32nd Annual

Kentucky Professional Engineers In Mining Seminar

Sponsored by
UK Department of Mining Engineering
KSPE/Professional Engineers in Mining
Co-Sponsor
Kentucky Coal Association

Friday, September 6, 2019
Clarion Hotel Conference Center North—Lexington, Kentucky

Understanding Geologic and Mining Conditions for Mine Management Decisions: A Case Study

Prepared by:
Kevin Andrews - Marshall Miller & Associates
Scott Nelson - Marshall Miller & Associates
Terry Hamrick – United Coal Company, LLC

Outline

- Introduction
- Case Study: A Tale of Two Mines
  - The Story
  - Geological Factors and Ground Control Measures
    - South Area
    - Transition Area
    - North Area
  - Incised Valley Fill Model
  - Reserve and Resource Before and After
  - Conclusions

Introduction

Geologic Hazard Mapping (or Conditions Mapping)

- Uses drilling, core logging, core photography, laboratory testing, underground observations/testing, stress modeling, geophysical surveys, etc.
- Predicts future mining conditions
- Links geologic interpretation with mining engineering
- Often results in optimization and enhanced mine operation
- **“Road map for mining”**

Introduction (continued)

> Numerous case studies

> Can make mining possible where it previously was not possible

> Technology and Communication/Presentation Advancements

- **Coal Mine Roof Rating (CMRR)** - standard means for geologists and engineers to communicate quantitatively with regard to mine roof conditions
- **Stability Mapping System (SMS)** - efficient means for analyzing numerous factors affecting coal mine stability
- geostatistical modeling, numerical modeling of stress, etc.

Introduction (continued)

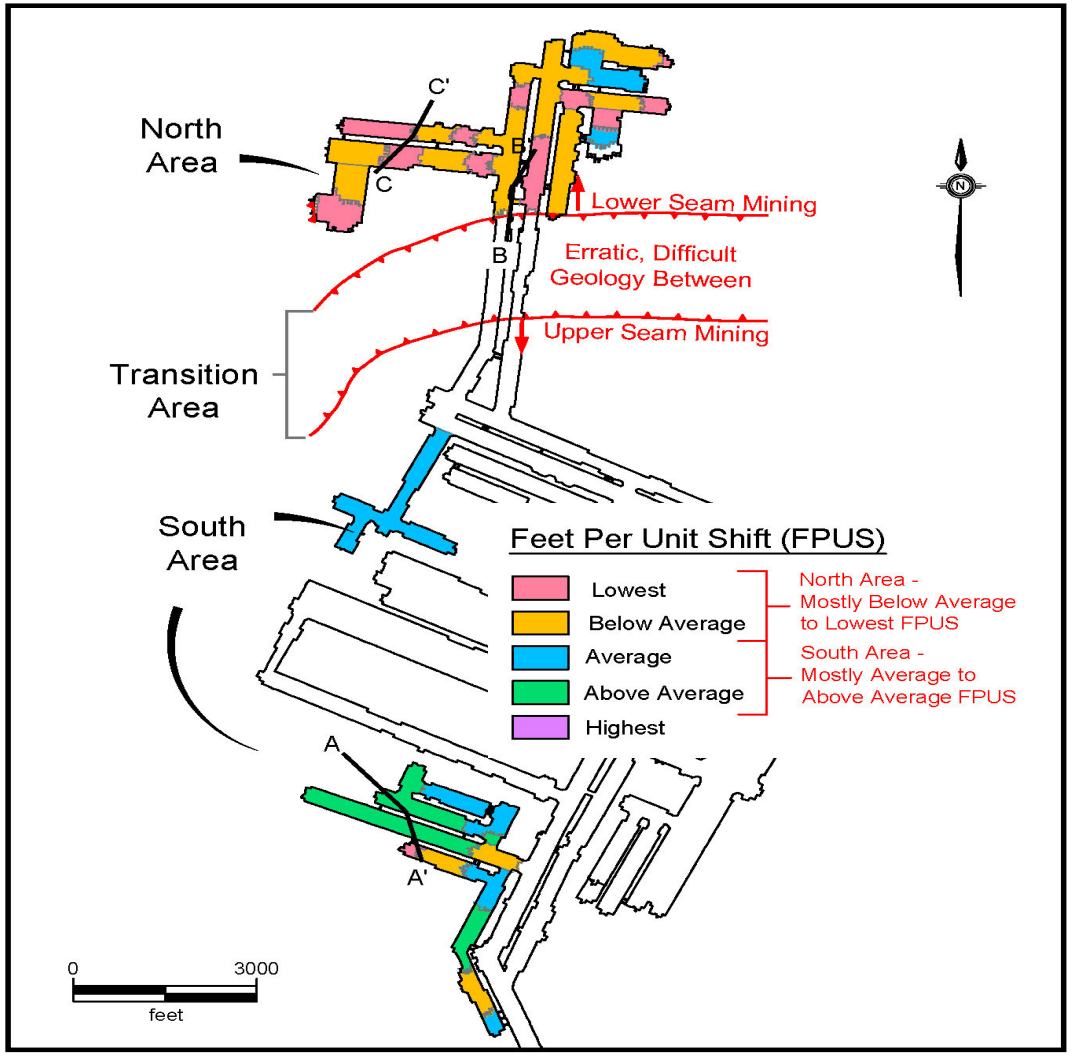
- Ability to integrate conditions mapping into the mine planning process is often essential for success
- Pro-active vs. Reactive
- Budget and time limitations restrict availability of geotechnical data and time to look at it
- ***<u>Collect when you can and use it!</u>***

Case Study – The Story

- **South Area**:
  - geologic conditions and feet per unit shift (FPUS) advance rates were typically "average" to "above average" while mining in the Upper Seam
- **Transition Area**:
  - erratic geology encountered as mining moved northward
  - abrupt elevation and thickness changes
  - required the mains to transition back and forth from the Upper Seam to new Lower Seam
  - Upper Seam disappeared
- **North Area**:
  - mining continued northward into the Lower Seam
  - Lower Seam of the North Area had quite favorable coal quality and CTPFA
  - geological conditions were difficult
  - FPUS rates were typically in the "below average" to "lowest range"

- **Conditions in the North Area ultimately caused the mine to stop production.**

Overview Map with Comparison of Feet Per Unit Shift (FPUS) for South vs. North Area

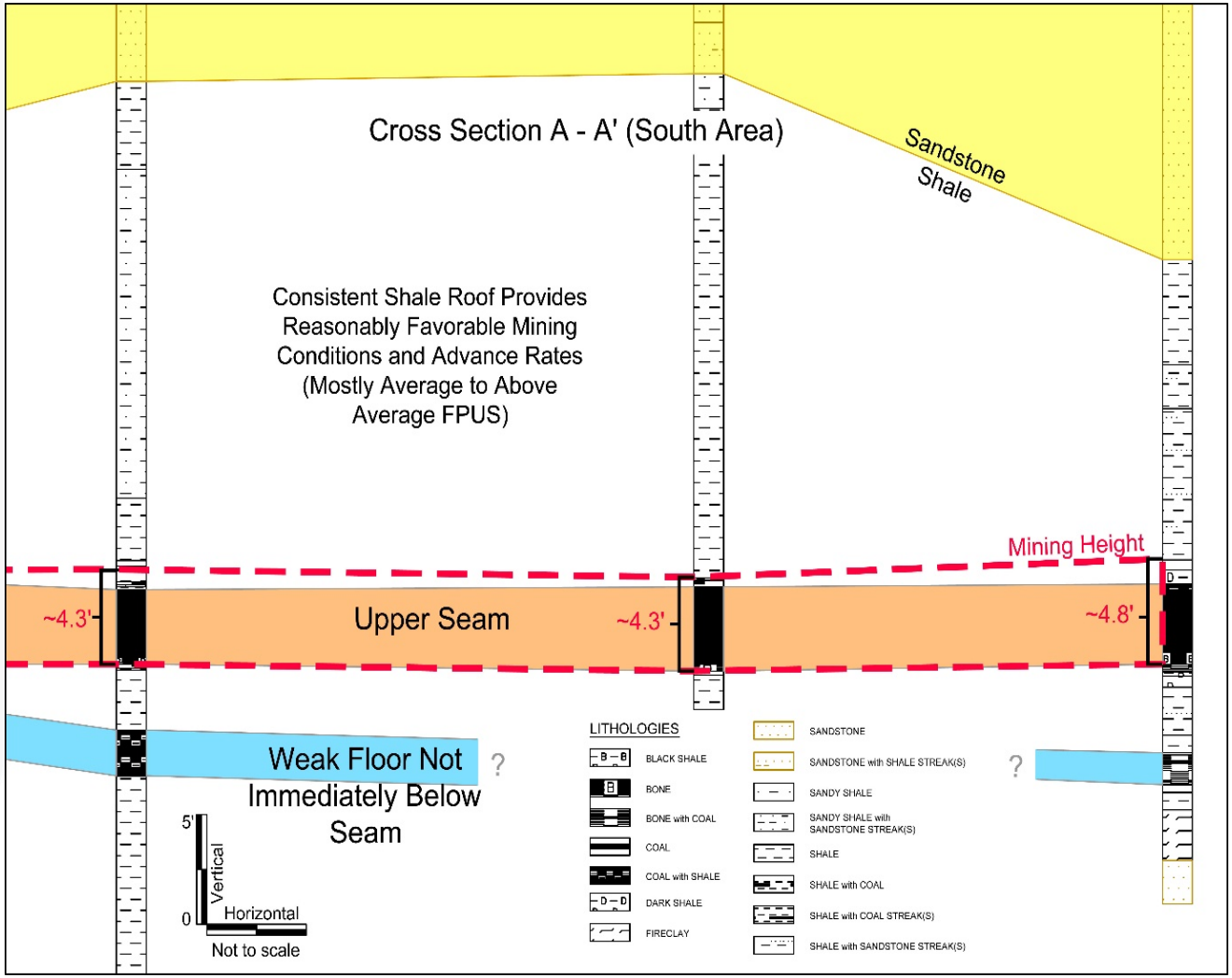


PEM

32nd Annual
Kentucky Professional Engineers in Mining Seminar

South Area Roof and Floor Geological Factors

- Out-of-seam dilution (OSD) levels typically minimal
- Strata left as permanent roof and permanent floor reasonably consistent
- Shale roof interval between the top of the coal seam and the overlying main sandstone roof consistently thick and not strongly impacted by differential compaction features
- Weak floor layer (highly carbonaceous, brittle shale bed) separated from mine floor by bed of stronger shale and did not create problems for pillar stability or OSD.

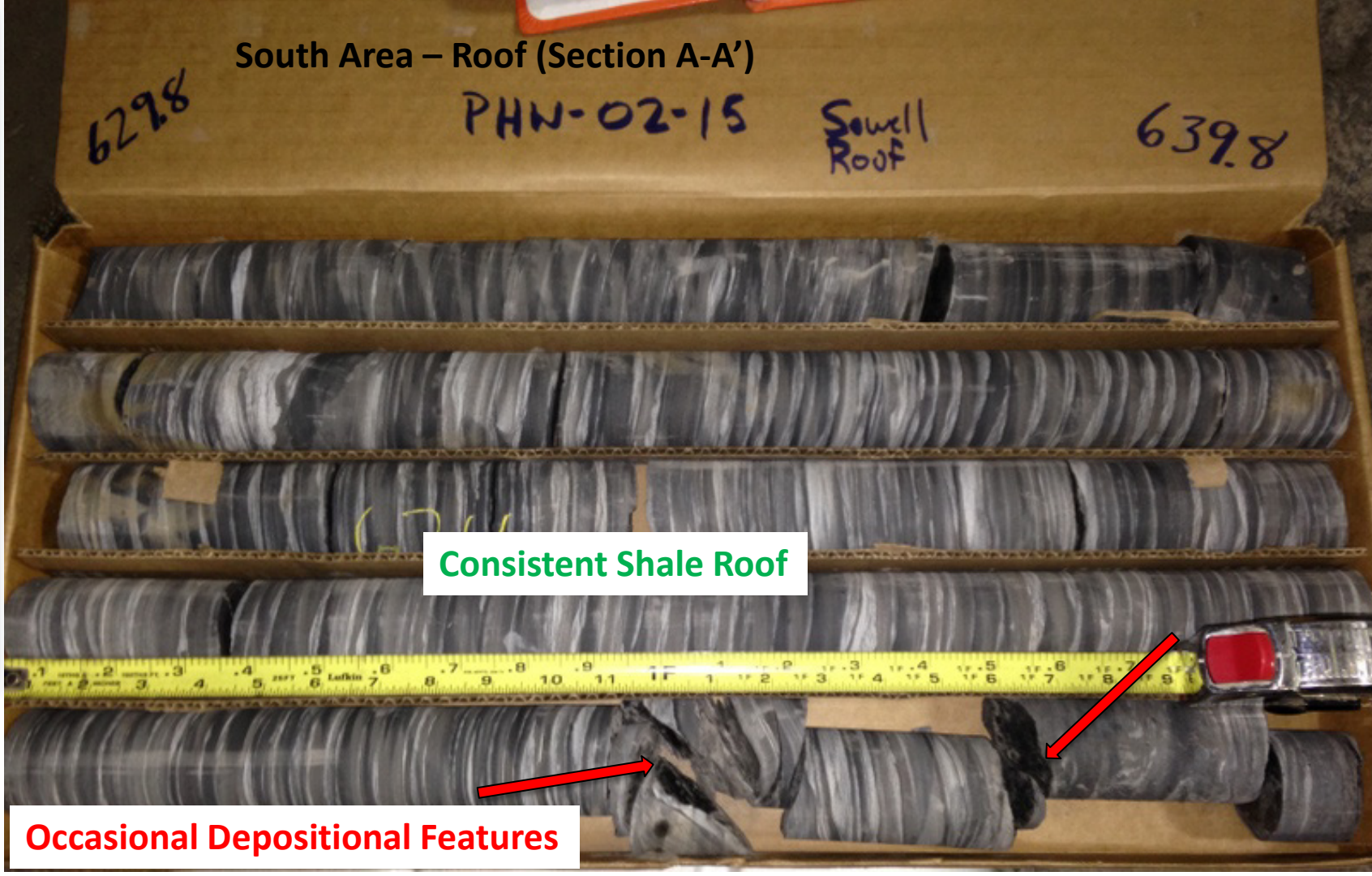


Cross Section A-A' Showing Typical Conditions for the South Area (Schematic)

PEM

32nd Annual
Kentucky Professional Engineers in Mining Seminar

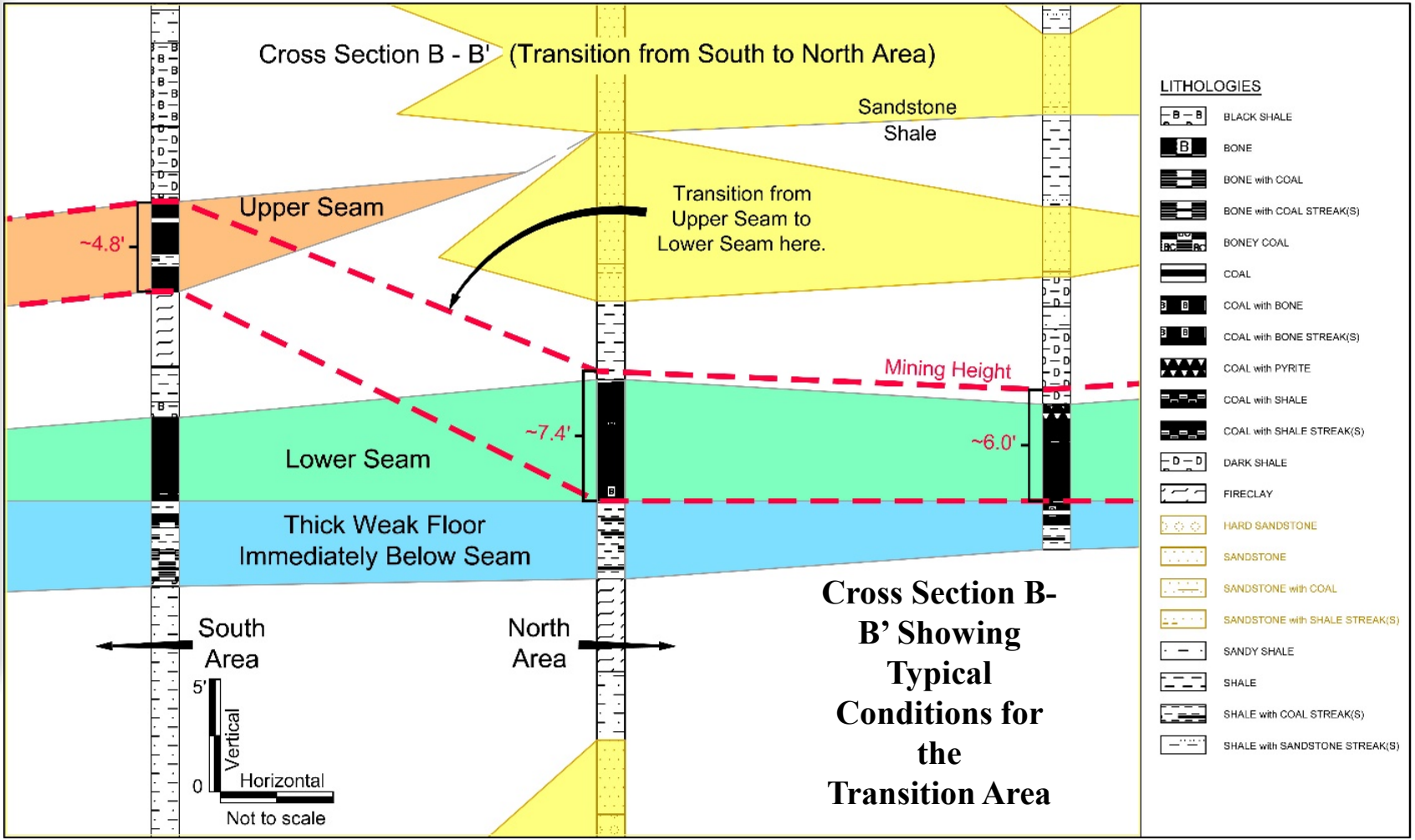
South Area – Roof (Section A-A')



South Area – Floor (Section A-A')

Transition Area Roof and Floor Geological Factors

- Upper Seam interbeds with roof shale until it becomes black/gray shale and absent
- Depositional environment results in complex, interbedded and discontinuous strata
- Mining encountered weak, poorly bedded lithology, multiple seam ‘rider’ interaction, erratic seam height and quality, and fracturing in roof and floor.
- Mains ramped down into the Lower Seam
- **Mining conditions and advance rates very difficult**



Cross Section B-B' Showing Typical Conditions for the Transition Area

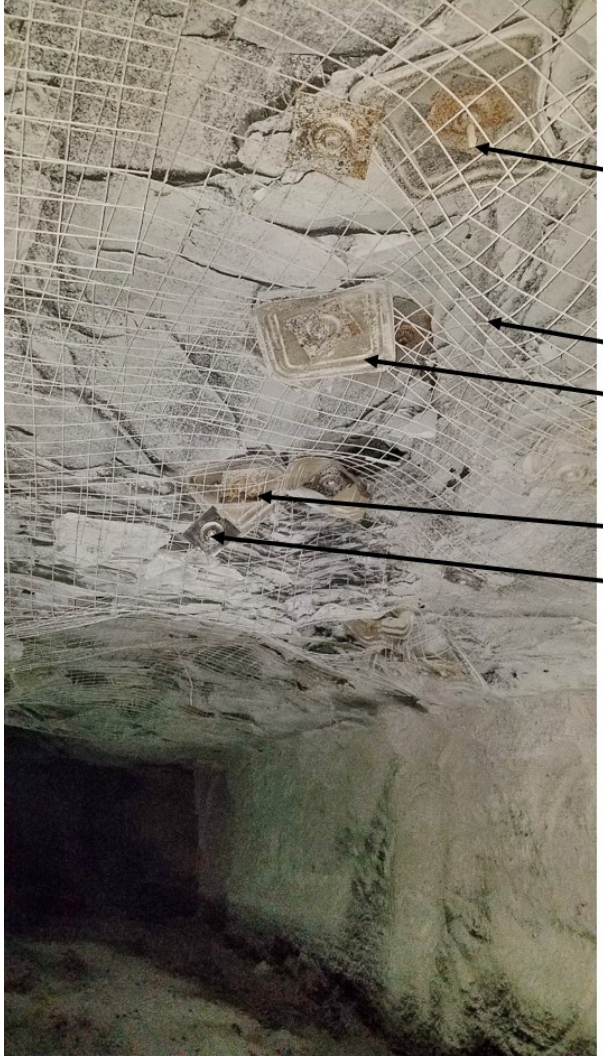
PEM

32nd Annual
Kentucky Professional Engineers in Mining Seminar

Transition Area – Ground Control Measures

- weak mudstone and claystone = 16 feet-long cable bolts, mesh, and mats
- slickensided shale and rider coals = increased use of cable bolts, pie pans, and t-channel
- Zones of increased seam/mine height (+7 ft) = rib control measures – rib bolting, rib strapping
- Implemented a bore scoping program for active faces and outby areas

Supplemental Roof Support in Transition Area



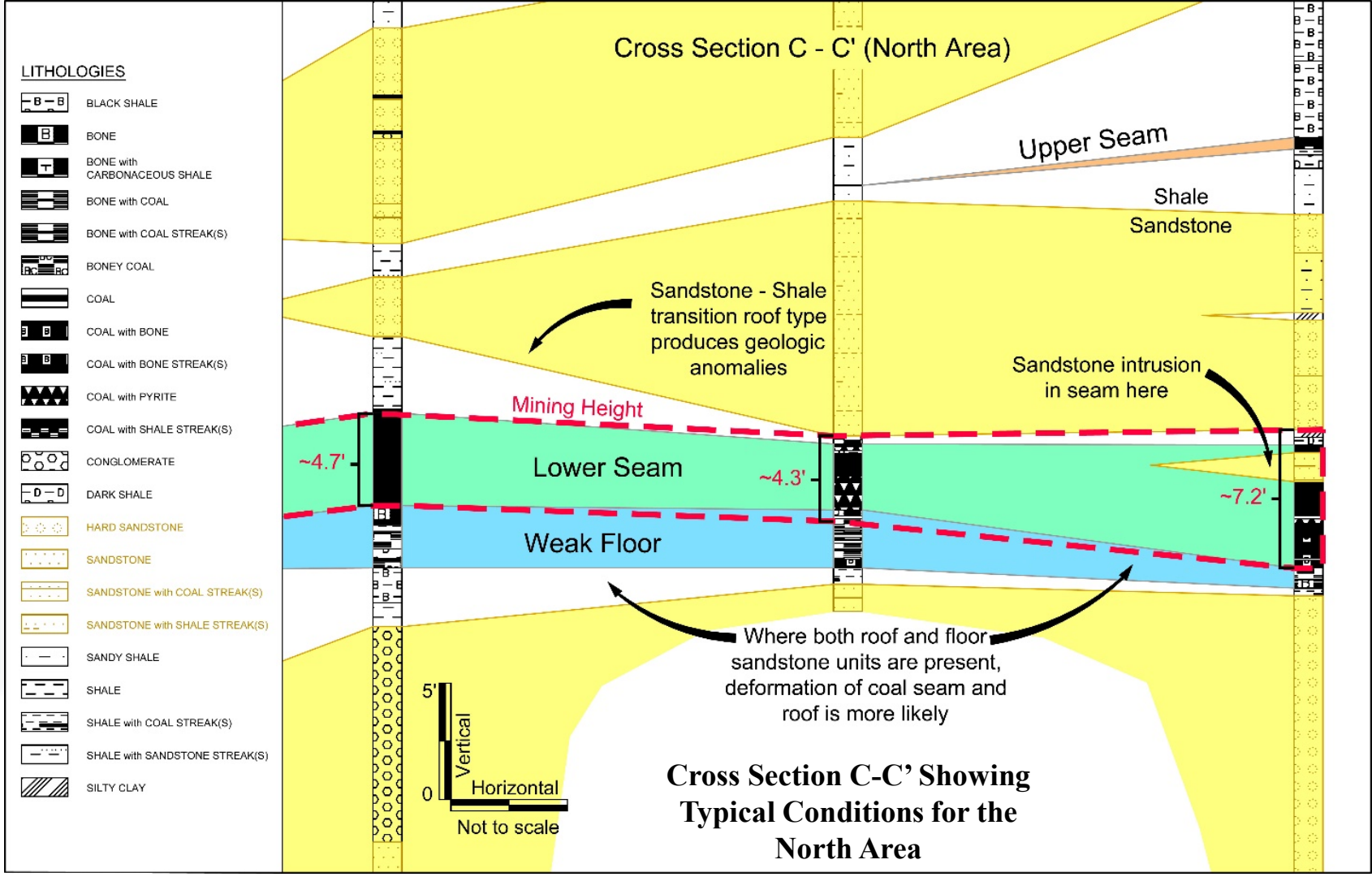
MARSHALL MILLER & ASSOCIATES®

PEM

32nd Annual
Kentucky Professional Engineers in Mining Seminar

North Area Roof and Floor Geological Factors

- Shale roof interval and main sandstone roof unit of variable thickness
- Strong impacts from differential compaction features such as slickensides, “rolls” (rapid, undulating floor or roof), sandstone intrusions into the seam, etc.
- Thick, weak floor (highly carbonaceous, brittle shale bed) immediately below the Lower Seam
- Floor sheared underfoot = secondary cleaning, stuck equipment/supplies, irregular entry widths and undermined ribs
- Below weak immediate floor, main floor sandstone of highly variable thickness enhanced differential compaction features
- Where seam was between roof and floor sandstone units = greater occurrence of seam deformed by diagenetic squeezing.
- Combination of both weak roof and weak floor strata = very difficult mining conditions.



Cross Section C-C' Showing Typical Conditions for the North Area

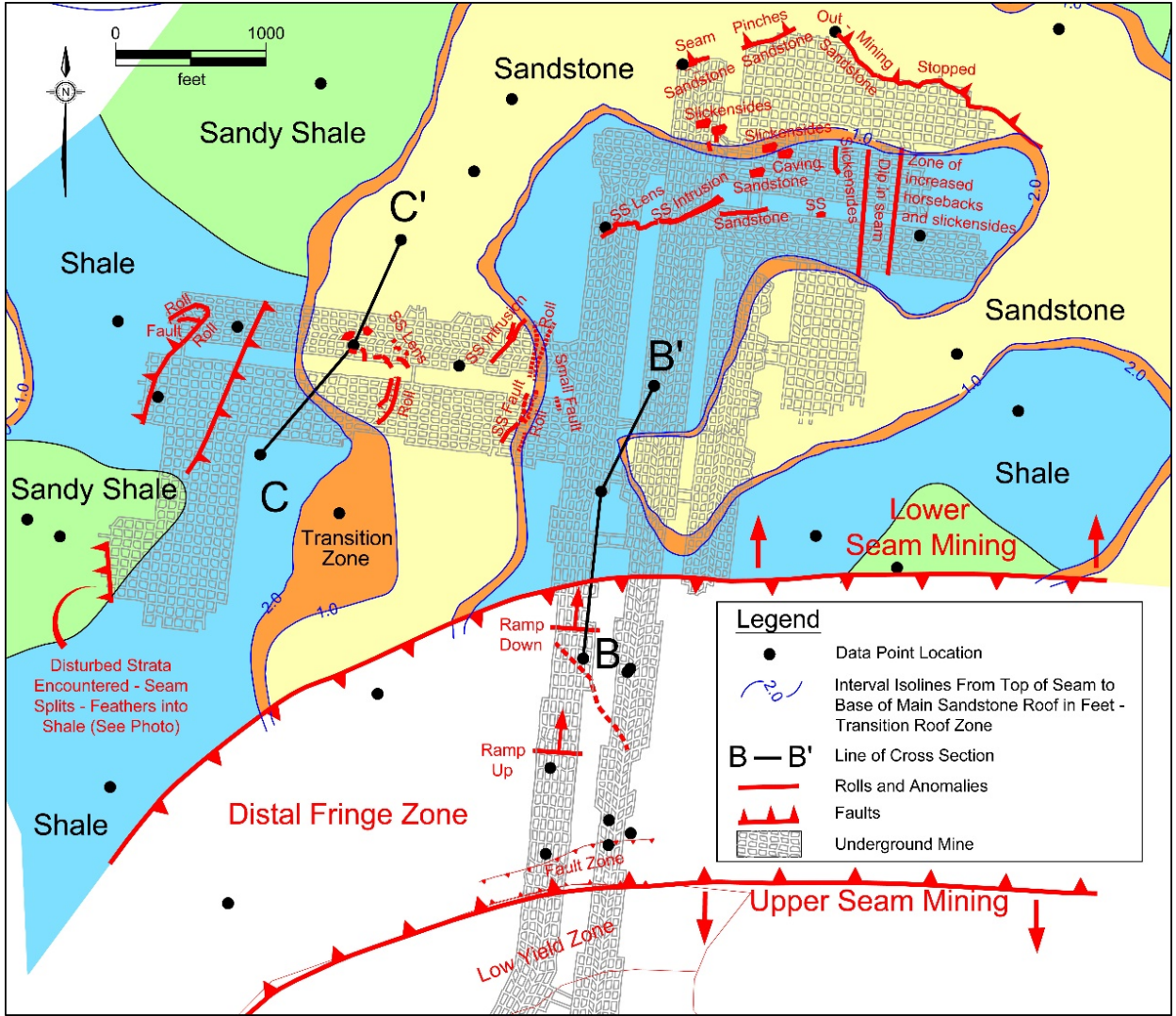
PEM

32nd Annual
Kentucky Professional Engineers in Mining Seminar

North Area – Roof (Section C-C')

Variable Thickness and Differential Compaction Features

North Area – Floor (Section C-C')



Roof Conditions and Geologic Anomalies Associated with Sandstone-Shale Transition for the North Area

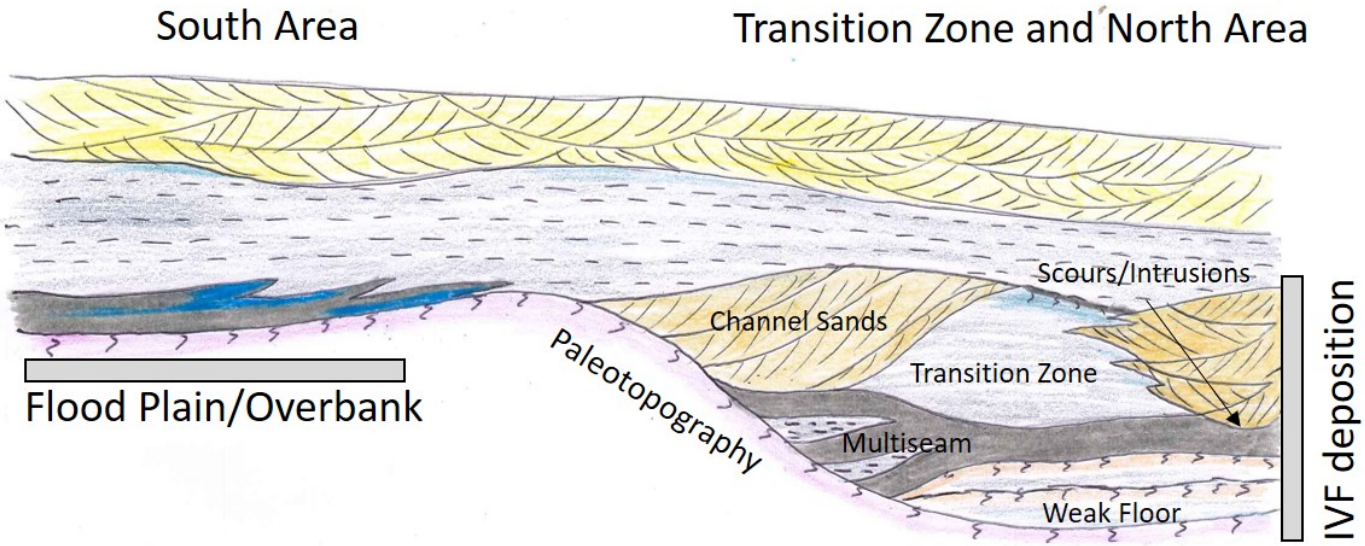
North Area – Ground Control Measures

- A standard system of primary bolting was developed based on the encountered conditions:
  - **sandy shale roof** = 5-foot fully grouted resin bolts were installed with cable bolts as needed.
  - **medium grain cross-bedded sandstone roof** = 4-foot resin bolts (firm rock) and 6-foot torque tension bolts (laminated or weakly bedded cross-bedded sandstone)
  - **fine grain ripple-bedded sandstone =** 5-foot resin bolts (firm rock) and 6-foot torque tension bolts (laminated or stacked)
- Slickensided roof with "horse backs" and draw rock on the periphery of sandstone channels required use of supplemental support (cable bolts, straps, etc.), **which increased the bolting cycle time and costs.**
- Sandstone roof was often hard, **increasing drilling and bolting time and drill bit usage.**
- Fractured and delaminated roof related to rider seam interaction was mitigated with 16-foot cable bolts, t-channel, wire mesh and mats, **resulting in increased roof control costs and mining cycle times.**
- Zones of increased mine height (+7 feet) required rib control measures such as straps and rib bolts, implemented both off-cycle and on-cycle to attempt to reduce delays.

Incised Valley Fill (IVF) Depositional Environments

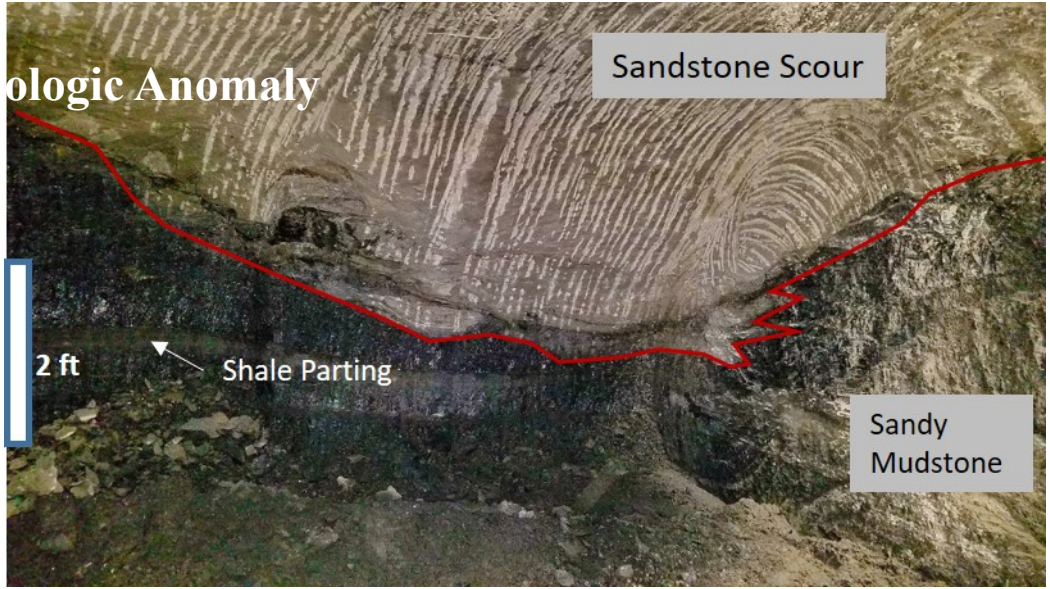
- Depositional backfilling of a valley in paleotopography
- Variable bed thickness is a common characteristic
- Often result in reduced accommodation space for sediment and increased sediment reworking, which leads to weak, irregular strata and lower FPUS (difficult mining conditions)
- By comparison, flood plain depositional environments often result in more uniform sedimentation and higher FPUS for mining (better mining conditions).
- The depositional environment of a coal seam is directly linked to required ground control measures and mine production.

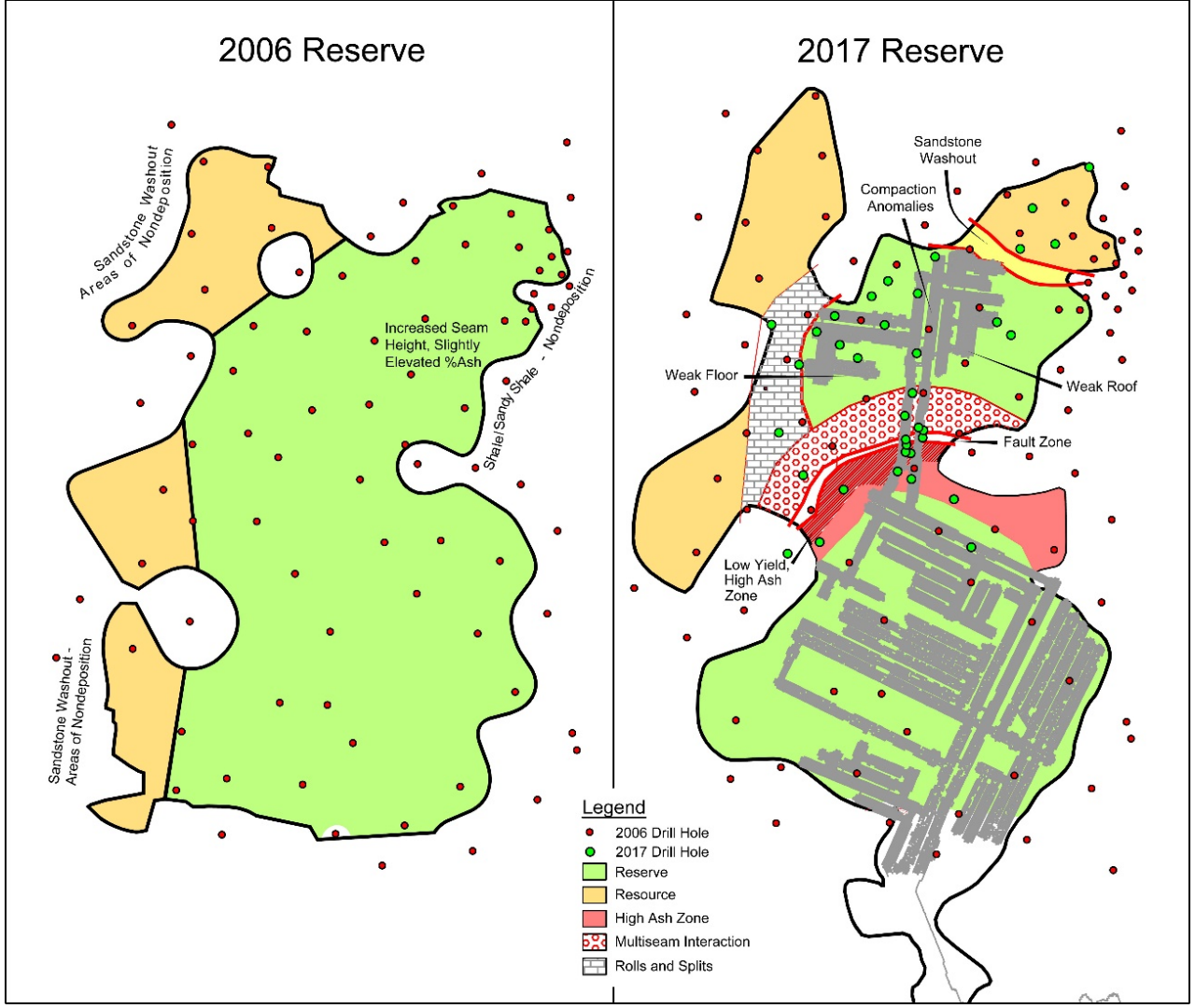
Idealized Sketch of Floodplain and IVF Depositional Environments



Coal splits, meandering streams, paleosols and unconformities.

- Anomaly encountered in the southwestern headings of North Area
- Erratic nature of contact = coal seam and roof strata were deformed by robust compressional forces (diagenetic squeezing)





Comparison of the Reserve and Resource Mapping Before and After Mining

Conclusions

- Case of geologic variability where widely-spaced drilling data provides only a general level of predictability for the location of anomalies.
- Geology of the not-yet-mined portions of the North Area were similar to the portions already mined; conclusion = lower productivity rates likely for continued mining
- Based on the geologic factors, management elected to reallocate its resources to a new mine at a nearby location
- Mapping and historical performance demonstrated that large portions of the mining block, previously considered reserves, were either isolated from the active block by unconformities or unmineable.
- Geological mapping and assessment changed the understanding of the mineability of the deposit over time and facilitated management decisions.

Acknowledgements

Terry Hamrick, Senior Geologist

United Coal Company, LLC

Metinvest Group

Scott Nelson, C.P.G.

Marshall Miller & Associates

Thank You!
Questions?