935b, p. 237) to 22 feet at the Dering No. 6 Mine (Brosky, 1930, p. 215). At the Binkley No. 10 and Submarine Mines this gray shale was described (Coal Age, 1935b, p. 237) as "*** fairly good top if taken care of within a reasonable time. If *** neglected, *** falls are frequent and extend to considerable heights ***." At some operations it was possible to remove most of the coal (as much as 85 percent) by mining out large areas (as much as 250 by 70 feet) without leaving any coal pillars and relatively few timbers for support. After such an area was quickly worked out, all equipment was withdrawn, and collapse of the roof— in some places accompanied by a large air blast — was awaited (Coal Age, 1935a, p. 287). Workers reopening the Miami No. 10 Mine found that the rock in part of the mine that had been abandoned for 15 years had fallen to an average height of 5 feet above the roofline and that some roof falls extended as high as 25 feet (Coal Age, 1938a, p. 63).

Serious roof-control and mining problems developed around numerous horsebacks (consisting of roof or floor material that intrudes into a coalbed) that occurred in several mines. At the Submarine No. 2 Mine (fig. 3) these features ranged from 6 inches to 5 feet in thickness and in some places completely cut out the coal. One report (Coal Age, 1932, p. 21) stated:

Horsebacks occur rather frequently and give no end of trouble. Their shape is lenticular, but as their length is irregular, it is not always feasible to drive through them. When they are of great size and run parallel to a room the face is abandoned and the room picked up ahead through a crosscut.

On the map of the Keller No. 5 Mine (fig. 3), several long and narrow subparallel (southwestward-trending) features labeled as "horsebacks" appear along the southeastern boundary of the mine (fig. 4).

Figure 4 (on facing page). Map of the same area as figure 3 showing undermined areas in the Survant coal northwest of Terre Haute, their locations relative to the Wabash River, contours of coal thickness, and geologic conditions that affected mining. In split-coal areas, thickness (in feet) is total coal thickness of all benches, not minable thickness of any single bench. Contour interval is 1 foot. Question marks are used where data are too sparse to allow extension of contour lines or the split-coal area. Information is based on drilling reports and mine maps. Cropline is from Friedman (1989).
UNDERGROUND MINES IN THE SURVANT COAL MEMBER

EXPLANATION

- Split coal
- Thickness contour
- Mine boundary
- Coal-seam subcrop
- Thick coal (>5 ft.) that is not split
- Moderately thick coal (4 to 5 ft.)
- Thin coal (<4 ft.)

MINE-MAP NOTATIONS

- Roof roll
- Split coal
- Bad roof
- Steep grade
- Fault
- No coal
- Horseback

IND.
A soft white soapstone roof is associated with these features. A single southeastward-trending horseback also occurs near the middle of the mine.

Slacking and flaking of the calcareous sandy shale roof of the Black Betty Mine occurred during the summer months when humidity was high, but no serious problems were created.

In the mines of this area the floor of the Survant coal was generally described as hard fireclay or sandy shale that was several feet thick and was underlain by sandstones and sandy shales of considerable thickness. Underclay was uncommon, although some might be found where the coal was split (Friedman, 1989). Apparently few problems were encountered with squeezes or with floors too soft to support equipment, and floor material in few places got incorporated into the coal during mining to degrade its quality.

Other geologic problems besides the relative thinness of the seam and one or more rock partings were encountered during mining of the Survant coal in these mines. Extensively interconnected clay veins and slips were reported in the Saxon Mine, and in some areas they apparently prevented adherence to the projected mine plan. Roof rolls are indicated on mine maps of the Miami No. 1 Mine and the Saxon Mine, and “faults” are noted on the maps of the Binkley No. 10, Fayette No. 4, and Wabash Mines (figs. 3 and 4). The geologic definition of “fault” requires displacement of strata on either side of the feature, and neither drilling records nor mine-map notations provide any evidence of displacement of the coalbed along any of the disturbances in these mines. We can only speculate about the true character of these so-called “faults,” but their distribution in the Binkley No. 10 Mine suggests features associated with the rapidly thickening split immediately to the west; the “faults” may be the same as the horsebacks and roof rolls reported elsewhere in the field.

In the southeastern part of the Wabash Mine (fig. 4) a northeast-southeast “rock fault” several hundred feet wide is indicated on the mine map. Except at the northeast end of this feature, mining apparently continued across the feature without interruption.

Northeastward mining in the Crown Hill No. 4, Keller No. 5, and Dering No. 8 Mines (fig. 3) was apparently limited by a “fault.” This “fault” (fig. 4) was actually a narrow zone (about 700 feet wide) in which the seam apparently suddenly split. The Crown Hill No. 4 miners tunneled through the zone, but mining to the northeast was limited to a small area. Another small mine, the Oak Hill No. 50, was developed immediately northeast of this “fault” zone. Water and poor roof conditions were encountered along the south edge of the zone, and the northwest corner of the Crown Hill No. 4 Mine was an area of numerous crosscutting rolls. Several “faults,” which may be roof rolls, are noted on the map of the Oak Hill No. 50 Mine. It is possible that the large split-coal area along the western boundary of the main mining district turns eastward at the northwest corner of the Universal No. 4 Mine and connects with the “fault” zone. If that is so, the small scattered mines to the north may be developed on the upper bench of the Survant coal in this area. Unfortunately, structural data are lacking on the map of the Crown Hill No. 4 Mine, so that it is not possible to determine the elevation of the northeastern part of the mine relative to the rest of the mine.

On the map of the Dering No. 8 Mine a “fault” is shown lying about 500 feet east of the easternmost boundary of the mine (figs. 3 and 4). The parallelism of this feature with the nearby subcrop of the coalbed strongly indicates that this “fault” is an erosional feature associated with the subcrop.

MINES IN SULLIVAN, GREENE, AND CLAY COUNTIES

The Survant coal was mined in more than 50 separate operations in east-central Sullivan County, western Greene County, and southwestern Clay County. Mines here are more dispersed and do not form such a continuous area of mining as do the mines northwest of Terre Haute (fig. 5). But this district can clearly be divided into two parts: the eastern part, which lies mostly in Greene and Clay Counties, and the western part, which is entirely in Sullivan County. The two parts are divided by a north-south area about 2 to 2.5 miles wide where the Survant coal is split and little or no mining has occurred (fig. 6). Maps of about 35 of the mines in this district are in

Figure 5 (on facing page). Map showing underground mines in the Survant coal in Sullivan, Greene, and Clay Counties and locations of datum points giving coal thickness. Some mine maps show data from exploration holes outside the mined area. Mine maps are on file at the Indiana Geological Survey.
the files of the Indiana Geological Survey; about 24 of these maps contain thickness notations and other notations regarding geologic conditions. The mining literature also contains descriptions of conditions encountered in several of the mines.

Mining began in this area immediately south and west of Linton in the early 1890's. Mine development surged in the early 1900's and about the time of World War I, but most underground operations were abandoned by the 1930's. The Peabody No. 48 Mine, the largest and longest lived underground mine in the Survant coal in the area, was abandoned in 1945. The only currently active underground mine in the Survant coal, the 4th Vein Mine, was opened in 1979 and lies in the central part of this field in Greene County (fig. 5). About 80 million tons of coal has been produced from underground mines of this district during its lifetime. Surface mining of the Survant in this area began about 1928, and several important surface mines (not discussed in this report), including the Linton Supreme Nos. 19, 23, and 24 Mines, the Linton No. 28 Mine, and the Latta Mine, have been developed here.

This mining district is bounded on the east by the cropline of the Survant coal (fig. 6), along which several major surface mines in Greene and Clay Counties were developed. Although West Linton is known to be undermined, no maps of underground mines show any workings under the city of Linton, which lies on and immediately west of the subcrop of the Survant. The maximum depth of underground mines in the Survant is 320 feet in Sullivan County. Along the cropline of the coal in Greene County some underground mines are only 25 to 35 feet deep, and land in the undermined area south of Linton has been severely disturbed by subsidence (Harper, 1982). Unlike problems encountered in the mining district northwest of Terre Haute, few problems have been encountered with emplacement of shafts through the unconsolidated overburden, which is less than 50 feet thick. At the 4th Vein Mine in Greene County access to the coalbed was obtained by drifting into the coalbed from the bottom of a 125-foot-deep pit.

The entire Survant mining district is bounded on the west by thin coal (less than 3 feet) (fig. 2). In many places within the district the Survant coal varies greatly in thickness across short distances. Most mines in Sullivan County were developed where the coal is between 5 and 6 feet thick (fig. 6). Coal more than 6 feet thick was encountered in the northern and western parts of the Peabody No. 48 Mine and in parts of the Little Betty No. 1 Mine. At all operations mining was terminated in certain areas where coal thickness was less than 5 feet.

In Greene and Clay Counties most mining took place where the coal was more than 4 feet thick, but significant mining also occurred where the coal was less than 4 feet thick (fig. 6). The coalbed thinned toward the north in the group of underground mines in the southeastern quarter of the mining district, and coal was removed in the Twin No. 1 and Central City Mines where the seam was less than 3 feet thick. A surface mine, the Linton Supreme No. 19 Mine, was developed along the crop of the Survant coal immediately east of the Black Creek No. 2 Mine; average thickness of the coal at this operation was between 3.3 and 3.8 feet. The underground Lenoir No. 1 Mine also operated where the coal was less than 4 feet thick, and the active underground 4th Vein Mine has been developed where the average coal thickness is between 3.5 and 4.0 feet. A surface mine, the Linton No. 28 Mine, was developed 3 miles due east of the 4th Vein Mine along the crop of the Survant coal; average thickness of the coal at this operation was about 3.5 feet. Mining between the underground White Ash and Calora No. 1 Mines in the northeastern part of the mining district was apparently limited by thin coal (less than 3 feet thick). East and southeast of the underground Queen No. 4 Mine is the inactive Latta Mine, a surface mine that operated predominantly in another coalbed but that sometimes also operated in the Survant coal; average thickness of the Survant at that operation was 3.5 feet.

Mines in the Survant coal throughout the Sullivan-Greene-Clay mining district had a sandy shale or hard sandstone floor. Ashley (1899, p. 112, 822) described the floor strata in Greene County as consisting of "micaceous sandstone 20 or 30 ft. thick" and as "a gray, shaly bituminous sandstone, not a good floor to dig gutters in, but making a solid foundation for posts and pillars." At the 4th Vein Mine the floor

Figure 6 (on facing page). Map of the same area as figure 5 showing undermined areas in the Survant coal in Sullivan, Greene, and Clay Counties, contours of coal thickness, and geologic conditions that affected mining. Contour interval is 1 foot. Thickness data are entirely lacking in much of the split-coal area. In areas where data are sparse or absent, inferred contour lines are dotted. Question marks are used where data are too sparse to allow extension of contour lines or split-coal areas. Information is based on drilling records and mine maps. Cropline is from Wier (1950, 1952b).
UNDERGROUND MINES IN THE SURVANT COAL MEMBER

EXPLANATION
- Split coal
- Mine boundary
- Coal-seam subcrop
- Thickness contour
- Thick coal (>5 ft.) that is not split
- Moderately thick coal (4 to 5 ft.)
- Thin coal (<4 ft.)

MINING MAP NOTATIONS
- Roof rol
- Split coal
- Bad roof
- Steep grade
- Fault
- No coal
- Blackjack
is sandstone overlain in places by as much as 1.6 feet of overclay. Wier (1952b, p. 13) noted that much of the sandy fireclay contained large Stigmaria (rootlike plant fossils) and that the sandy shale contained abundant impressions of leaves. In the Peabody No. 48 Mine in Sullivan County the bottom was so hard that all grading work was done by removing roof rock. In some places a thin layer (several inches) of fireclay was between the coal seam and the underlying sandstone.

Roof conditions in underground mines of the Survant in this district have been described as moderately good to poor. In a few places the immediate roof was reportedly sandstone, and in a few other places black shale and limestone were present. At the portal of the 4th Vein Mine the roof consists of about 15 feet of fissile black shale (containing siderite bands) overlain by about 10 feet of sandstone; no serious rock falls have occurred. But the roof strata of the Survant in most places have been described simply as a "gray or blue shale." In Sullivan County the Little Betty No. 1 Mine had a moderately good roof, but the Peabody No. 48 Mine had a bad roof. One observer (Coal Age, 1938a, p. 56) stated: As soon as a room is picked up, * * * all material is removed, including timber, which is pulled out with locomotive and cable. Then the top is allowed to cave or, if necessary, is shot to bring it down. This practice grows out of the presence of water and gas under pressure in the roof. Bringing down the roof in worked-out territory relieves the pressure in adjacent openings.

Mine-map notations indicating bad roof in Greene County are mostly confined to mines very near the cropline (fig. 6); this indicates that the coal was mined at very shallow depths. Northward mining in the Templeton No. 4 Mine in Sullivan County may have been limited by the roof rolls indicated on the map of that mine (fig. 6). Few data are available for the area lying between the Templeton No. 4 and Vigo No. 15 Mines on the south and the Peabody No. 48 Mine on the north; a short panel driven southward into this area from the Peabody No. 48 Mine terminated against a feature labeled "fault" on the mine map (fig. 6). It is not possible by available information to say whether the area between these mines remained unmined because of coalbed discontinuities, thin coal, or some other reason.

Problems were encountered in many places with roof partings in the seam. Ashley (1909, p. 72) observed that "there is usually only one parting, which is irregular, in many areas not showing at all or only as a smooth parting, while elsewhere this parting may thicken up and vary widely within short horizontal distances." A rock parting about 12 inches thick was present in the eastern part of the Linton Supreme No. 23 and No. 24 Mines (surface mines immediately southwest of the Buckeye, South Linton, and Sponsler No. 1 Mines). This parting thickened rapidly westward to more than 12 feet, so that mining of the lower bench (21 to 25 inches thick) was discontinued. Where it was mined by surface operations, the upper bench ranged from 34 to 44 inches in thickness and was characterized by many "fireclay slips."

Rock partings also apparently limited mining to the northwest in the Lattas Creek No. 6 Mine (fig. 6) and to the southeast and the northwest in the Vigo No. 27 Mine. At the 4th Vein Mine there is no significant rock parting at the portal, but a parting (described by a mine official as a "blue band" that is also red in some places) is present west of the portal and thickens westward. The seam also thickens westward and contains less sulfur.

A parting ("dirt band") ranging from 2 to 28 inches in thickness was present about 3 feet above the floor of the Peabody No. 48 Mine in Sullivan County. This rock had to be separated from the coal before loading. The mine map of the Peabody mine indicates that the "dirt band" thickened northeastward and reached 1.8 feet in thickness along the northeastern boundary where mining was terminated. The mine map of the Peabody mine also indicates rash (impure coal mixed with clay or shale) in the lower part of the seam and underlying the seam; the rash ranged from 2 inches to 1.8 feet in thickness and increased northeastward. Southward mining in the Templeton No. 4 Mine (Sullivan County) was probably also limited by a rock parting that reached 9 inches in thickness in the middle of the seam. Eastward mining was probably terminated in the Superior Mine because of a "dirt band" that reached a thickness of 1.1 feet in places. Therefore, westward mining in the Greene-Clay part of the mining district was limited by rock.
UNDERGROUND MINES IN THE SURVANT COAL MEMBER

EXPLANATION
- Mine-map datum
- Drilling datum
- Mine-map notation
- Thickness contour

R 8 W

BERGAN-MCPHERSON

GLEN AYRE NO. 2

GLENCO

GLEN AYRE NO. 1

SOULES-DURAND

HEIN-LOUDELMILK

Coal-seam cropping

Roll

Tault

NON-CLINKER

1 Mile
1 Km
partings, as was eastward mining in the Sullivan part of the district. The long, narrow (2 1/4-mile-wide) north-south zone in which no mining occurred therefore represents an area in which the Survant coal is split by rock partings (fig. 6). Where mining has occurred along the margins of the area of split coal, the total thickness of rock partings is generally less than 6 inches. In many parts of split areas between mines, total coal thickness is indeterminate, but where data exist, total coal thickness is commonly less than 5 feet, and most individual benches are less than 3 feet each.

Wier (1951) noted that "in the northeastern part of the [Linton] quadrangle, a few inches to nearly 2 feet of black bituminous shale is present instead of the upper part of the coal. This shale, or 'jack,' causes the coal to be too thin to be minable under present economic conditions." There are numerous notations referring to "blackjack," or black fissile shale, along the east edge of the Lattas Creek No. 6 Mine (fig. 6), and the area between that mine and the Calora No. 1 Mine may have remained unmined by underground operations for that cause. Even though some of this area is overlain by Jasonville, much of that town was undermined, and thin coal or "blackjack" might have inhibited even more extensive mining there. The surface Latta Mine also commonly encountered "blackjack" in the upper part of the Survant coal in this area.

Wier (1952b, p. 13) noted that the Survant had a medial shale parting that was almost 3 feet thick along the cropline northeast of the Primrose No. 3 Mine. About 2.5 feet of coal was above and below the parting, and Wier (1952b, pl. 3) included a photograph of the parting where it was exposed in a surface mine.

Besides poor roof and rock partings, other important seam irregularities contributed to unfavorable mining conditions in the Survant coal. In the Peabody No. 48 Mine grades of as much as 12 percent were reported, and the mine map indicates an upward grade of 10 percent to the east in the northeast corner (fig. 6). Faulty conditions occurred along the entire western boundary of the Peabody mine, and a single continuous line (labeled as a "fault") is shown on the mine map.

MINES EAST OF TERRE HAUTE

A cluster of small underground mines lies less than 3 miles east of Terre Haute along the south side of Otter Creek (fig. 2). The mines are bounded on the north and the west by the cropline of the Survant (fig. 7). These mines are shallow, all less than 100 feet deep, and the undermined land is severely affected by subsidence. Gradients across most of the area are very gentle and average about 27 feet per mile. A small structural trough trending in a north-south direction is at the southeast edge of the area.

The Survant coal averages 5 feet in thickness across most of the mined area. Data from the mine map of the Glen Ayre No. 1 Mine indicate a long, narrow zone of thick coal in a northwest-southeast direction along the southwestern margin of the mine. Within this zone the coal exceeds 7 feet in thickness. The orientation of mine entries was changed to a northwest-southeast direction, and mining soon terminated southwest of this narrow zone where coal thickness diminished to less than 4 feet. Problems with water inflow were also reportedly experienced there. Although no data are given, the orientation of mine entries at the southwestern margin of the Soules-Durand Mine suggests that similar geologic conditions were encountered in that area. A roll is indicated on the map of the Soules-Durand Mine near the place where entries were reoriented, which suggests that roof irregularities are associated with the long, narrow zone of thick coal. East of the mining district the thickness of the Survant apparently decreased more gradually, and mining was discontinued where the thickness diminished to less than 4 feet. Small surface mines were developed 1 mile east of the underground mines along the cropline of the coal.

Rolls and faults are indicated on maps of several mines in this cluster, but most of these features, which are close to the subcrop of the Survant coal, are probably erosional.

The three largest mines in this group of mines opened during 1907-8. Maximum annual production was reached by the Glen Ayre No. 1 Mine in 1924, when almost 290,000 tons was produced. Total production of all the mines in this group was about 6 million tons.

WESTPHALIA MINE IN NORTHEASTERN KNOX COUNTY

The Westphalia Mine is in northeastern Knox County (fig. 2) near Edwardsport. At a depth of 220 feet this mine produced 3.1 million tons of Survant coal between 1917 and 1939. Average thickness of coal in the mine was 4.8 feet, but the seam reached a maximum thickness of 5.3 feet (as determined by drilling) north of the mine (fig. 8). According to drilling information, the mine appears to occupy about the eastern one-quarter of a pod of thick (greater than 4 feet) coal. To the north and the northeast min-
UNDERGROUND MINES IN THE SURVANT COAL MEMBER

The mining district northwest of Terre Haute was in a geologic deposit of major economic importance; if by some chance it had remained unexploited to the present, it would represent a highly attractive coal reserve. There is no evidence at present that any other such deposit of the Survant coal (about 40 contiguous square miles of low-sulfur coal averaging more than 5 feet in thickness) exists anywhere within the Illinois Basin. Smaller undiscovered or unexploited deposits of thick Survant coal comparable in extent to some mines of the Sullivan-Greene-Clay district may exist, but publicly available information is generally inadequate to delineate such areas clearly or to determine the existence of thick rock partings within the seam.

The largest single area of thick Survant coal is in northern Vigo County and southern Vermillion County, but throughout most of the southern half of Vigo County and along the western margin of that county, the Survant is less than 2 feet thick, is divided into multiple splits, and in many places is absent or too thin to be recognizable (Harper, 1985). In most of Sullivan County the Survant is generally thin (less than 2 feet), absent, or not recognizable outside its mining district in the east-central part of the county (Harper, 1988). Identification on geophysical logs of the coalbed, which is commonly split, is usually uncertain in much of Sullivan County. Extending westward from the mining district in Sullivan County is an irregular, elongate trend of thick coal where the seam may reach 6 feet in thickness in a few places (fig. 2). Where the coal is thick, rock partings may also be present within the coalbed. Several other isolated areas of coal more than 2 feet thick are scattered across the county, but in these areas the coal exceeds 5 feet in thickness in a few places and rock partings are common.

Spencer (1953, p. 18) gave estimates of remaining reserves of the Survant coal in Indiana exceeding 28 inches in thickness as 3.2 billion tons. In 1965 total reserves recoverable by surface and underground mining were estimated to be about 1.6 billion tons (Indiana Geological Survey, 1965). But these estimates include much thin coal (1.2 to 4.5 feet) that is unlikely to attract the interest of operators of underground mines in the foreseeable future. Harper (1985; 1988) estimated reserves of thick Survant coal (greater than 4.5 feet) in Vigo and Sullivan Counties to be about 110 million tons, but these reserves are scattered among numerous relatively small pods and in places may be split by rock partings that are thick enough to prevent mining. Spencer (1953, p. 28) noted that the Survant thinned to the west in northern Knox County, was about 3 feet thick in Daviess and Pike Counties, thinned southward in Warrick...
County, and was absent or unworkable in Vanderburgh County. In Gibson County the Survant coal is typically less than 4 feet thick where it is present and recognizable, and it rarely reaches 5 feet in thickness; the coal is also typically split into two and in some places three benches (Donald L. Eggert, 1985, oral communication).

In western Kentucky the Survant Coal Bed (historically referred to as the Well coal or Western Kentucky No. 8 coal) has been characterized as “generally thin” (Mullins and others, 1965, p. 21-22). The Survant coal has not been mined underground in western Kentucky, has been exploited at only a few small surface mines, and is not considered to be economically significant (David Williams, 1985, oral communication).

The Survant coal of Indiana has been correlated with what was formerly called the Shawneetown Coal (No. 2A Member of southwestern, southern, and eastern Illinois and the Lowell Coal Member of northern and western Illinois. The Illinois State Geological Survey has now adopted the name Survant for formal usage in eastern and southern Illinois and recognizes the Shawneetown as the upper beach of the Survant (Russell J. Jacobson, 1985, written communication). Harrison (1951, p. 15) in a report on subsurface geology and coal resources of White County, Ill., characterized the Survant: “* * * it has vague pattern in the electric log, it is uncertain whether or not there are two benches, the interval between the two benches is variable, and the coal is apparently absent in about 30 percent of the electric logs.”

Potter (1956, p. 10) noted that the Survant was commonly thin and not always present in Crawford and Lawrence Counties, Ill., immediately west of Sullivan and Knox Counties, Ind. Regarding the Survant in southeastern Illinois, Smith (1957, p. 10) reported: “Coal No. 2A is less persistent than coal No. 2 and generally is thinner.” Smith (1961, p. 13) reported several occurrences of coal in west-central Illinois that might be equivalents of the Lowell coal. These were less than 4 feet thick except the Kerton Creek Coal Member that was locally thick. Clegg (1961, p. 14) noted that in central Illinois “* * * there are indications of one or possibly two additional coals in the interval [containing the Survant coal]. Information on the thickness of these two coals is meager, but at least one of them appears to attain local thickness of about 3 feet.” Smith (1968, p. 11-12) reported on a possible occurrence of the Lowell coal in north-central Illinois: “In * * * Livingston County, and * * * near the northwest corner of Kankakee County, locally occurring deposits of coal have been worked * * *. These deposits * * * reached a thickness of 12 feet near Cardiff. In both of these areas, the coal, which apparently formed in a channel-like depression, has been largely mined out * * * R. A. Peppers * * * has tentatively correlated the Cariff Coal with the Lowell Coal.” But more recently acquired evidence suggests that the Cariff Coal Member may be slightly older than the Lowell coal (Russell J. Jacobson, 1985, written communication).

From electric logs of borings made for petroleum exploration in central Illinois, Clegg (1972, p. 19) observed: “Neither the Summum nor the Lowell Coal appears to be thick enough to be a potential reserve of minable coal within the study area [De Witt, McLean, and Piatt Counties, Ill.].” Hopkins and Simon (1975, p. 188) observed of the Survant coal: “It normally is thin, but in a few scattered drill holes it has been reported to be as much as 8 feet thick.” They also noted that the Lowell coal in northern and western Illinois was thin—only 10 inches at its type section. In their report on Vermilion and Edgar Counties, Ill., which lie immediately west of Vigo and Vermillion Counties, Ind., Jacobson and Bengal (1981, p. 8) reported that “a coal possibly correlative with the Shawneetown Coal lies * * * in this area. This coal is usually thin, and is split into two benches. In localized areas of eastern Edgar County, where the two benches have merged and thickened, this coal has been reported to be up to 6 ft thick.” Since the 1950’s the Illinois State Geological Survey has published many other reports on strippable coal reserves and on subsurface geology and coal resources of Illinois counties, but few of these mention the Survant coal. But the characterizations of the Survant given above apply well to the Survant of Indiana outside the known mining districts: irregular in occurrence, commonly split by thick rock partings, generally thin (less than 3 feet) or absent, but with scattered drill holes indicating abnormally thick (as much as 8 feet) coal.

**CONCLUSION**

Since the 19th century, coal companies operating in southwestern Indiana have drilled thousands of holes in exploring for minable coal beds. Much of the information obtained from that drilling, especially by early companies that no longer exist, has been lost, and much of the information is held as proprietary by present companies. Nevertheless, even though publicly available information regarding the thickness and the character of the Survant coal is sparse and some of it is fragmentary and of doubtful reliability, some conclusions regarding the state of...
development of Survant reserves are possible after considering available drilling data, mine distribution, mine-map notations, and production history.

In Indiana underground mining has declined to insignificance in all major coalbeds. But in some coalbeds, such as Seelyville, Springfield, and Hymera, underground mining may be inhibited primarily because of changes in markets related to coal quality and secondarily because of geologic factors directly affecting minability, such as adequate reserves of thick coal free of large rock partings. By contrast, significant underground mining in the Survant coal appears to have ended primarily because of the exhaustion of thick (greater than 4.5 feet) coal reserves.

If Indiana ever experiences a revival of underground coal mining, market demands and minability will determine which coalbeds are most extensively exploited. If sulfur content diminishes in importance, as through the development of preparation technology to remove sulfur cheaply, there will still be little chance of significant revival of underground mining in the Survant coal. Coal would be mined from thicker, although poorer quality, coalbeds where mining productivity would be greater. But if low-sulfur coals continue to be sold at a significant premium far into the future and if other market forces, such as rising transportation costs, reduce the desirability of low-sulfur coal from competing regions, some modest revival of mining in thin (less than 4.5 feet) reserves of the Survant might eventually occur. Even then, underground mining in the Survant would necessarily be from small- to medium-scale mines, probably developed by small, locally based companies because large midwestern mining companies have shown little interest in such operations in recent times. Large companies that have acquired reserve tracts that might be adequate for moderate- to large-scale underground mining at some future time have apparently done so only with coalbeds other than the Survant.

REFERENCES


Ashley, G. H., 1899, The coal deposits of Indiana: Indiana Department of Geology and Natural Resources Annual Report 23, 1573 p.

_ 1909, Supplementary report to the report of 1898 on the coal deposits of Indiana: Indiana Department of Geology and Natural Resources Annual Report 33, p. 13-150.


Brosky, A. F., 1923, In sinking Spelterville shafts through wet sand sizes are increased to offset list of caisson: Coal Age, v. 24, no. 8, p. 273-276.

_ 1930, 9 1/2 tons per man is Clinton’s daily average in a continuous mining process: Coal Age, v. 35, no. 4, p. 215-217.


Coal Age, 1930, Arrowall-type machines loading coal in Mid-west mines: v. 35, no. 8, p. 465-467.

_ 1932, Room conveyors add to profit margin mining thin seam in Indiana: v. 37, no. 1, p. 19-21.

_ 1933, Little Betty Mine expands mechanical loading operation? v. 38, no. 5, p. 159.

_ 1934, Face preparation shares honor with safety at Indiana Institute meeting: v. 39, no. 7, p. 272-274.


_ 1935b, Low cost and safety feature entry timbering with the hitch drill at Indiana coal-mining operations: v. 40, no. 6, p. 237-239, 244.


_ 1938a, Coal mining in Indiana: v. 43, no. 12, p. 36-108.

_ 1938b, Two seams stripped and prepared in all-welded plant at new Maumee Collieries operation: v. 43, no. 9, p. 29-34.

_ 1939, 1,550-ton bin built in interval between two seams stores Fayette No. 4 Mine output: v. 44, no. 8, p. 44-49.

_ 1942, New shovel operation and 14-yd. dragline for rider work mark advances at Maumee mines in Indiana: v. 47, no. 3, p. 40-42.


_ 1967, Chineok modernized; digs deeper, upgrades preparation: v. 72, no. 4, p. 82-90.

Davis, Harold, 1955, A power-package for modern industry: Coal Age, v. 60, no. 6, p. 60-64.

Edwards, J. H., 1929, Bad top and parting no bar to use of loading machines: Coal Age, v. 34, no. 7, p. 410-412.
Flowers, A. E., 1956, Blackfoot strips, hauls, cleans, and dries two coals in an exercise in coordination: Coal Age, v. 61, no. 6, p. 60-65.


Given, R. A., 1935, Clinton conveyor plan designed to provide maximum flexibility in operation of four-room units: Coal Age, v. 40, no. 3, p. 104-106.

Hasenmueller, W. A., 1986a, Complete mechanization marks resumption of operations on old Talleydale property: Coal Age, v. 41, no. 11, p. 419-498.


1988, New Bobolink stripping uses 30-yd. shovel and 25-ton trailers to mine 36-in. coal seam: Coal Age, v. 41, no. 4, p. 131-134.

1936a, Complete mechanization marks resumption of operations on old Talleydale property: Coal Age, v. 41, no. 11, p. 419-498.

1936b, New Bobolink stripping uses 30-yd. shovel and 25-ton trailers to mine 36-in. coal seam: Coal Age, v. 41, no. 4, p. 131-134.


Indiana Division of Mines and Mining, 1933-36, Annual report, 1933-36: State of Indiana.


McKenna, J. V., 1946, Safe support provided by hinging and pocket timbers: Coal Age, v. 51, no. 7, p. 78-82.


Richart, F. W., 1944, High loader output reflects equipment and methods at Saxton: Coal Age, v. 49, no. 10, p. 95-105.


Wier, C. E., 1950, Geology and coal deposits of the Jason-


1952a, Distribution, structure, and mined areas of coals in Vigo County, Indiana: Indiana Geological Survey Preliminary Coal Map 1.


