AN ANOMALOUS MASS-FLOW DEPOSIT IN THE LEE FORMATION (PENNSYLVANIAN), EASTERN KENTUCKY COAL FIELD

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ABSTRACT

Magnetic and gravity anomalies along the Rockcastle River in Laurel County, Kentucky, are interpreted to represent a fault. East of this fault, the Lee Formation contains a complex mosaic of matrix-supported, shale-clast conglomerates and fine-grained sandstones informally called the Poison Honey beds. This type of lithology has not been previously reported in the coal measures of the Appalachian Basin.

Matrix-supported conglomerates were deposited by mass flows. The complex mosaic of conglomerate and sandstone lithotypes resulted from multiple surges of mass flows in a small tributary drainage that drained an upthrown fault block. Fault control of the Poison Honey beds is suggested by (1) the rarity of mass flows in this part of the section and the location of the flows along a fault, (2) the abundant brittle shale clasts indicating short transport distances and the proximity of Breathitt Formation shales west of the fault, (3) a siderite-pebble source west of the fault, and (4) the reversal in sedimentation direction from southwest in the underlying sandstone to east and toward the direction of downthrow in the Poison Honey beds. Periodic flooding in a tributary may also have instigated flows.

INTRODUCTION

A sequence of unique rocks in the coal measures of the Appalachian Basin is exposed along outcrops on Kentucky Highway 80 in the Billows Quadrangle, Laurel County, Kentucky (Figure 1). The unit is informally termed the “Poison Honey beds.” The Poison Honey beds pose several sigificant problems to interpretations of local depositional history. The unit (1) is texturally different from other sandstones described in this part of the basin, (2) exhibits paleocurrents opposite those in surrounding units, and (3) may indicate Pennsylvanian fault movement.

Geologic Setting

The Poison Honey beds are located on the western outcrop margin of Pennsylvanian rocks in the Eastern Kentucky Coal Field (Figure 1). Several hypotheses have been proposed for the margin of the Lee Formation in this area. Along Highway 80, 1.4 kilometers west of the Rockcastle River, shales and coals mapped as the Lower Tongue of the Breathitt Formation (McDowell and others, 1981) are apparently juxtaposed against quartzose sandstones of the Lee Formation. The sandstones are 30 meters thick in outcrops 1.2 kilometers west of the river and are absent 1.5 kilometers west of the river (Greb and Chesnut, 1989). The juxtaposition of lithofacies has been interpreted as a possible fault (Greb and Chesnut, 1989), an abrupt facies transition along a delta front (Amig, 1988), and a fluvial channel/sand-belt margin similar to other Lee sandstones (Rice and Weir, 1984; Chesnut, 1988). The limit of the Rockcastle Sandstone Member of the Lee Formation as mapped by Hatch (1963) suggests a fluvial, sand-belt margin (Figure 1).

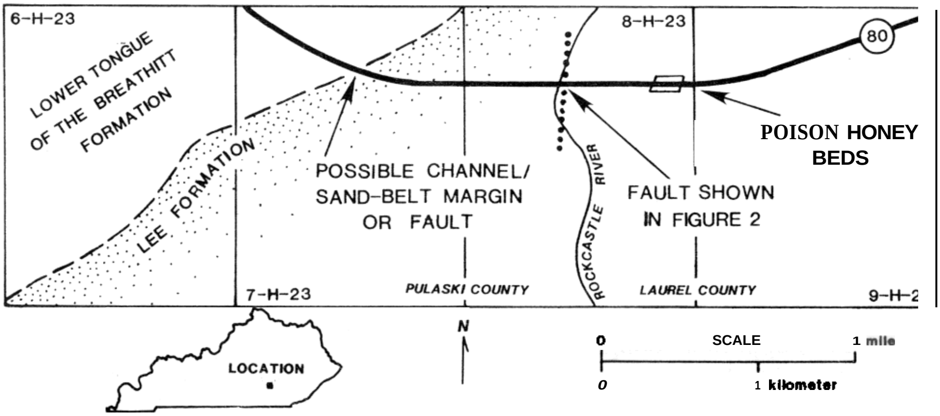

Figure 1. Planview map of study area showing outcrop locality, margin of the Rockcastle Sandstone Member of the Lee Formation, and a fault at the Rockcastle River (after Hatch, 1963, with presently accepted nomenclature from McDowell and others, 1981).

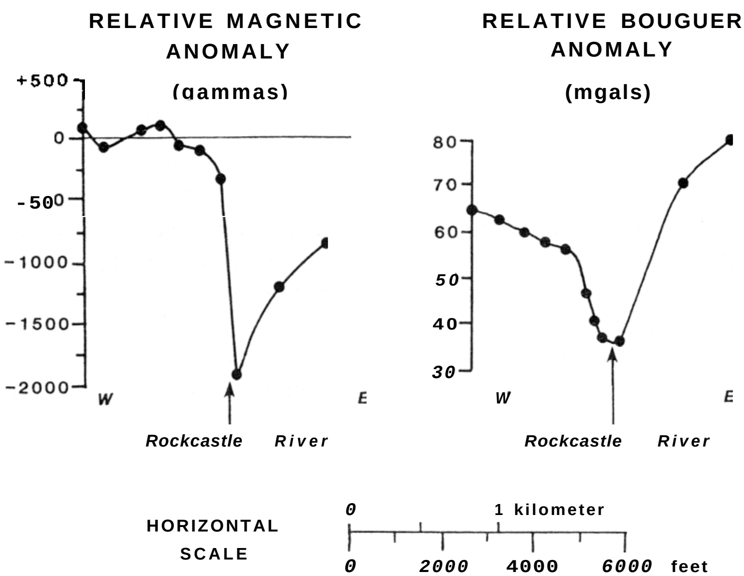

Figure 2. Gravity and magnetic lines along Kentucky Route 80 to delineate a fault at the Rockcastle River.

East of the Lee Formation margin, along the Rockcastle River, magnetic and gravity anomalies suggest the presence of a fault on the east side of the Rockcastle River valley (Figures 1-2). Because geophysical surveys were only made along Highway 80 in the vicinity of the Rockcastle River, the trend of this previously unknown fault is not known, although the straightness of the river in this area may suggest a north-south orientation (Figure 1). Offset along the fault is minimal (0 to 5 meters as determined from the stratigraphy on both sides of the river).

The Poison Honey beds outcrop on Highway 80 just east of the fault on the Rockcastle River (Figure 1). The beds are only exposed in the roadcuts on Highway 80, and do not continue beyond the limits of the hillside bounding the Rockcastle River and Pine Creek (Figure 1). Stratigraphically, they sharply overlie an informal member of the Lee Sandstone Formation called the Pine Creek sandstone (Greb and Chesnut, 1989) and are truncated by unnamed channel-fill deposits of the Lee Sandstone Formation (Figure 3).

LITHOFACIES DESCRIPTION

The Poison Honey beds consist of a complex mosaic of matrix-supported, shale-clast conglomerates and fine-grained sandstones. Analysis of the vertical and lateral distribution of lithotypes indicates that the Poison Honey beds consist of a lower and upper conglomerate-dominated unit separated by zones of fine-grained sandstones (Figures 3-4).

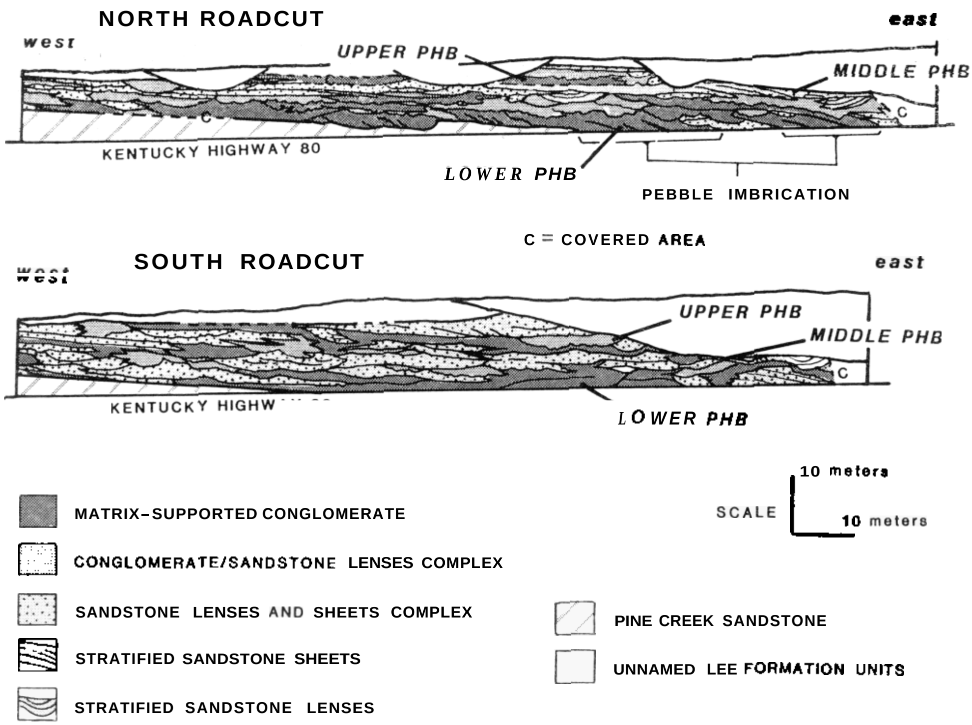

Figure 3. Roadcut sections along Kentucky Highway 80 illustrating complex mosaic of lithotypes in the Poison Honey beds.

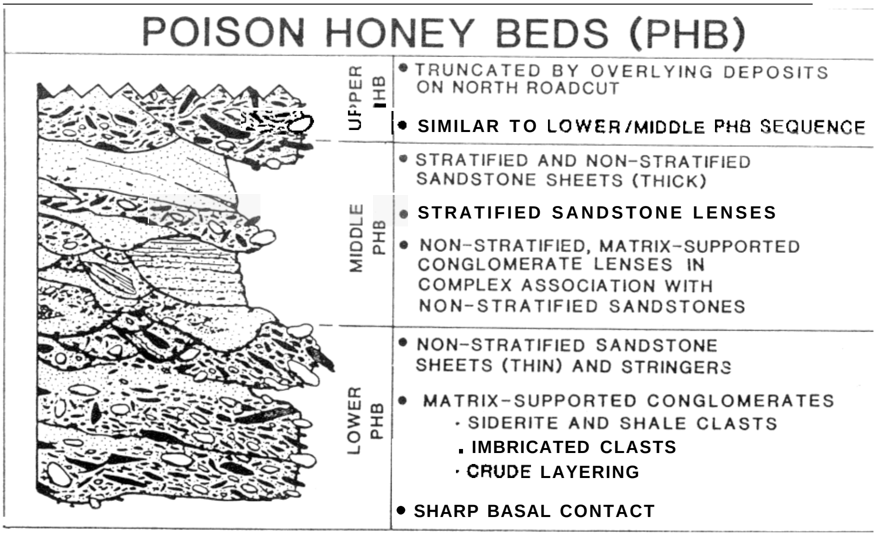

Figure 4. Generalized geologic section.

Matrix-Supported Conglomerates

The lower and upper thirds of the Poison Honey beds are dominated by matrix-supported conglomerates. The conglomerates consist of detrital shale clasts (as chips and megaclasts) and detrital siderite clasts (as cobbles, pebbles, and boulders) supported by a matrix of fine-grained, moderately sorted, quartzose sandstone (Figure 5a). The basal contact of the conglomerates with the underlying Pine Creek sandstone is sharp. Pebble injection along this contact is common, Individual conglomerate layers may have sharp or gradational contacts with surrounding lithotypes, and are often capped by thin sheets or stringers of relatively clast-poor (<l0 percent), fine-grained sandstones. Thickness of individual layers ranges between 0.04 and 1 meter. Grading trends are not evident within any of the matrix-supported conglomerate layers.

Conglomerates in the lower third of the Poison Honey beds exhibit a preferred clast imbrication (Figure 5b) that creates the appearance of low-angle accretionary layering (Figures 3-4). Pebble-fabric measurements (Figure 6) in the accretionary layered conglomerates (eastern end of Lower PHB, Figure 4) indicate a moderately well-developed imbrication (a-axis) of siderite pebbles to the east. Nonimbricated conglomerates in other parts of the unit exhibit a subhorizontal fabric (Figure 6).

The accretionary layered conglomerates of the lower third of the Poison Honey beds are truncated by lense-form scours, similar in appearance to shallow troughs (Figures 3-4). Several scours from 0.3 to 4.5 meters in width and 0.1 to 0.7 meter in thickness occur within the lower conglomerates. The minor scour fill may contain clast-rich (10 to 50 percent) matrix-supported conglomerates or relatively clast-poor (<l0 percent) sandstones (Figure 5c).

Fine-Grained Sandstones

The conglomerates of the Poison Honey beds may be truncated or grade into clast-poor (>l0 percent), moderately sorted, fine-grained sandstone lithotypes that

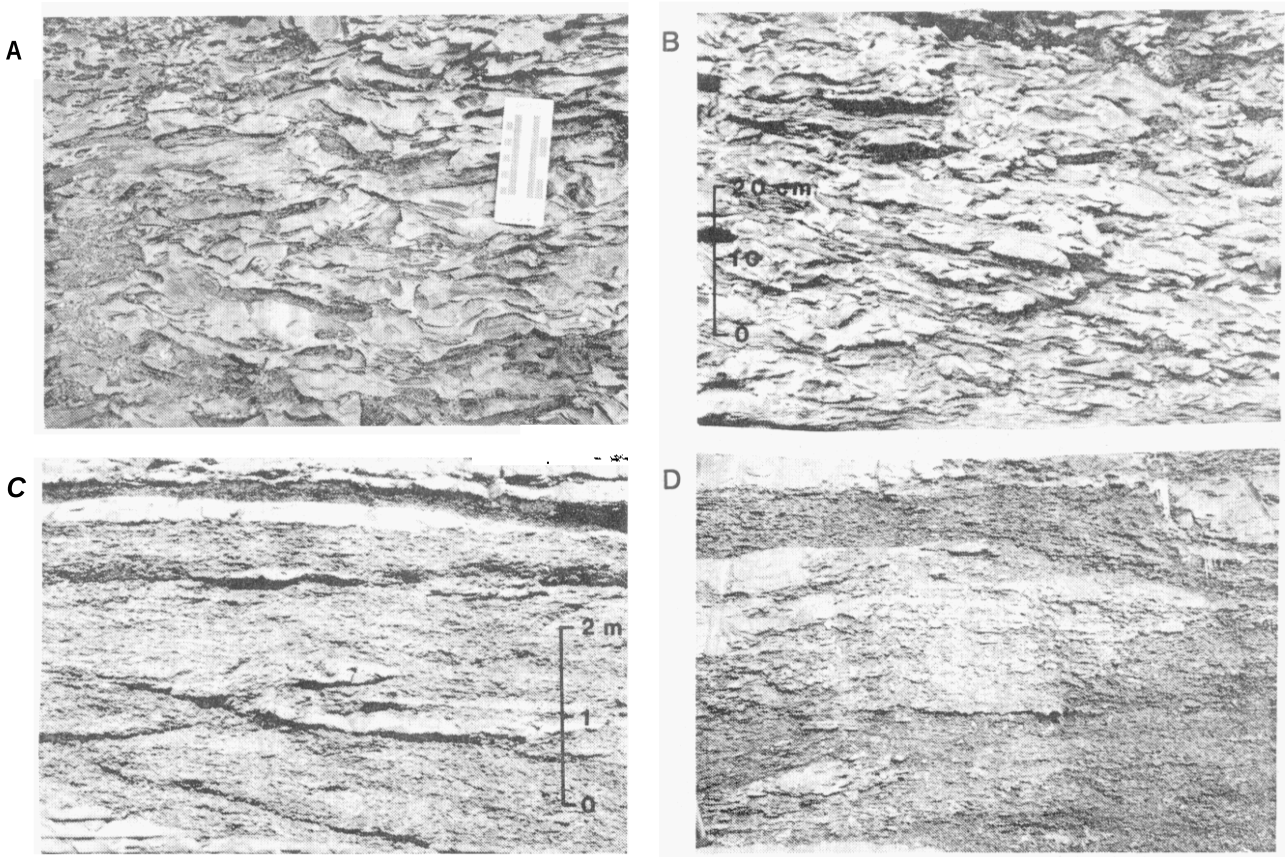

Figure 5. Photographs of conglomerates: (a) Matrix-supported shale and siderite clasts. (b) Imbricated clasts create accretionary layering. (c) Crosscutting troughs or lenses. (d) Complex interfingering of conglomerates and fine-grained sandstones (hammer for scale in bottom left corner).

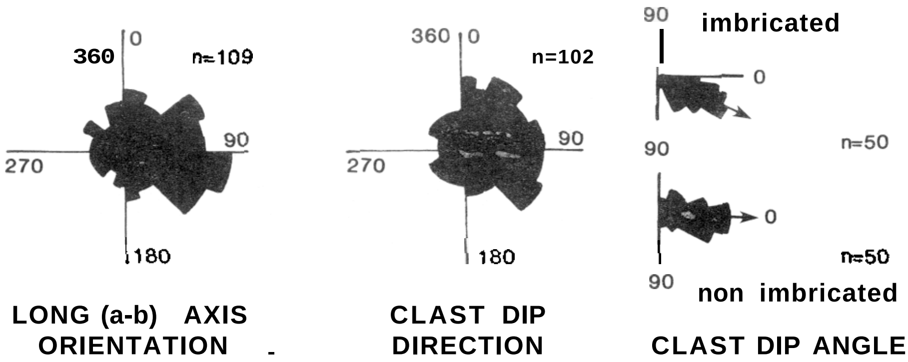

Figure 6. Clast orientation in conglomerates.

exhibit both lenticular and sheet-form geometries (Figures 3-4). The trough or lensoid layering exhibited in the conglomerates complexly interfingers with the fine-grained sandstones (Figure 5d). Sandstones also occur as distinct (conglomerate-free) lenses ranging in length from 1 to 6 meters. Sandstone lenses are highly discontinuous and cannot be correlated between outcrops (a distance of only 10 meters). Many appear to grade to the west into sheet-form sandstones.

Near the eastern end of the roadcut (Figure 3) a few of the sandstone lenses are distinctly stratified. These lenses consist of a sequence of flat-bedded sandstone grading upward into horizontally laminated sandstone (laminations in the sandstone are formed from chips of detrital shale rather than being distinct clay layers or bedding surfaces) and laminated shale (Figure 7a). Abraded fragments of stratified sandstone similar to the bedding in these lenses are also preserved as rip-up clasts (from 0.01 to 1.10 meters) in the conglomeratic portions of the Poison Honey beds (Figures 7b-d).

Sandstones with sheet-form geometries occur as thin stringers in the lower and upper third of the Poison Honey beds, and as thick persistent layers in the middle Poison Honey beds (Figures 3-4). Sandstone sheets range in thickness from 0.1 to 0.6 meter. Thin sheet sandstones (< 0.3 meter) in the lower and upper thirds of the Poison Honey beds are not stratified, and often separate layers of conglomerates. The lower contacts of these thin sheets are usually gradational with underlying lithotypes (Figures 7c-d).

The thicker sheet sandstones (> 0.3 meters) in the middle part of the Poison Honey beds (Figure 3) may exhibit small-scale planar crossbedding with eastward paleocurrents. These sheets exhibit both gradational and sharp contacts with surrounding lithotypes. Many exhibit soft-sediment deformation and minor offset along slip planes. The overall distribution of the thick sheet sandstones suggests an eastern stepping of successive sheets (Figure 3).

INTERPRETATION

Depositional Environment

Matrix-supported, conglomeratic sandstones are commonly inferred to represent mass-flow deposits (Harms and others, 1975; Middleton and Southard, 1978). The classification of mass-flow deposits is based on the inferred rheology (fluid versus plastic behavior) and the clast-support mechanisms of the flow

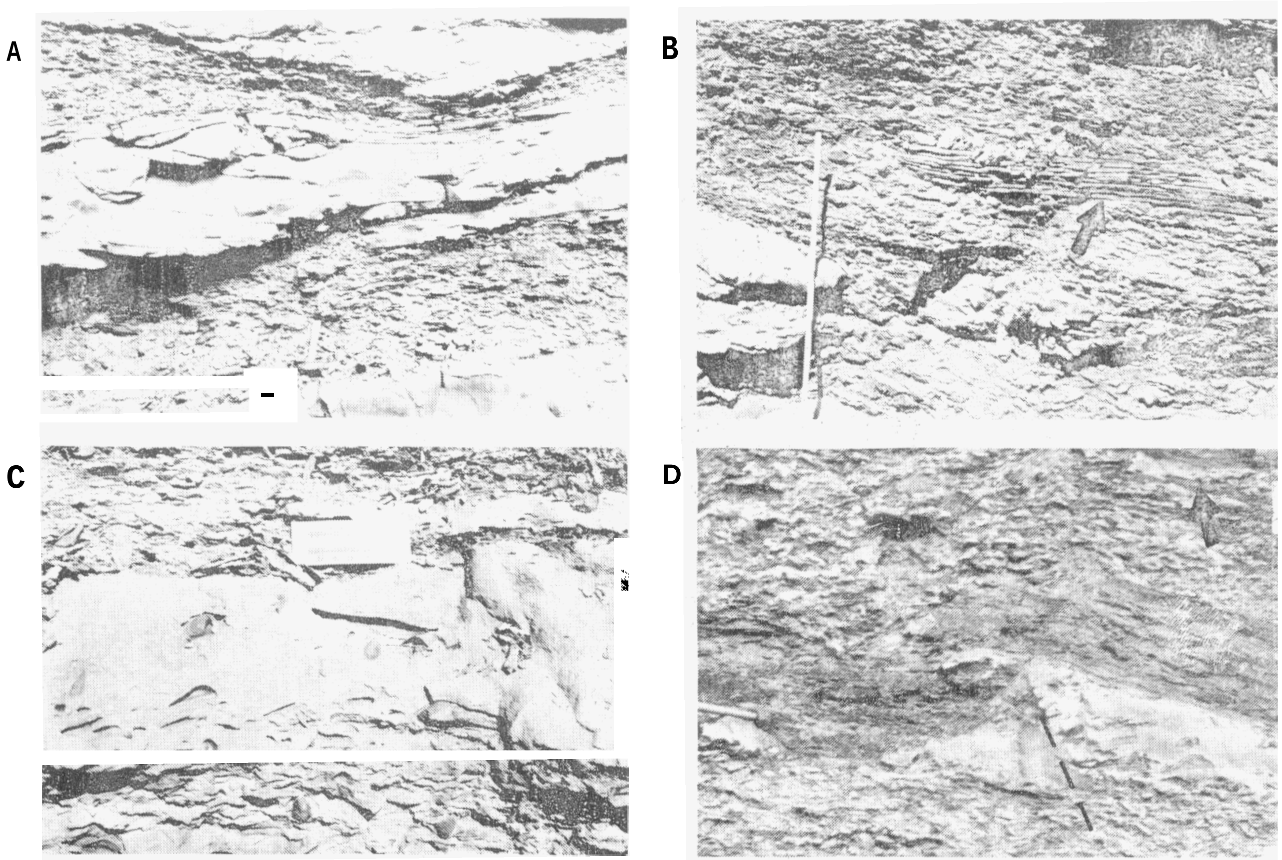

Figure 7. Photographs of fine-grained sandstones: (a) stratified sandstone lens with thinning upward bedding (hammer for scale). (b) Transported clast of stratified sandstone (arrow) with bedding similar to the bedding at the top of Figure 6a. (c) Thin, sheet sandstone capping conglomerate layer. (d) Sheet sandstone capping conglomerate. Note minor faulting (dashed line), broken and transported stratified clast (arrow), and the differences in clast orientation above (nonimbricated conglomerate in upper Poison Honey beds) and below (imbricated conglomerates in lower Poison Honey beds) the sandstone sheet.

during transport (Lowe, 1982; Postma, 1986).

Most mass flows pass through a continuum of rheologic conditions and clast-support mechanisms that change as physical conditions change during transport (Middleton and Southard, 1978; Lowe, 1982; Lash, 1984). Thus, a flow might be initiated as a slump that becomes liquefied or remolded into a grain flow, liquefied sediment flow, or debris flow before it is deposited. The final form may mask the rheologic path taken by any one flow surge (Middleton and Southard, 1978; Lowe, 1982; Postma, 1986).

Of the many types of classified mass flows, the Poison Honey beds most closely resemble the subaerial mass-flow models of Nemec and Steele (1984). Composite conglomeratic units, with discontinuous and complexly interbedded sandy zones, are common in subaerial mass flows (Nemec and Steele, 1984; Schultz, 1984; Pierson and Costa, 1987). Composite units result from changes in flow rheology during individual surges, and from the stacking of multiple surges with different flow behavior. The Poison Honey beds are interpreted as composite mass flows (Figure 8).

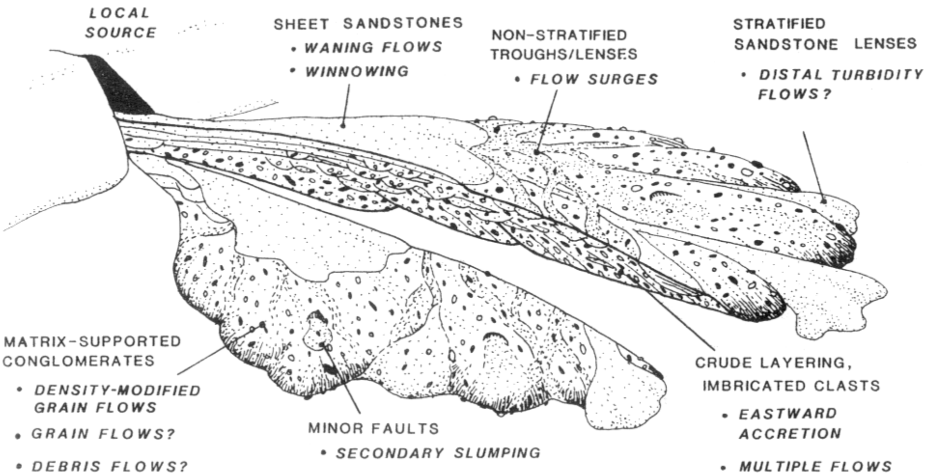

Figure 8. Interpretive model of Poison Honey beds mass flows. The cut-away view represents the lower and middle portions of the north outcrop.

Matrix-Supported Conglomerates: The crude layering, pebble imbrication, and complex associations with surrounding facies exhibited by the matrix-supported conglomerates suggest mass flows with high-concentration fluid conditions and limited mobility of clasts rather than plug flow with no mixing during transport (Enos, 1977; Middleton and Southard, 1978; Lowe, 1982; Postma, 1986). Also, the lack of grading, and imbrication of detrital clasts in the accretionary layered conglomerates suggest that the dominant clast-support mechanism was laminar shear during the final stages of flow (Fisher, 1971; Enos, 1977; Lewis and others, 1980; Nemec and Steel, 1984; Postma and Roep, 1985).

The Postma (1986) classification of mass flows describes several types of laminar, high-concentration flows. The fine-grained sandstone matrix, the orientation of clasts parallel to flow, the accretionary layering, and the pebble-injection structures exhibited in the conglomerates of the Poison Honey beds are similar to laminar, high-concentration mass flows called grain-flows. However, the conglomerate layers of the Poison Honey beds do not exhibit the inverse grading common in grain flows (Lowe, 1976; Middleton and Southard, 1978; Nemec and Steele, 1984; Postma, 1986). Mass flows that share similarities with grain flows but exhibit no grading have been interpreted as density-modified grain flows (Lowe, 1982; Lash, 1984; Todd, 1989). Because of the wide diversity in clast concentration and orientation in the conglomeratic lithotypes, individual layers of the Poison Honey beds were probably deposited by the range of high-concentration mass flows (Figure 8), including density-modified grain flows, grain flows, and true debris flows (Lowe, 1976; Lash, 1984; Todd, 1989). Modern mass flows involving some combination of density-modified grain flows, grain flows, and debris flows have been discussed by Schultz Pierson and Costa (1987), and Todd (1989).

Fine-Grained Sandstones: The fine-grained, lensoid sandstones of the Poison Honey beds are problematic because they interfinger and truncate matrix-supported conglomerates and because they occur as (1) lenses that grade into thin sheets and stringers, (2) distinct, stratified lenses, and (3) persistant, crossbedded sheets (Figures 4, 5c-d). Possible depositional interpretations include (1) channeling and sedimentation by fluvial or brackish-bay processes between flow surges, (2) gravity winnowing, (3) high-concentration turbidity currents, and (4) waning flow conditions.

Reworking of the conglomerates into clast-poor sandstones by fluvial or brackish-bay processes is an attractive interpretation because underlying and possibly lateral sandstones are interpreted as fluvial sandstones, and overlying and possibly lateral shales are characteristic of bay-fill and tidal-channel environments (Greb and Chesnut, 1989). In near-shore environments there would be many opportunities for small-scale channeling and reworking of mass-flow tops between flow surges. However, if the lenses of Poison Honey sandstones (and interfingering conglomerates) are actually channels, the scale of channeling and the crude layering/stratification of these lenses is significantly different than lateral, underlying, and overlying facies (Greb and Chesnut, 1989).

If the sandstone lithotypes of the Poison Honey beds are not similar to surrounding facies, other mechanisms must be analyzed. Nonbedded to crudely stratified lenses of sandstone in mass flows that grade into sheet sandstones, similar to those in the Poison Honey beds, may be caused by post-movement gravity winnowing of mass-flow tops (Postma and Roep, 1985). Winnowing of flow tops might explain the common gradational contacts between the thin sandstone sheets or stringers and underlying conglomerates.

Although gravity winnowing may explain the nonstratified sandstone lenses that can be traced laterally into sandstone sheets or the thin, isolated sandstone stringers that are gradational with underlying conglomerates, other mechanisms need to be investigated for the stratified sandstone lithotypes. Stratified sandstone lenses occur at the eastern end of the roadcut (Figures 3-5a). The sequence of flat bedding, soft-sediment deformation, and upward thinning into laminated shale is similar to partial Bouma sequences (Middleton and Hampton, 1973; Walker, 1975; Nemec and Steele, 1984) commonly deposited in high- concentration turbulent flows (Lowe, 1982; Nemec and Steele, 1984). Lowe (1982) indicated that high-density turbidity currents could be produced from density-modified grain flows if the flows became turbulent. High-concentration turbulent flows that bypass the more viscous portions of mass flows (Lowe, 1982; Postma and Roep, 1985) or result from turbulence created on top of flows (Lash, 1984) have been interpreted in many modem mass-flow deposits and may have occurred in the Poison Honey beds (Figure 8).

Sheet-sandstone lithotypes of the Poison Honey beds that have minor crossbedding also occur (middle PHB on Figure 3), and were probably not deposited by gravity winnowing processes. These thick, sheet sandstones divide the upper and lower conglomerate-dominated parts of the unit (Figures 3, 4, 9). Sheet sandstones that contain small-scale crossbedding in mass-flow deposits can result from sheet floods from lateral or intermittent fluvial sources (Wells, 1984; Todd, 1989). If the thicker, persistant sheet sandstones of the middle Poison Honey beds were the result of concomitant fluvial processes, a westward accretion would be expected, since surrounding fluvial sandstone facies exhibit southwestern paleoflow (Greb and Chesnut, 1989). However, where current bedding occurs in these sandstones, paleocurrent measurements indicate an eastward flow. Also, the eastward stepping of several sheet sandstones in the lower two-thirds of the Poison Honey beds suggests an overall eastward accretion (Figure 9).

Rather than flooding from fluvial processes, the thick sheet sandstones in the middle Poison Honey beds may have been deposited by waning flows on subaerial mass flows similar to the sandstone sheets described by Nemec and Steel (1984). The positioning of the thick sheet sandstones between conglomeratic portions of the Poison Honey beds (Figures 3, 4, 9) in repetitive layers supports a waning-flow hypothesis (Figure 8). Waning flow could cause small-scale crossbedding in the direction of movement. Also, waning flow on mass-flow tops could create turbulence and local turbidity currents, and would not preclude gravity winnowing of mass-flow-surge and -intersurge events

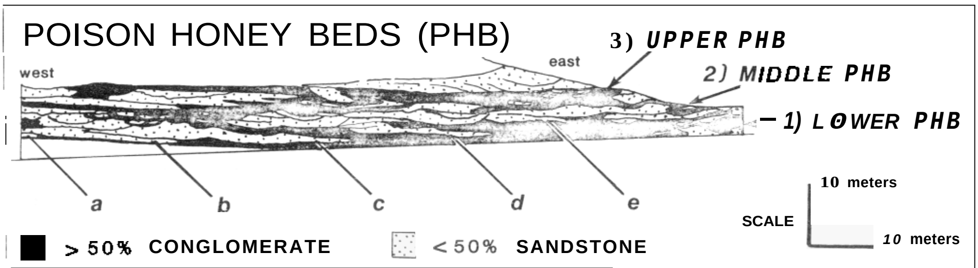

Figure 9. Cross section of south roadcut. Note two zones (upper and lower) of conglomerate-dominated units that delineate two major mass-flow sequences. Also note sandstone-dominated sheets (a, b, c, d, e) that delineate smaller accretionary (probably intersurge) events within the major flow sequences.

Multiple Flows

The vertical repetition of sandstone and matrix-supported conglomerate lithotypes in the Poison Honey beds suggests repeated depositional events. There were at least two large subaerial mass flows with interflow periods of waning flow and reworking recorded by the thick sheet sandstones that divide the Poison Honey beds into upper and lower conglomeratic units (Figure 9). Within the upper and lower flows were also several accretionary (possibly intersurge) winnowing or waning-flow events of smaller scale recorded by the accretionary layering in the lower Conglomerate and the repeated sequence of matrix-supported conglomerate layers overlain by thin sandstone stringers (Figure 9). Each of these events required a mechanism to initiate flow.

Two mechanisms are discussed for the formation of the Poison Honey beds: fault control and climate control. Preservation of brittle shale clasts in the Poison Honey beds indicates a short transport distance. The most plausible local source for the abraded shale and siderite clasts of the Poison Honey beds is the Lower Tongue of the Breathitt Formation, which is juxtaposed against Lee Formation sandstones 1.3 kilometers west of the Rockcastle River Fault (Figure 1). The sharp juxtaposition of lithofacies may be another fault, or it may be a sand-belt margin. Geophysical evidence does not extend far enough west of the Rockcastle River to include the Lee sandstone margin in this area. Regardless, the shales west of the margin are still the most plausible source for the detrtial clasts of the Poison Honey beds. The location of a source horizon to the west and inferred transport of the Poison Honey beds to the east are significant, since underlying, lateral, and overlying facies exhibit southwestern paleocurrents (Greb and Chesnut, 1989).

Breathitt shales and quartz sandstones from the Lee Formation are suggested to have been mixed prior to mass flows because of the high concentration of shale and siderite clasts in the Poison Honey beds (unknown in any other Lee sandstones in this area), and because thorough mixing would be inhibited in the mass flows. One method of mixing these horizons would be by accumulating detritus in a tributary system west of the Rockcastle River Fault. Detritus may have accumulated along a scarp (either fault-bound or channel margin) at the margin of the Lee sandstones and been transported east in a small tributary drainage. The Poison Honey beds are not widespread and therefore must have been locally confined.

Potter (1957) noted locally disturbed shale-pebble breccias similar to the Poison Honey beds in the Illinois Basin along the flank of an anticline in the McCormick Fault Zone. Downslope thickening and inferred paleocurrents suggest that the deposit was triggered by movement along the structure. The Poison Honey beds may also be fault controlled, as suggested by (1) the rarity of these shale-pebble breccia and conglomerate facies in the Carboniferous of the Appalachian Basin (and in the Illinois Basin) coupled with the coincidence of the Poison Honey beds to a fault, (2) 'the reversal in Poison Honey beds' paleoflow (with respect to surrounding units) corresponding to the direction of downthrow on the fault, and (3) the structural control of this type of facies in other areas.

But each of the flows need not have been triggered by a seismic event. Individual flow surges in the Poison Honey beds could also have been triggered by periodic floods washing debris out of the tributary channel. In the modern Monument Creek flows (Webb and others, 1988), subaerial debris flows are washed into a river during seasonal tributary flooding. Subaerial debris flows afford analogs that allow for the relatively rapid accumulation of multiple flows, variability within individual flows, and climatic triggering mechanisms (seasonal floods in ephemeral streams) rather than multiple movements along a fault (Nemec and Steele, 1984; Schultz, 1984; Pierson and Costa, 1987; Webb and others, 1988).

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