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PREPARATION AND ANALYSIS OF COAL SEAM DATA UTILIZING PALEOENVIRONMENT MODELING, HAZARD #7 COAL, EASTERN KENTUCKY

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ABSTRACT

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Pennsylvanian strata of the Hazard coalfield, Eastern Kentucky, contain fluvial, upper-delta plain facies characterized by thick localized coals, bay-fill shales, levee silt- and sandstones, and channel-fill sands and gravels. Although the deltaic nature of these sediments has long been established, mining and exploration activities in the district require a thorough understanding of small areas within the delta environment. Coal quantity and quality trends in the Hazard #7 seam, the major producer in the area, have been examined in detail.

The #7 coal accumulated in a peat swamp restricted laterally by a major fluvial channel. Three types of non-coal parting are recognized. Thin, tabular, fine-grained partings resulted from periods of increased terrigenous influx into the swamp. Lenticular crevasse-splay deposits locally split the coal. Wedge-shaped, fine- to coarse-grained partings, of probable levee origin, are found along the channel margin. Post-swamp deposits consist of thick bay-fill shales, thin shales, silt- and sandstones deposited on floodplains, and channel-fill sandstones and gravels.

The modeling technique discussed provides guidance for mine development and regional exploration by prediction of coal seam quantity and quality trends from local geologic features. The thickest #7 coal is split by thin tabular partings and is overlain by thick shale sequences. Coal overlain by silt and sandstone is thinner and unsplit, and typically of higher heat value. Regional seam thinning due to channel scour is recognized. Factors which control the configuration of the coal seam include position within the peat swamp, proximity to the fluvial channel, swamp burial processes, and paleochannel sinuosity.

INTRODUCTION

The deltaic characteristics of the coal-bearing Pennsylvanian strata of Eastern Kentucky have long been recognized (Smith et al., 1971; Baganz et al., 1975; Horne et al., 1978). Most of this work is based on exposures in recent highway roadcuts, and provides an overview of regional facies variations and coal distribution. One of the shortcomings of these studies, due to the inavailability of drill core information, is the lack of detailed descriptions of small areas. The scale of mining operations and district exploration requires local variations in facies to be correlated with trends in coal quantity and quality. This study utilizes abundant drill core information to closely examine the facies relations associated with the Hazard #7 coal seam.

Horne et al. (1978) attributed the rocks of the Pochahontas Basin to processes in five major depositional settings: (1) barrier; (2) back-barrier; (3) lower delta plain; (4) transitional delta plain; and (5) fluvial upper delta plain. Rock sequences typical of these environments are exposed along a northwest to southeast traverse from the Cincinnati Arch to Pine Mountain (Smith et al., 1971). In the Hazard coalfield (Fig. 1), the strata consist primarily of transitional and upper delta plain sequences. The Hazard #7 coal, one of the major producing seams in the district, originated in these environments.

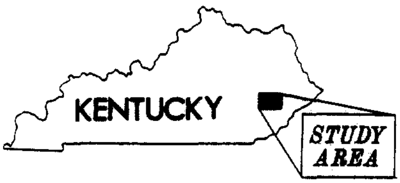

Fig. 1. General location map.

The isopach maps and geologic cross-sections presented were constructed primarily from drill core data. These were supplemented by field observations, underground mine maps available at the Kentucky Department of Mines and Minerals, U.S. Geological Survey Coal Investigation Maps (Stafford and Englund, 1953; Williamson and Adkison, 1953; Johnston et al., 1955), and U.S.G.S. geologic quadrangle maps. Although a considerable amount of drill data was available, much of it was clustered in small areas. This facilitated detailed observations, which were developed into a paleoenvironment model to provide regional interpretations.

COAL THICKNESS CONFIGURATION

The geometry of the Hazard #7 is shown in Fig. 2. Total coal thickness is distinguished from seam thickness by the exclusion of shale, clay, and bone coal partings. Bone is a dull, brittle, high-ash coal which is low in heat content and breaks with a conchoidal fracture. It is locally a common component of the #7 seam.

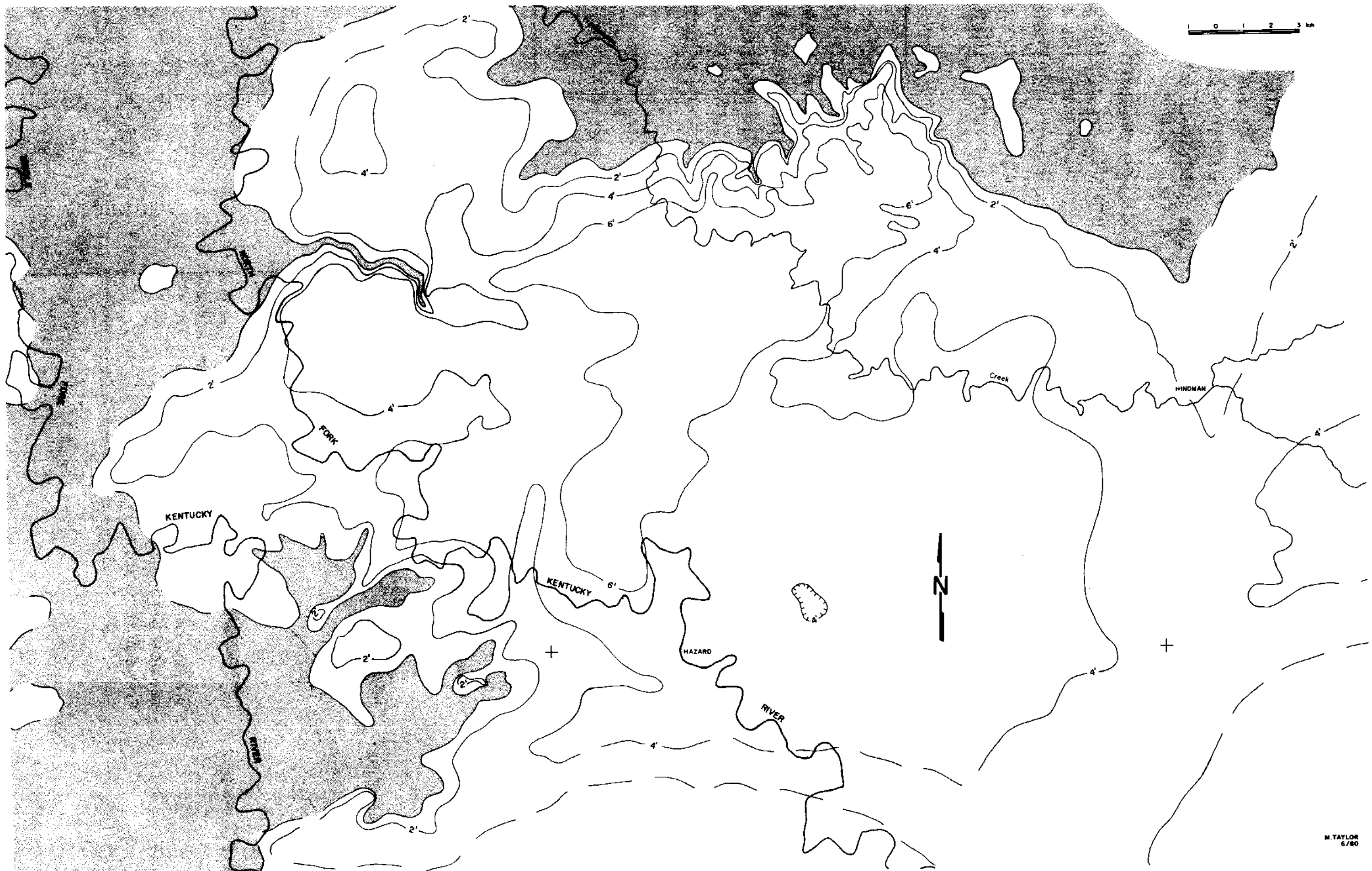

Fig. 2. Hazard #7 coal seam. Total coal thickness.

A persistent bone parting indicates a period of fine-grained terrigenous influx into the peat swamp. This interrupts the coal-forming process by diluting the peat with sediment. Terrigenous influx often occurs after a fire in the swamp (Staub and Cohen, 1979). Areas of the swamp below water level would also accumulate sediment influx. Either of these mechanisms would result in high ash content in the coal seam, and the formation of bone and non-coal partings.

The Hazard #7 coal abuts thick fluvial sandstone in the western and northern parts of the study area (Fig. 2). The sandstone consists of multiply-stacked, upward-fining units, is poorly sorted, arkosic, and contains mudstone and coal clasts and coalspar above scour surfaces. Maximum thickness locally exceeds 100 m. The immaturity of the sandstone and facies characteristics resemble the point bars of modern meandering rivers (Allen, 1969, pp. 118–148; Selley, 1970, pp. 22–51).

Coal thickness is related to peat swamp setting, proximity to the fluvial sandstone at the swamp margin, and swamp burial processes (Figs. 2–4). The partings and their geometries reflect persistent terrigenous influx, encroachment of bay margins or levees, and crevasse splays. Three types of parting result (Table I and Fig. 3). The thin tabular shale, clay, or bone partings resemble the fire-splays of Staub and Cohen (1979). The crevasse-splay deposits are more lenticular and consist of coarser clastic material. A third type of parting comprises wedge-shaped units which thin away from the margin of the fluvial sandstone. These are interpreted as levees which resulted from overbank flooding.

TABLE I

Description of non-coal partings

Type	Geometry	Lithology
thin, tabular		bone coal, organic-rich clay, clay
crevasse-splay	 perpendicular section	clay, siltstone, sandstone, with coarsest material in the center of the lens
wedge-shaped	 source of sediment → section perpendicular to channel margin	clay, siltstone, sandstone, grain size increases with thickness

Fig. 3. Hazard #7 coal seam. Partings.

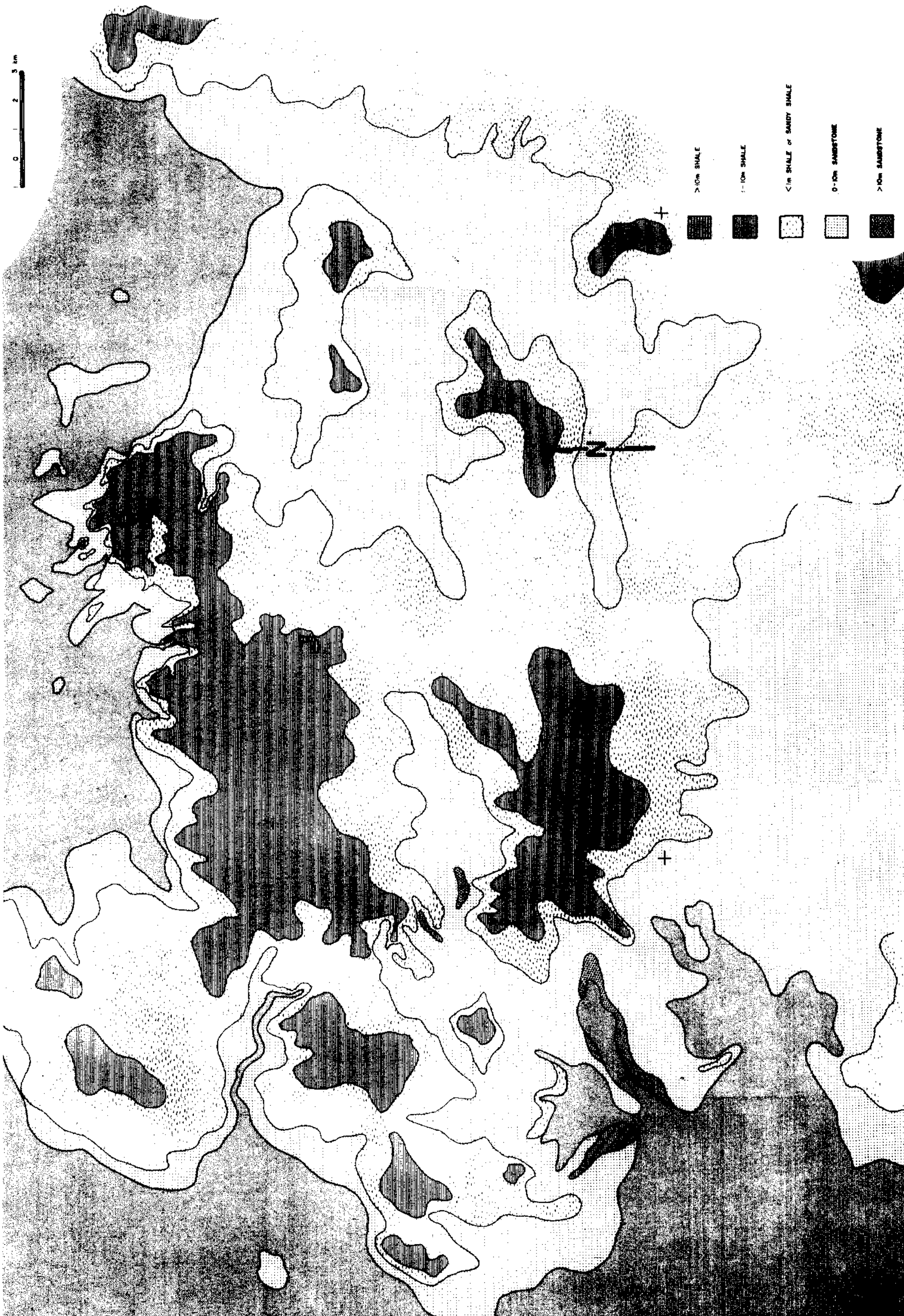

Fig. 4. Hazard #7 coal seam. Overlying strata.

Peat swamp setting

The quantity and quality of the Hazard #7 coal varies with the area of the peat swamp in which the coal accumulated. Controlling factors include type of vegetation, rate of subsidence, and proximity to the fluvial channel. Areas of thick #7 coal (Fig. 2) are characterized by numerous bone and non-coal partings (Fig. 3) which lower the heat content of the seam. Reduced coal thickness is generally accompanied by a reduction in the number and extent of partings and an increase in heat value.

Subsidence, burial and compaction of peat is the most effective mechanism of coalification (Coleman and Prior, 1980). The relationship of subsidence to coal quality and seam thickness is shown schematically in Fig. 5. Provided adequate vegetation, an area which subsides rapidly will accumulate more peat than a more stable area. An area of rapid subsidence will also sink below water level more often than one which is sinking slowly, increasing the influx of terrigenous sediment.

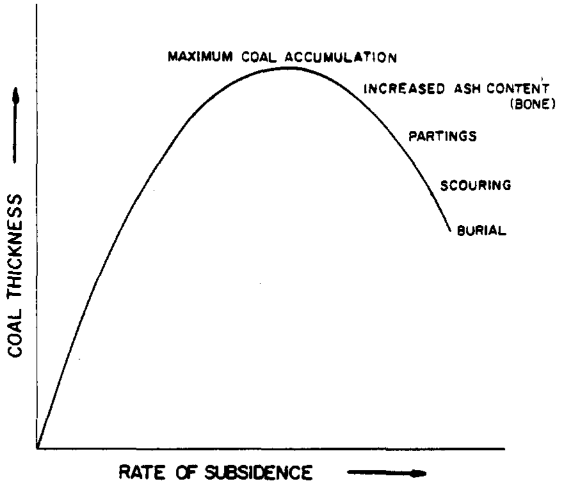

Fig. 5. Schematic relationship between the rate of swamp subsidence and coal quality and seam thickness.

The configuration of the Hazard #7 coal seam appears to have been strongly influenced by the rate at which different portions of the peat swamp subsided. The thickest #7 coal coincides with the largest number of thin tabular partings (Figs. 2 and 3). The partings consist primarily of bone coal, but locally grade into clay or shale. The geometry and lithology of the partings, as well as the coal thickness, indicate that the central portion of the swamp acted as a sump for both peat and terrigenous influx.

Fig. 6. Hazard #7 coal zone, several hundred meters from paleochannel margin (pocket-knife for scale).

Proximity to a source of sediment

The majority of the coal-sandstone (no coal) contact is codepositional. In most areas the coal thins laterally to the point at which it is replaced by sandstone. Virtually all the coal within 1 to 2 km of the channel contact is overlain by sandstone. This high-energy environment was unfavorable to peat accumulation and preservation.

The codepositional nature of the contact is illustrated in Fig. 6, photographed in a recent roadcut. The coal zone consists of:

30 cm grey clay
23 cm coal
100 cm grey underclay
9 cm coal

The coal zone is overlain by more than 10 m of medium-grained, cross-bedded sandstone, and lies above nearly 2 m of fine-grained, horizontally bedded sandstone. The basal sandstone contains plant fragments and undisturbed root casts (below the knife in Fig. 7, Figs. 8 and 9). These features demonstrate that, although it was choked with sediment influx and unproductive, the peat swamp did exist along the channel edge. Lower total coal thickness near the paleochannel (Fig. 2) reflects non-accumulation as well as erosion of peat in areas adjacent to the channel. It is not simply an erosional contact.

The coal-sandstone contact is significantly different in the north central region of Fig. 2. In this area, the major channel has encroached upon the most productive portion of the swamp. Total coal thickness of the #7 seam drops from 90″ (2.3 m) to zero over distances of 0.5 to 1 km. Very thick (10 m) shale cover is found within a kilometer of the channel. The number of non-coal partings in the seam increases from one to three or four near the channel (Fig. 3). The partings are wedge-shaped and contain coarse clastic material near the sandstone contact. The contact in this area is an erosional feature, not the result of codeposition of peat and sandstone.

Geologic cross-sections (Figs. 10 and 11) clearly illustrate the interaction between the major channel and the productive peat swamp. The top of the Francis (Hazard #8) coal has been used as a reference elevation to eliminate post-depositional dip associated with the Pine Mountain thrust fault.

At the southeast end of Fig. 10 the coal is unsplit, and near maximum thickness. The small "marker" split above the seam is a distinct coal, included in the Francis coal zone (Fig. 11). It is not included in the total coal thickness measurements of the #7 seam. Thin shale partings appear along section toward the paleochannel. The partings are attributed to the high sediment influx provided by the major channel (levee deposits). At this point in the traverse, the seam configuration resembles that discussed in the section on subsidence. The prospect of continuing in thick coal, split by thin partings, would appear to be good.

Fig. 7. Root casts in fine-grained, horizontally bedded sandstone beneath Hazard #7 coal zone near paleochannel margin (close-up of Fig. 6).

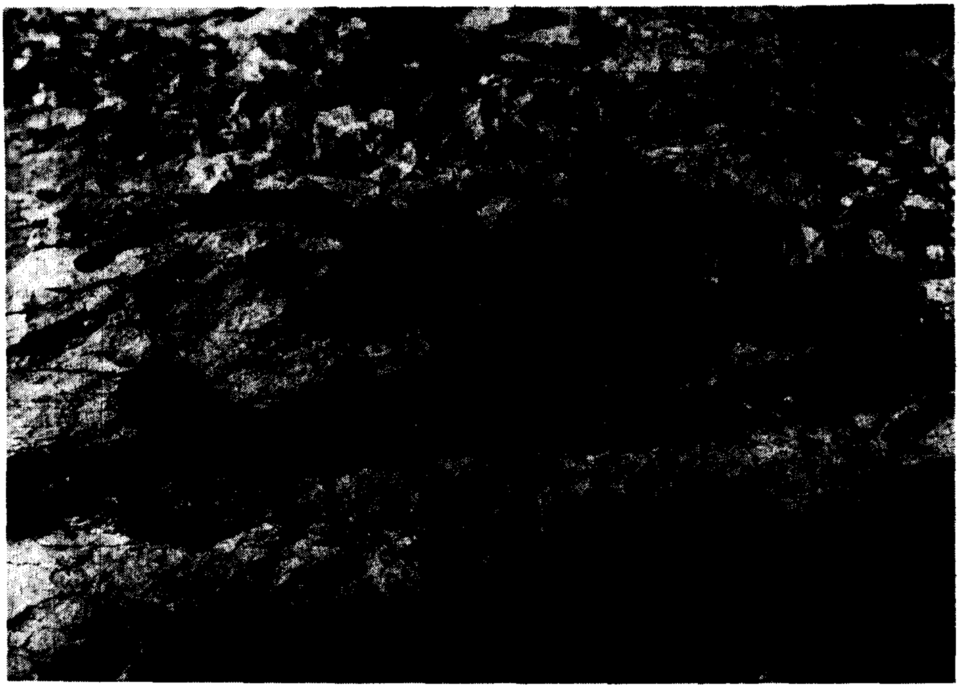

Fig. 8. Root zone in fine-grained sandstone beneath Hazard #7 coal zone. Same outcrop as Figs. 6 and 7.

Continuing to the northwest, the non-coal partings increase in thickness and total coal thickness decreases. The coal seam at the channel margin is very thin and dips toward the channel. This is the result of undercutting of the peat by the fluvial channel. As the swamp was undercut, blocks of peat slumped into the channel and were subsequently buried and coalified. These facies relations are exposed by a roadcut through the Hazard (#5-A) coal (Fig. 12).

A similar sequence is observed along a southwest to northeast traverse toward the contact (Fig. 11). In this area, the coal is split by three shale partings for a considerable distance. The undercutting of this portion of the swamp was less abrupt than in the area of Fig. 10. Again, the seam dips toward the channel, and the partings thicken incrementally. Each coal split is individually replaced by sandstone. This cross-section illustrates sporadic interruptions of the peat-accumulating process. The bottom (oldest) split was undercut and buried by levee silt and clay. The resulting shale parting thins away from the channel. Withdrawal of the channel allowed resumed coal accumulation. The cycle of peat accumulation / channel undercutting / burial / stabilization / peat accumulation was repeated five times before burial of the swamp beneath fluvial sandstone.

Fig. 9. Expanded view of Fig. 8, showing relationship of fine-grained sandstone and root zone to overlying #7 coal zone.

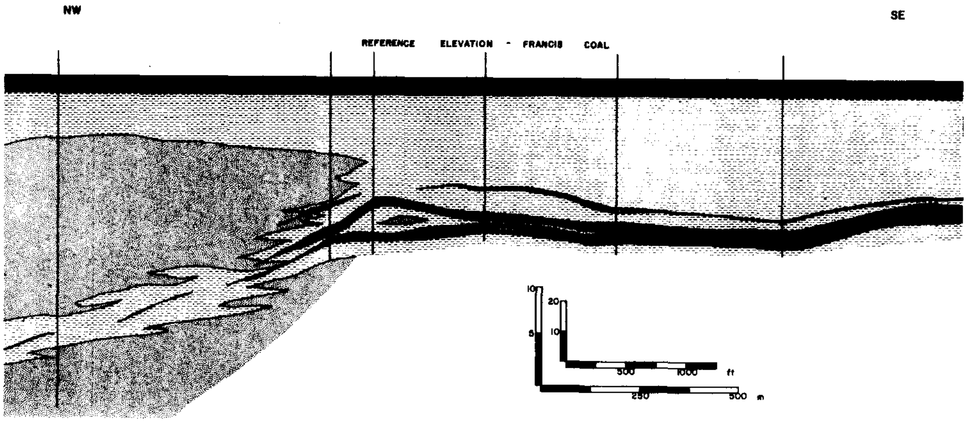

Fig. 10. Geologic cross-section perpendicular to paleochannel margin, illustrating the effect of undercutting on the coal seam. Horizontal dash = shale; diagonal dash = siltstone; stipple = sandstone; black = coal.

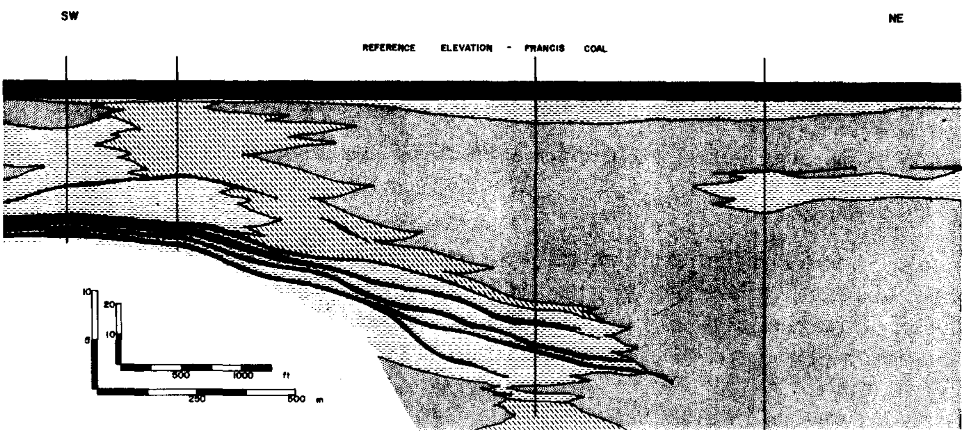

Fig. 11. Geologic cross-section perpendicular to paleochannel margin. Undercutting of swamp was more gradual in this area than in that of Fig. 10. Same symbols as in Fig. 10.

PEAT SWAMP BURIAL

The areas of thick Hazard #7 coal underlie shales 1 m to over 10 m thick (Figs. 2 and 4). Laterally, the thick shale sequences thin and grade into sandy shales (siltstones) and sandstones of probable floodplain and levee origin. Upright stumps have been preserved in place above the coal by the enclosing shale. These strata are attributed to the infilling of interdistributary bays.

Distributary channels dominated the post-peat-swamp environment. They drained the area into the major fluvial channel. These channels control the

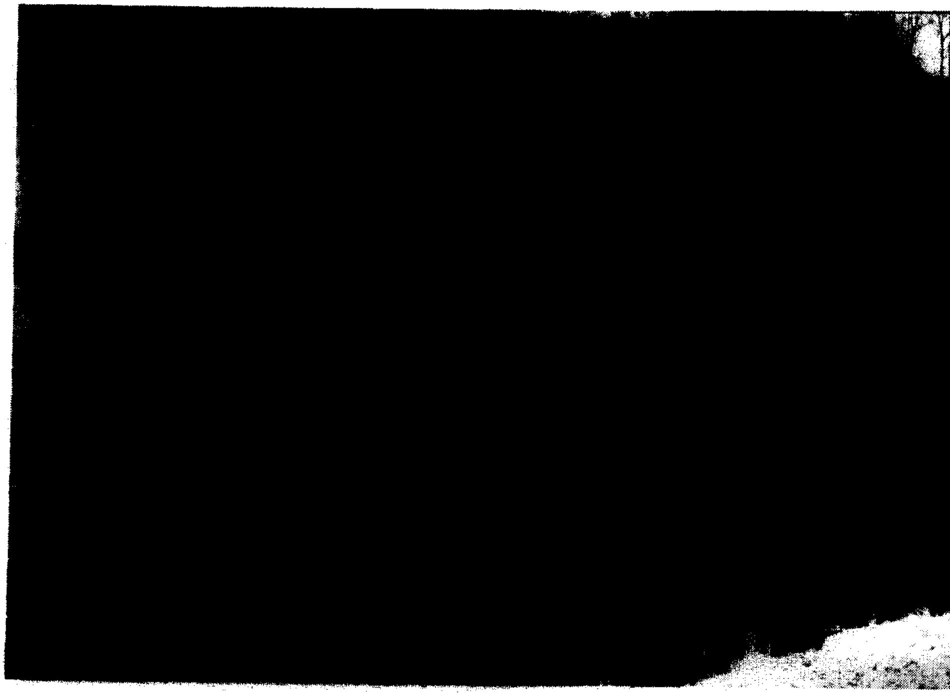

Fig. 12. Roadcut exposure of coal undercut by fluvial channel. Hazard (#5-A) coal, Knott County.

thickness and configuration of the #7 coal seam in areas where the two come into contact. The factors controlling the location and migration of distributary channels in modern deltas are described as complex by Coleman and Prior (1980, p. 40). Trends in their distribution can be recognized in Figs. 2 and 4.

Two types of interaction between a distributary channel and the peat are illustrated in Figs. 13 and 14. Regional thinning of the #7 seam has resulted from erosion of peat by channel scouring (Fig. 13). The channel-fill material consists of medium-grained, cross-bedded sandstone with associated lag gravels and siltstones. Fluvial conditions are indicated by the wedge-shaped shale partings which grade laterally into channel sandstone. The flow regime required to carry the pebbles 2 cm in diameter found above the coal could easily erode peat, and some peat has undoubtedly been scoured away.

Figure 14 illustrates the result of a narrow, migrating channel eroding through the peat. Relatively thick coal (1.2 to 1.8 m) has been removed and replaced by fluvial sandstone. The overlying shale or sandy shale is also locally replaced by sandstone. Sandstone partings are found within the coal seam.

The dimensions of the two channels differ greatly. They have different effects on the coal as well. The channel-fill sandstone in Fig. 13 is more

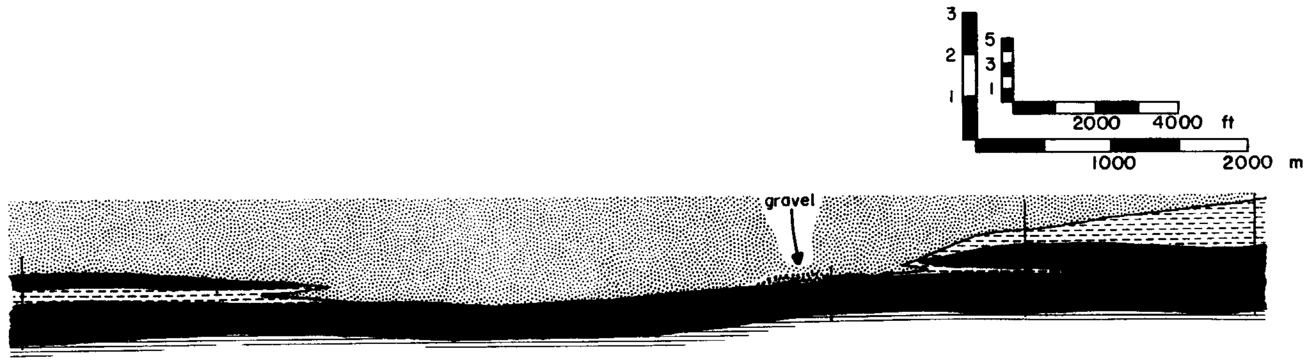

Fig. 13. Regional thinning of Hazard #7 coal due to channel scouring. Horizontal line = underclay; other symbols same as in Fig. 10.

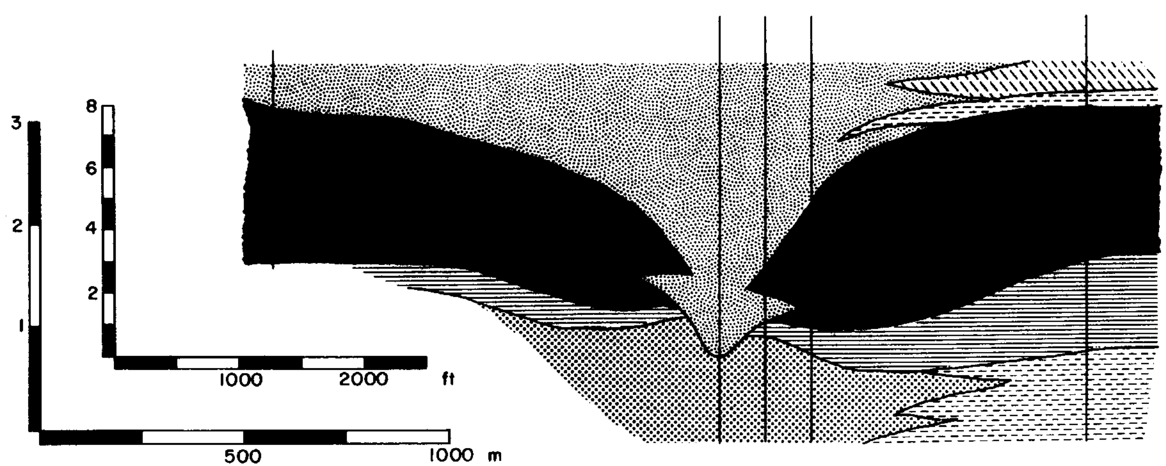

Fig. 14. Local replacement of Hazard #7 coal by channel-fill sandstone. Same symbols as in Fig. 13.

extensive laterally than that in Fig. 14. It does not replace the entire seam as the narrow channel does. It has either removed a significant amount of peat from the swamp, or inhibited peat accumulation, or both, to the extent that the #7 coal is appreciably thinner (0.6 to 1.2 m) in the vicinity of Fig. 13 than in that of Fig. 14.

The abrupt lateral transition from thick coal to sandstone distinguishes the local washout from the regional thinning due to channel scouring. Along an outcrop or mine cut, thick coal will thin, split, and disappear in a short distance. Similarly, shale cover will be replaced by sandstone. Partings, typically coarse-grained clastics, will appear and thicken rapidly along section. Conversely, the transition from thick coal to thin coal, and from shale cover to sandstone, is less pronounced in the vicinity of a large channel or channel system. However, the resulting thin coal is areally more extensive. Each feature terminates in the bordering sandstone (Figs. 2 and 4).

PALEOENVIRONMENT RECONSTRUCTION

The Hazard #7 coal probably accumulated in an upper delta plain environment (cf. Horne et al., 1978). Characteristics compatible with this model include:

(1) Thick coal bed laterally restricted by distributary sandstones.

(2) Narrow sandstone washouts.

(3) Crevasse-splay deposits.

(4) Overlying bay-fill shales, levee siltstones, and channel-fill sandstones and gravels.

Crevasse-splay and levee deposits provide the only evidence of drainage into the swamp during peat accumulation. Following burial, distributary channels, levees, and interdistributary bays developed. Each facies is recognized by its lithology: sandstone, thin shale/sandy shale, and thick shale, respectively (Fig. 4).

Areas of sandstone roof are interpreted as the drainage paths followed at the time of swamp burial. The thin shale/sandy shale facies was deposited on floodplains and as levees adjacent to distributary channels. Thick shale sequences accumulated in interdistributary bays. The entire area drained into the major channel throughout the coal accumulation and burial process. Each of the drainage features affects the configuration of the coal seam along its contact.

The major fluvial channel either deposited sediment (as point bars and levees) along the edge of the swamp, or undercut and eroded the swamp during lateral migration. The solid line in Fig. 15 illustrates the path of the major channel during the development of the peat swamp. The thick coal accumulations in the north-central and northwest portions of the swamp can be partially attributed to undisturbed accumulation of peat on point bars. Peat development was inhibited by encroachment of the channel and bay margins in the northeast and southwest sections of the swamp.

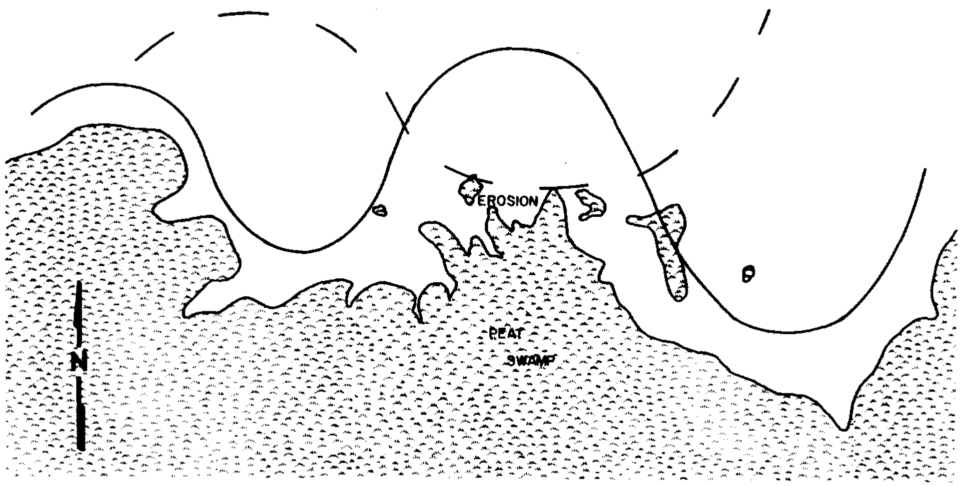

Fig. 15. Lateral migration of the fluvial channel during accumulation of the Hazard #7 coal. Solid line indicates channel course early in the development of the swamp. By the time of swamp burial, the channel (dashed line) was eroding peat from the swamp margin.

After the peat swamp was well established, the channel migrated to the position indicated by the dashed line in Fig. 15. The abandoned meander loops filled with sediment (fine sand, silt, then clay) and began to support vegetation (Figs. 6—9). Erosion of accumulating peat took place with minor disruption as the channel migrated laterally (Fig. 11). Gross displacement of semi-compacted peat occurred where the channel undercut the well-developed swamp (Fig. 10).

ECONOMIC SIGNIFICANCE

Trends in coal quantity and quality can be recognized from an examination of the number and geometry of bone and non-coal partings and the strata overlying the coal (Figs. 2—4). Thin, tabular, bone, clay, or shale partings developed either as fire-splays, or from terrigenous influx due to rapid subsidence. Areas of the Hazard #7 coal characterized by these partings tend to be thick and high in ash content. A decrease in total coal thickness is usually accompanied by increased heat value.

Wedge-shaped shale or sandstone partings in the #7 seam indicate a near source of sediment (flowing water) in the peat swamp. Abrupt, coarse-grained partings (Fig. 14) indicate local sedimentary features (narrow channel-fill or lenticular crevasse-splay deposits). Gradually thickening shale wedges are accompanied by decreasing coal thickness. The volume of levee sediment accumulated in a non-coal parting is a direct function of distance from the source of the sediment (Fig. 11). Neither of these types of parting can be correlated with significant changes in the quality of the #7 coal.

Relatively small quantities of coal are disturbed by washout and crevasse-splay deposits. The major channel terminates the #7 coal in the Hazard area.

The processes which deposited the strata overlying the #7 seam also affected the total coal thickness. Thick shales accumulated in an environment favorable to peat preservation, and thick #7 coal underlies areas of shale cover of more than 1 meter (Figs. 2 and 4). Sandstones were deposited from a flow regime capable of eroding peat, and regional thinning of the Hazard #7 has resulted from channel scouring (Fig. 13). These sedimentary features and their significance are summarized in Table II.

TABLE II

Sedimentary features indicative of changes in coal seam configuration

Feature	Origin	Effect on coal seam configuration
thin, tabular bone, clay, or shale partings	flooding of swamp or fire in swamp	possible increase in seam thickness; increase in ash content
coarse-grained, wedge-shaped partings	crevasse splay; distributary channel	lenticular wedges locally splitting and thinning coal seam; narrow bodies of channel sandstone (washouts, "faults")
fine-graned, wedge-shaped partings	outwash from a major source of sediment	continued thinning and splitting of coal seam, nearby displacement by sandstone
overlying sandstone	late-stage distributary channel	regional thinning of coal seam, eventual displacement by sandstone

There appears to be a strong correlation between point bars in the paleochannel and areas of thick Hazard #7 coal. Descriptions of the Lower Peach Orchard coal (a correlate of the Hazard #7) on the adjacent David quadrangle support this observation:

> Lower Peach Orchard coal bed tends to be badly split, thin, or absent in the southeast part of the quadrangle, better developed in northwest corner and eastern part of quadrangle (Outerbridge, 1968).

This description fits the channel sinuosity proposed in Fig. 16. The thickest Lower Peach Orchard (#7) coal in the David quadrangle would lie on a point bar in the paleochannel. Paleochannel geometry could be effectively applied to regional coal seam exploration.

CONCLUSION

The quantity and quality of the Hazard #7 coal are systematically related to the local paleoenvironment in which the coal accumulated, and hence to

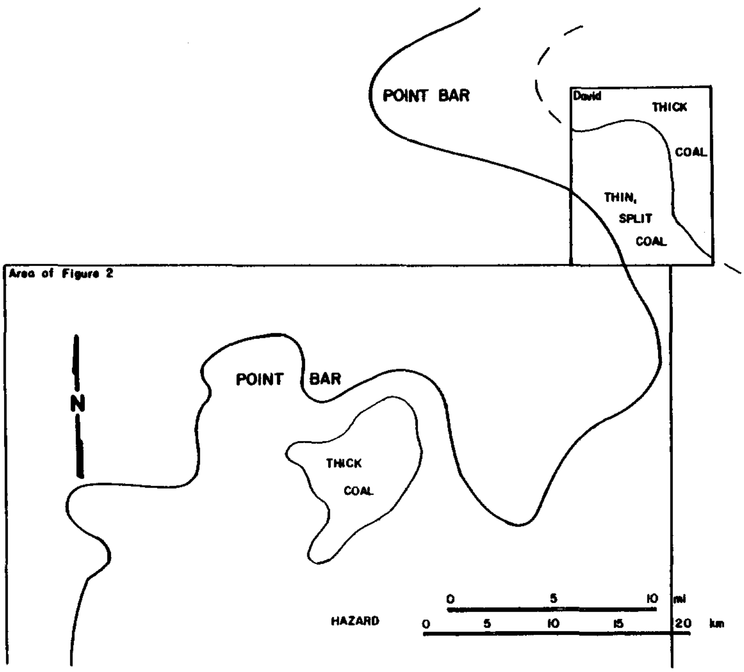

Fig. 16. Relationship of thick Hazard #7 coal to paleochannel point bars. Coal information on the David quadrangle from Outerbridge (1968).

parting and adjacent and overlying facies types. The technique described allows geologic data to be developed into a model of paleoenvironment conditions. This model can then be used to guide mine development and coal seam exploration.

ACKNOWLEDGEMENTS

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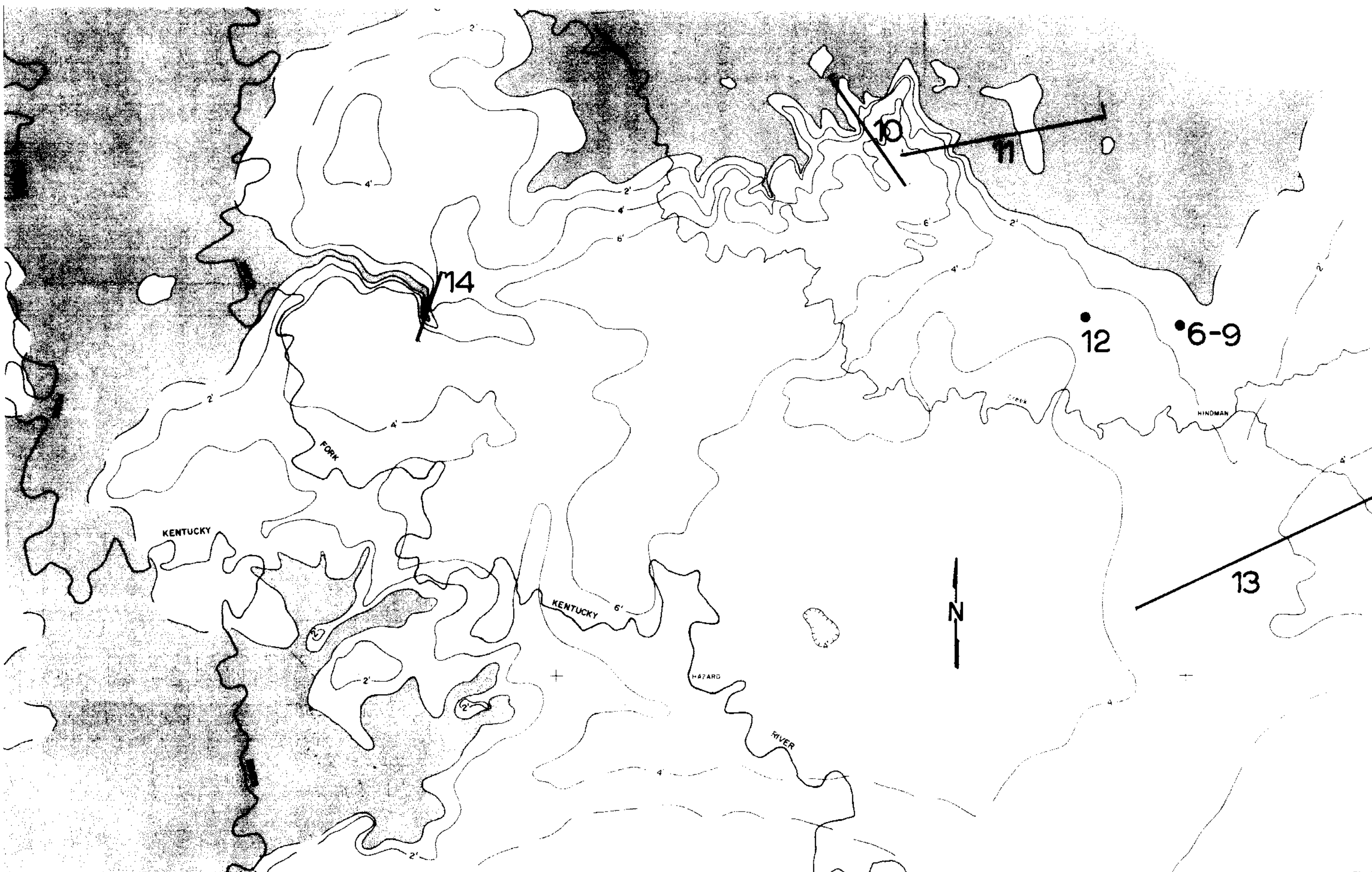
The author especially acknowledges the invaluable insights and observations which evolved from many discussions with Joel Davis, of Star Fire Coals, Inc.

APPENDIX — Location of figures.



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