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Merging Coal Mine Geologic Hazard Mapping with Mine Production Rates—Industry Experience

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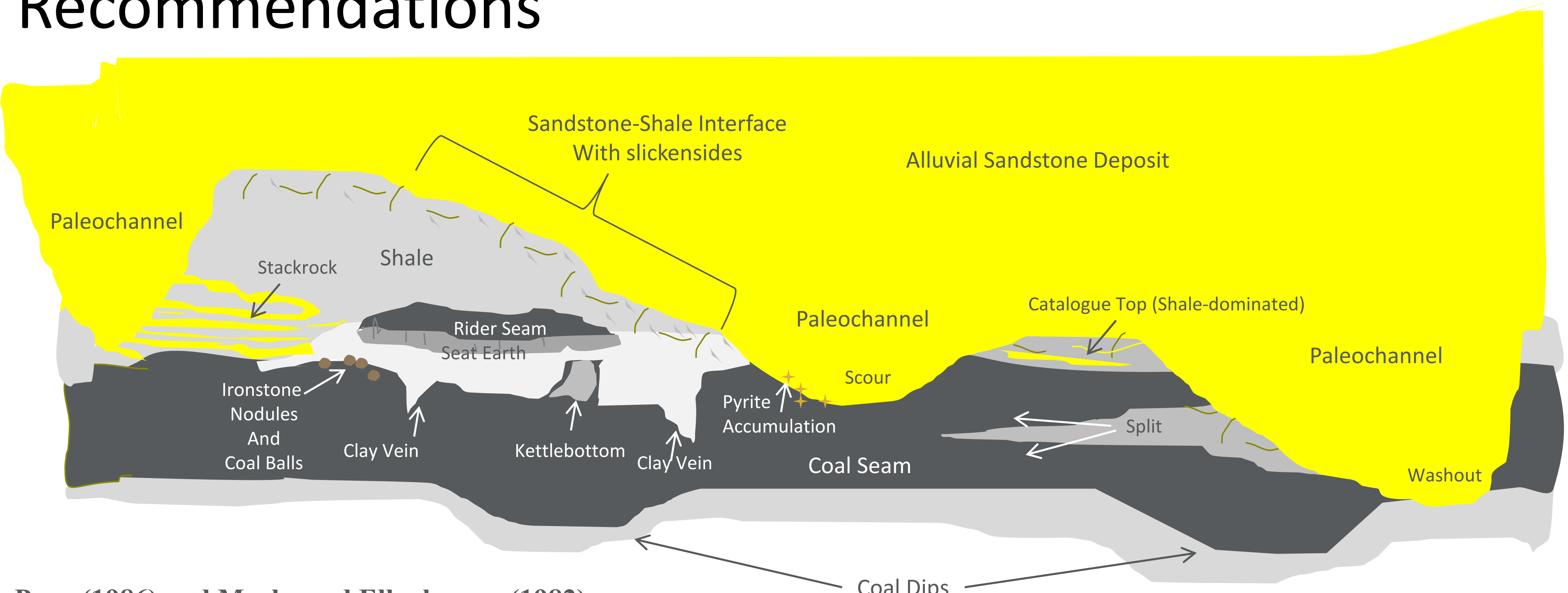
Outline

> Introduction
> Case Study
> Summary
> Recommendations

Merging Coal Mine Geologic Hazard Mapping with Mine Production Rates—Industry Experience



after Peng (1986) and Moebs and Ellenberger (1982)

Geologic Hazard Mapping (or Conditions Mapping)

- >Uses data from drilling, core logging, core photography, laboratory testing, underground observations/testing, stress modeling, geophysical surveys, etc. – **or whatever you have!**
- >Predicts future mining conditions
- >Links geologic interpretation with mining engineering
- >Often results in optimization and enhanced mine operation
- >**"Road map for mining"**

Introduction

- > Documentation began in the late 1970’s and early 1980’s, but concepts used much earlier
- > 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
  - Many other examples – geostatistical modeling, numerical modeling of stress, etc.

Introduction (continued)

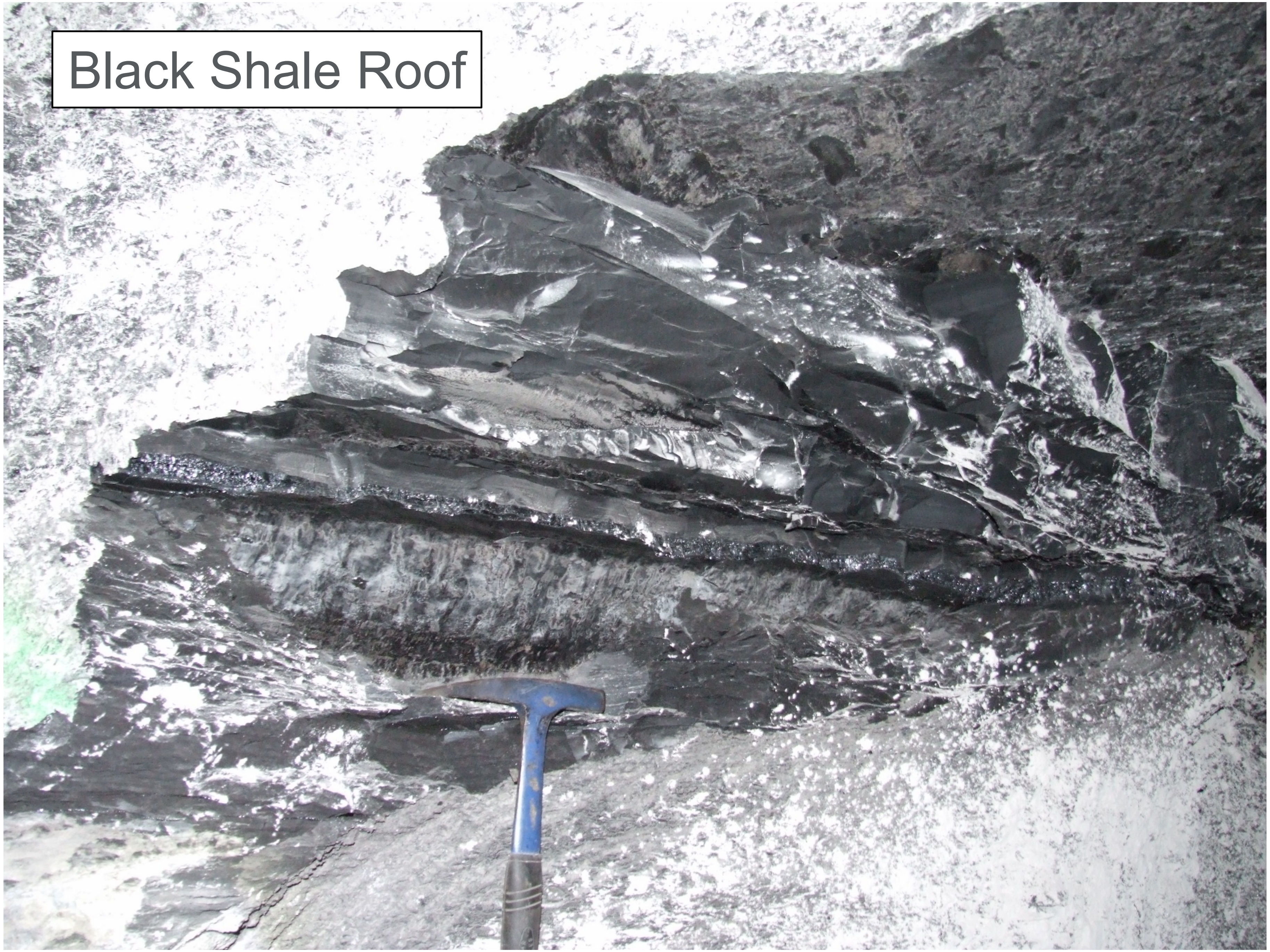
- Ability to integrate conditions mapping into the mine planning process is often essential for success
- Pro-active vs. Reactive
- Budget and time limitations restrict availability of geotechnical data and time to look at it
- ***Collect when you can and use what is available***

Case Study

- **Description: Coal mine in southern West Virginia (Confidential)**
- **Data:**
  - mixture of older core logs with only general strata descriptions
  - new core records with geological descriptions
  - down-hole geophysical logging
  - rock core photographs
- No detailed geotechnical core logging or lab data
- **Action:** basic geological information + in-mine mapping + mining production records = correlation of low mining productivity rates to certain problematic geologic conditions
- **Results:** reasonable prediction of future rates of mining advance

Case Study (continued)

> 22 geologic cross-sections
> Geophysical logs, core photographs, and general geologic information = qualitative assessment of overall rock mass quality
> **ROOF ROCK CHARACTERIZATION MAPPING**
  > Five principal immediate roof rock categories are identified:
    – 1) weak black shale,
    – 2) rider coal,
    – 3) sandstone (in fracture zone and away from fracture zone),
    – 4) shale or sandy shale, and
    – 5) shale roof overlain by a sandstone unit (transition roof).
> **Black shale roof, rider coal roof, and "fracture zone" areas are the most problematic.**


Black Shale Roof

Brittle Black Shale Roof - Increased OSD

Fracture Zone – water inflow, rib spall

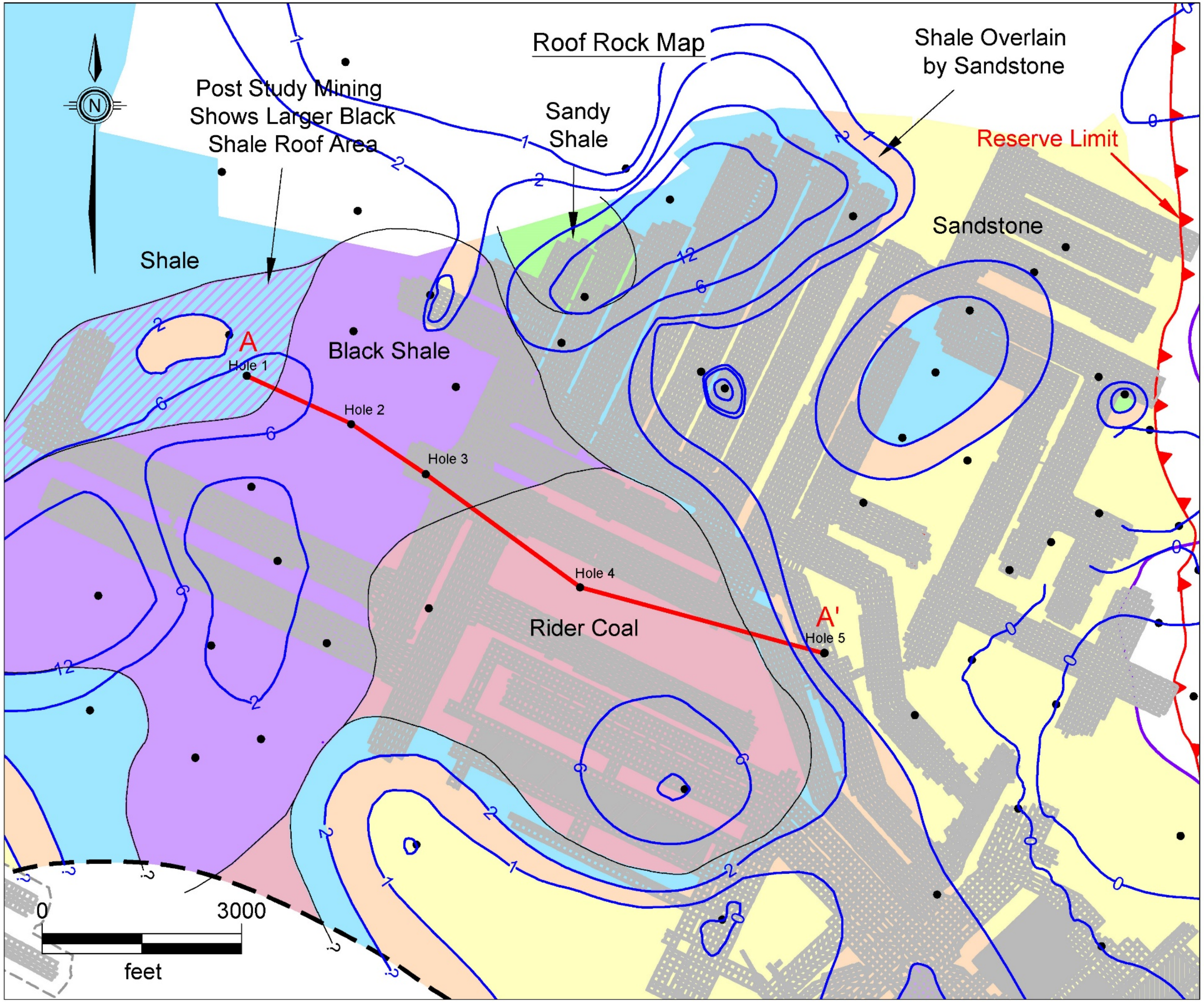
Fracture Zone Roof –
water inflow, yielded supports


Sandstone Roof – Good!


Sandstone Roof – Good!

Roof Rock Map

0-1’ = SS roof
1-2’ = SS/SH
>2’ = non-SS



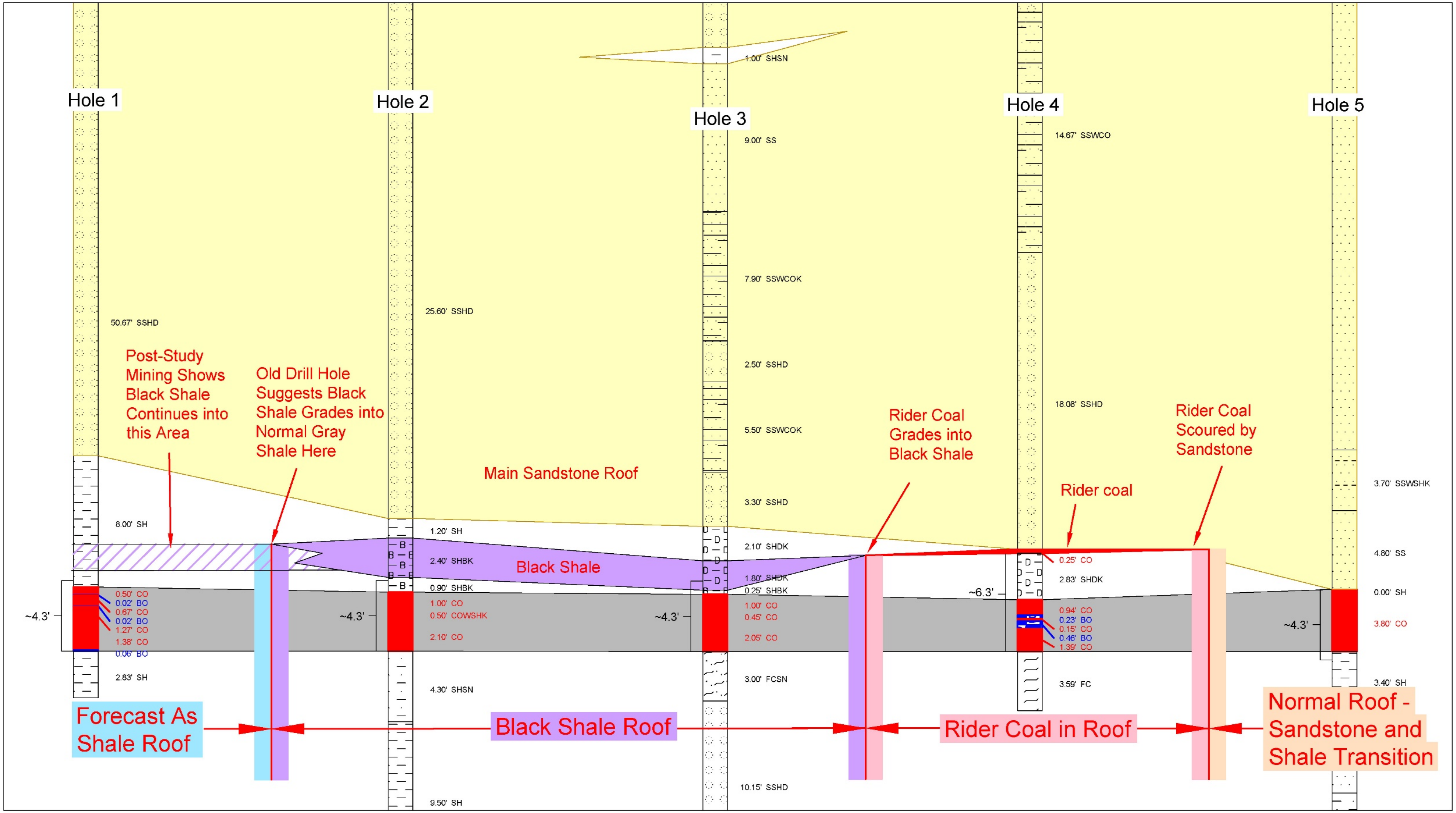
Case Study (continued)

- Criteria for selecting the roof and floor material to be mined with the seam:
  - Weak strata are included first (to provide for better entry stability)
  - If no weak strata, more competent shale lithologies are included first
  - If no material difference between roof and floor strata competency, roof strata are included first
  - Included last, if necessary, are more abrasive sandstone lithologies
- Estimate out-of-seam dilution (OSD) and determine “permanent” roof and floor
- **Roof rock mapping based on “permanent” roof**

Case Study (continued)

- Minimum cutting height = 4.33 feet; coal seam height is generally < 4.33 feet
- Roof or floor strata is cut to provide adequate machine clearance
- **Cross-section A-A' :**
  - Typical representations of roof types
  - strata in each hole most likely to be included within the 4.33 feet mining height
  - areas where the sum of seam height and weak strata in the immediate roof or floor > 4.33 feet
  - interval between top of coal and the overlying main sandstone roof (shale roof thickness)
    - Assists with prediction of shale drawrock and estimation of required bolt lengths

Cross-Section A-A’

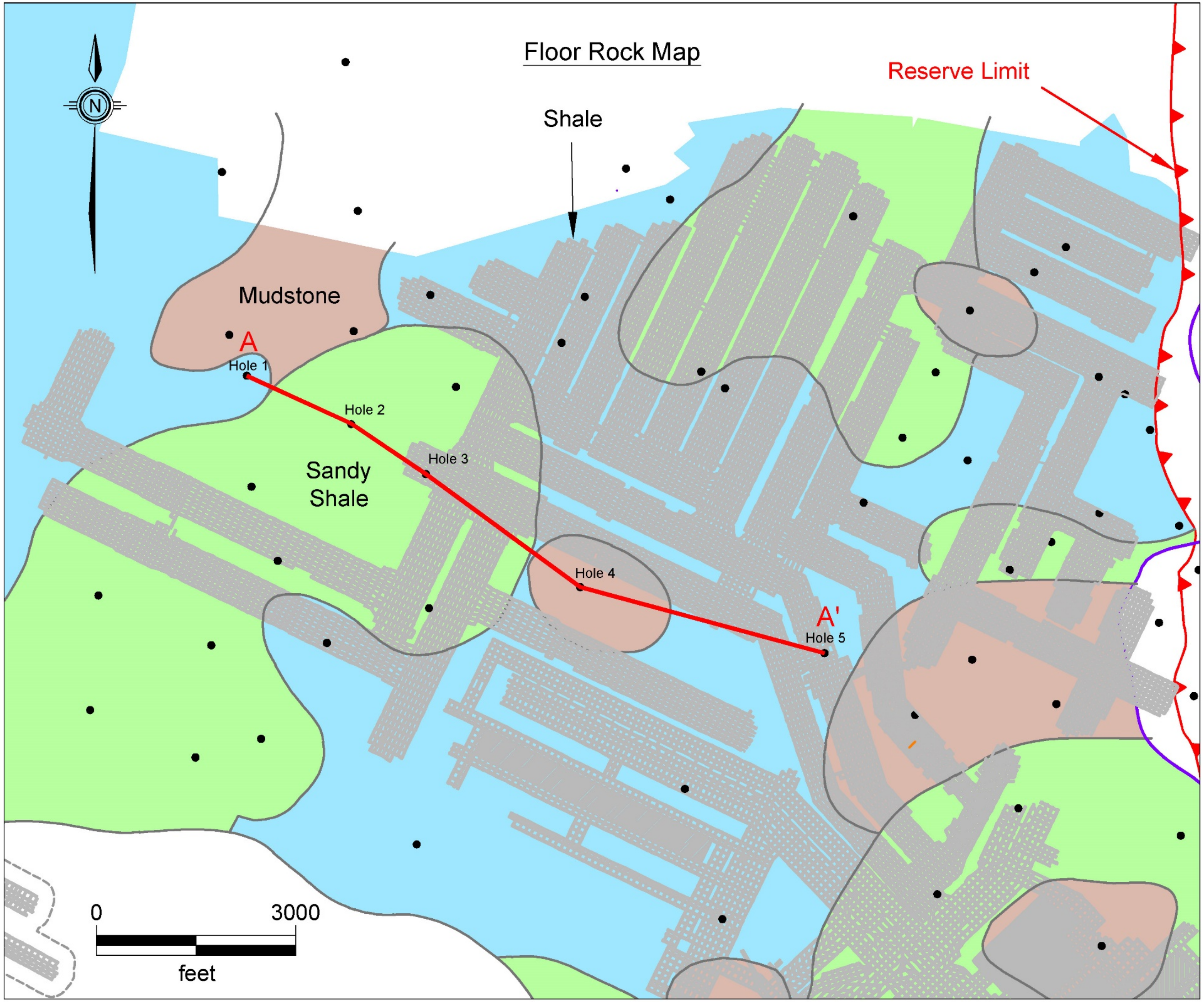


Case Study (continued)

> **FLOOR ROCK CHARACTERIZATION MAPPING**

- Majority of floor rock is shale and sandy shale, neither expected to cause advance rate issues.
- Where roof is sandstone and floor must be cut to for machine clearance height:
  - If the floor rock is hard, abrasive sandstone or sandy shale, advancing mine entries can be slower and costlier.
- There are no areas of sandstone floor identified in the current study area.
- **In general, the active mine has reasonably good floor conditions.**

Floor Rock Map



Case Study (continued)

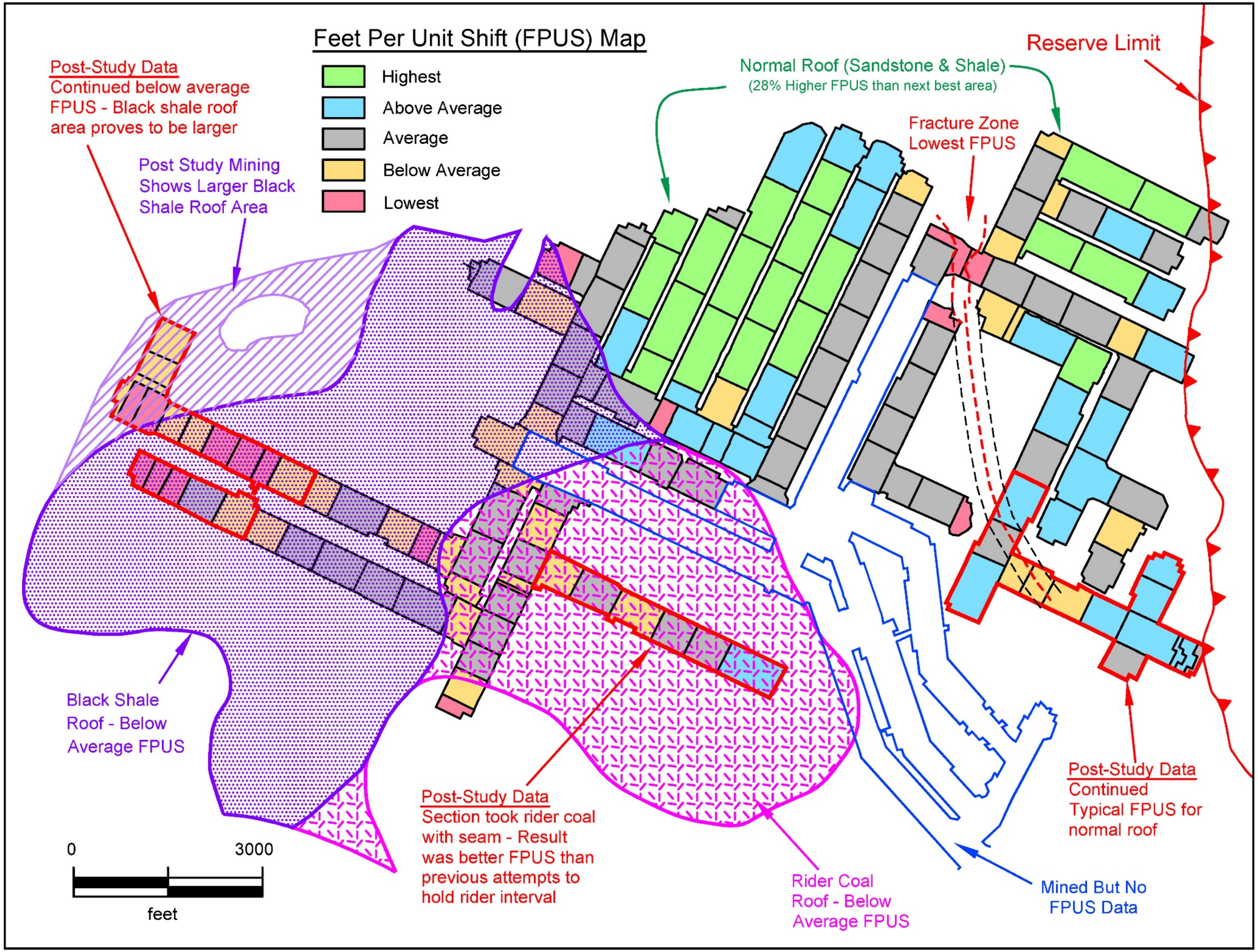
> **Overall, spatial trends in FPUS visually compared to:**

- Roof and floor mapping
- Overburden/surface topography
- Lineaments
- Dip angle of coal seam
- Overmining/undermining
- Operational/equipment changes

Case Study (continued)

CORRELATION OF MINE PRODUCTIVITY WITH MINE ROOF CHARACTERIZATION

- Daily rate of advance in feet per unit shift (FPUS) provided.
- An average FPUS value, by calendar month, was calculated.
- Rating scheme based on monthly FPUS:
  - GREEN = Highest average rate of advance
  - BLUE = Above average rate of advance
  - GRAY = Average rate of advance
  - AMBER = Below average rate of advance
  - RED = Lowest average rate of advance


Feet Per Unit Shift (FPUS) Map
Highest
Above Average
Average
Below Average
Lowest
Post-Study Data
Continued below average FPUS - Black shale roof area proves to be larger
Post Study Mining Shows Larger Black Shale Roof Area
Normal Roof (Sandstone & Shale)
(28% Higher FPUS than next best area)
Reserve Limit
Fracture Zone Lowest FPUS
Black Shale Roof - Below Average FPUS
Post-Study Data
Section took rider coal with seam - Result was better FPUS than previous attempts to hold rider interval
Rider Coal Roof - Below Average FPUS
Mined But No FPUS Data
Post-Study Data
Continued Typical FPUS for normal roof
0
3000
feet

Case Study (continued)

- Significant correlations are evident between low productivity areas and three roof rock types:

  1) the fracture zone,

  2) the black shale roof area, and

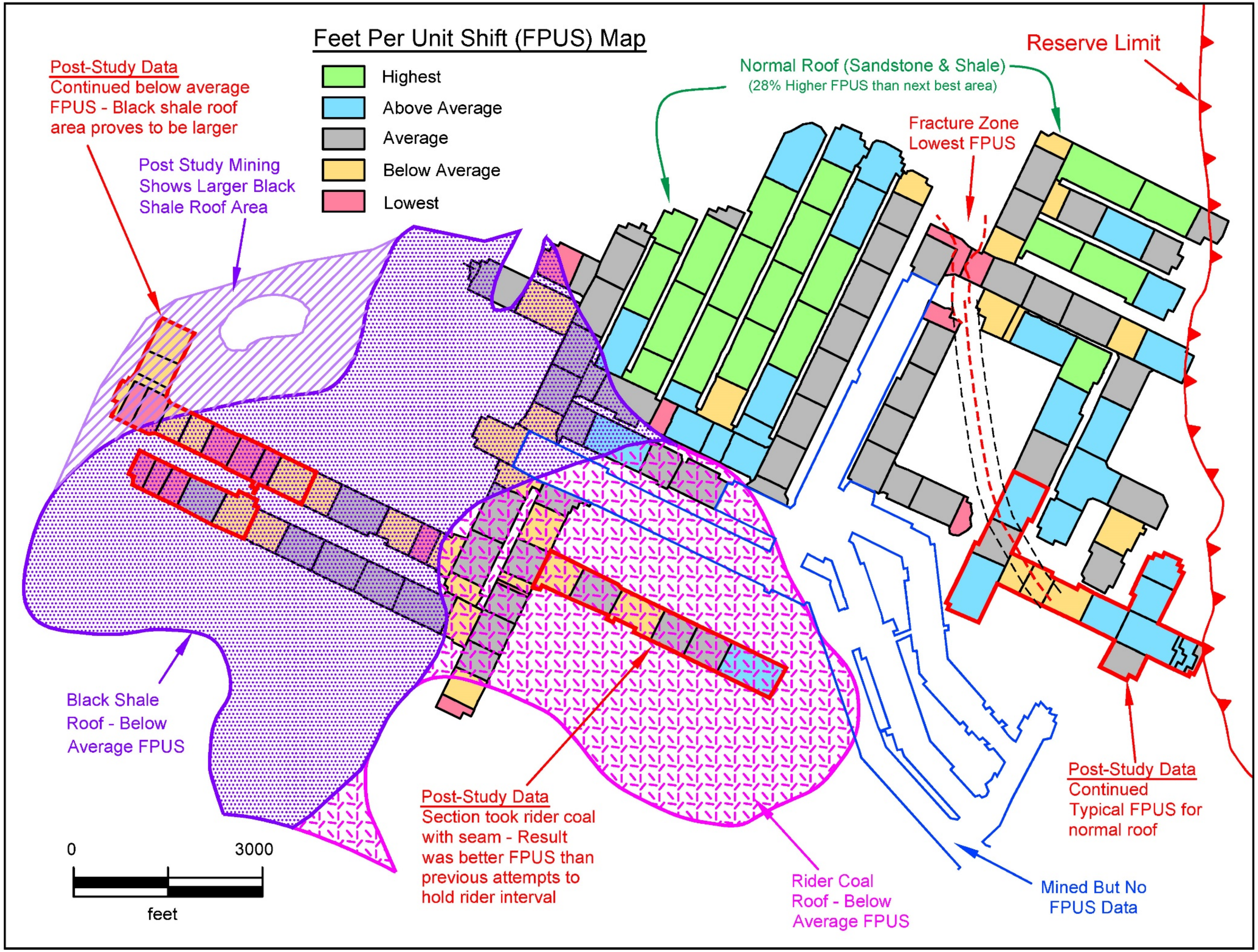
  3) the rider coal roof area.

- Compared to the gray shale and sandstone roof rock areas, future mining within the black shale and rider coal roof areas can be expected to have relatively lower (perhaps ~28% lower) advance rates.
- Black shale and rider coal roof strata types exhibit lower strength and a higher incidence of discontinuities and slickensided planes.

Case Study (continued)

COMPARISON OF POST-STUDY PRODUCTION RATES TO RATES OF ADVANCE PREDICTED BY GEOLOGIC CHARACTERIZATION – BOLD RED AREAS

1. **In western part of the mine, mining advanced in a northwest direction through the black shale roof area.**
   - As predicted, the average monthly advance rates were below average or low.
   - Mining eventually turned to the northeast, potentially out of the black shale roof area. Rate of advance continues to be below average and low, and black shale roof actually extends beyond what was predicted.
   - Low and below average advance rates after the turn also attributable to a large roof fall and additional roof support requirements in the area.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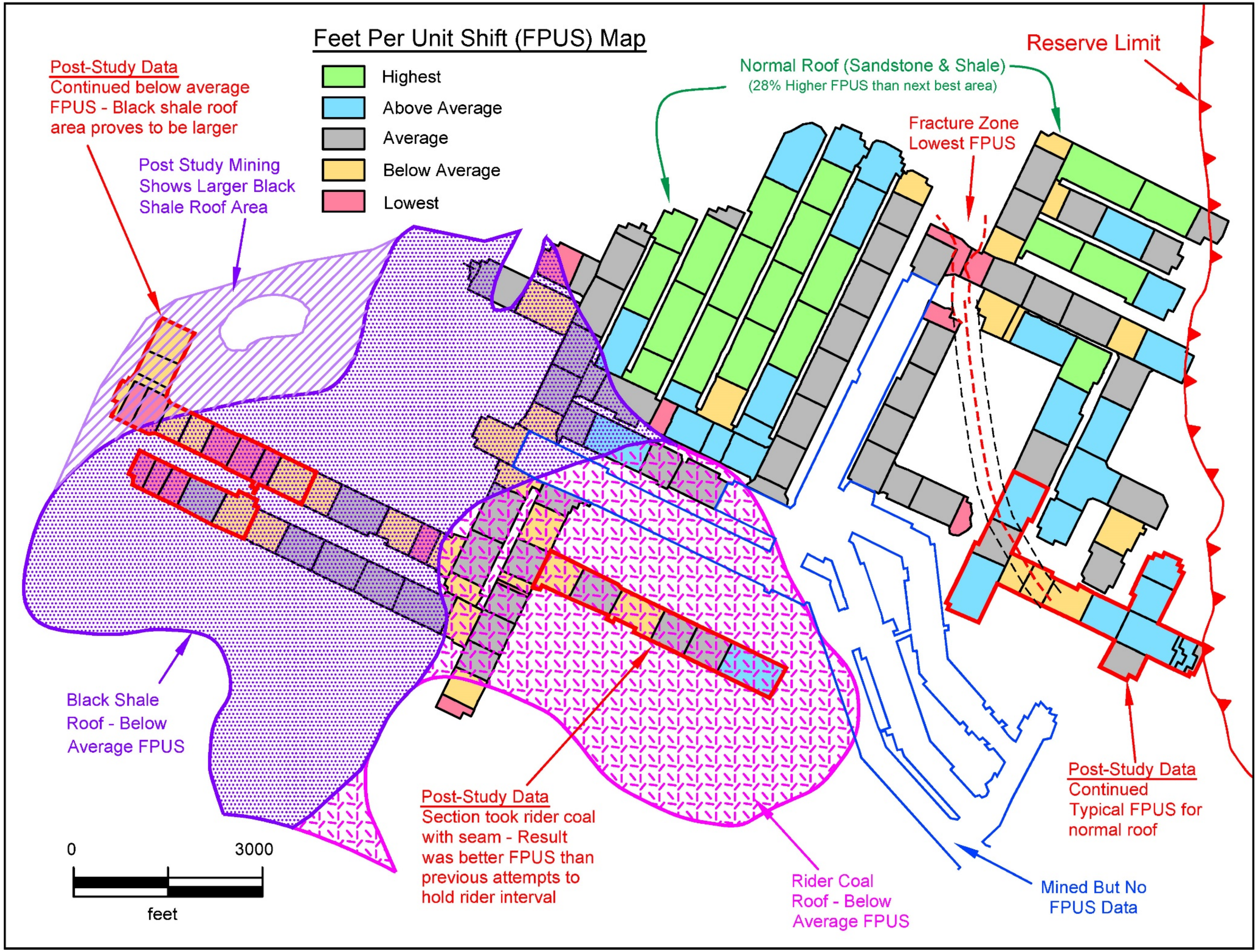
Case Study (continued)

2. **In the south-central portion of the mine, mining advanced in a southeast direction through the rider coal roof zone.**
   - Rates of advance are still mostly average to below average, with one section that exhibited above average advance rate.
   - Increase in production rate is most likely a result of a management decision to start to include the rider coal in the mined section.
   - Increase in rate of advance in the area can also be, at least, partially attributed to an additional roof bolter.



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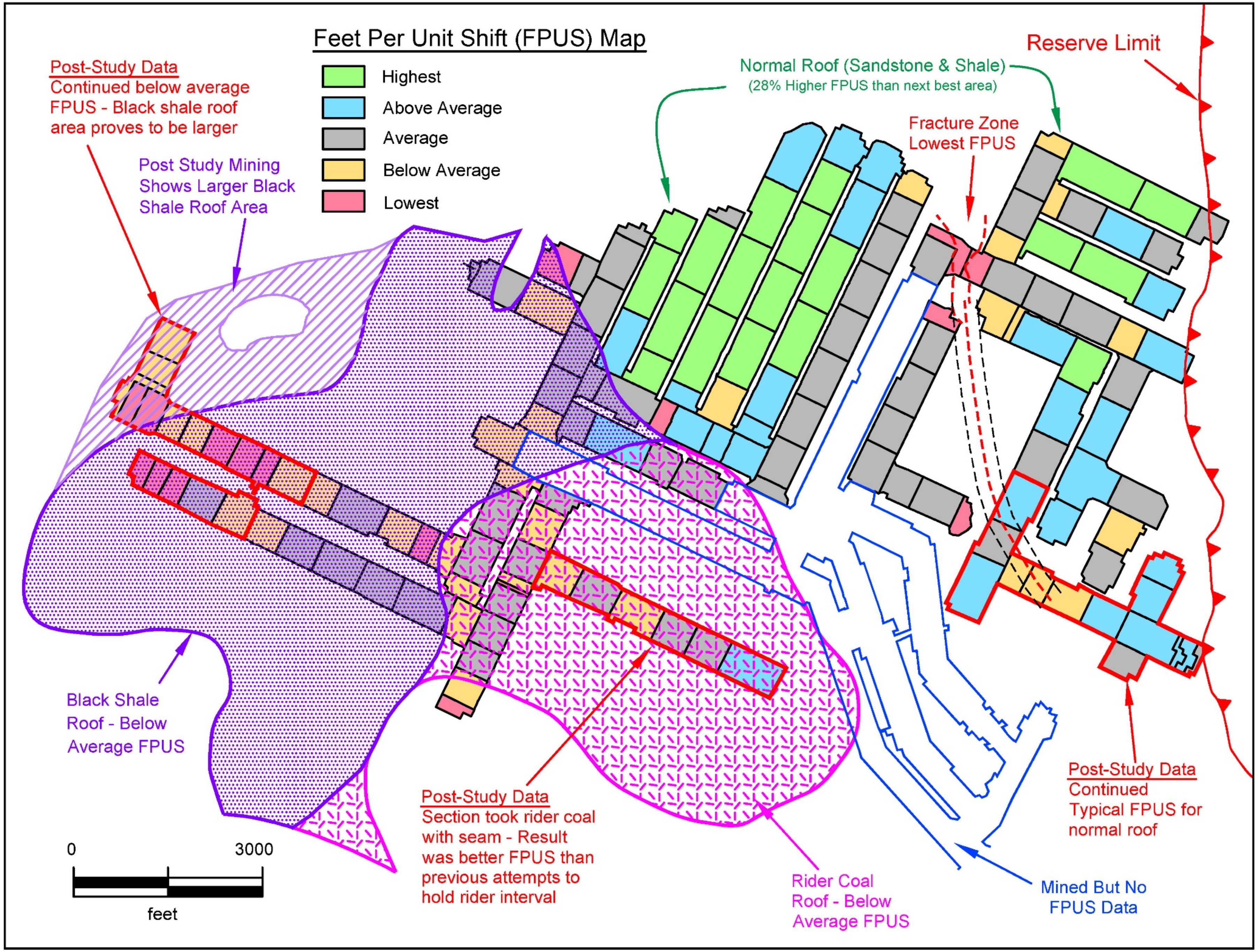
Continued Typical FPUS for normal roof
0
3000
feet
MARSHALL MILLER & ASSOCIATES

Case Study (continued)

3. **In the eastern portion of the mine, recent mining occurred in and around a projected fracture zone.**

   - Advance rates in the immediate vicinity of the fracture zone were average to below average, a little better than would have been expected based on previous data from the fracture zone area.

   - As expected, rates of advance increased to above average as mining moved away from the fracture zone and into the normal roof zone.



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Summary

- For the case study, average production rates most affected by roof rock conditions.
- Mining in areas of **black shale roof** and **rider coal roof** are expected to exhibit a reduction in advance rate of approximately 28 percent compared to mining in the more prevalent sandstone and shale roof rock types.
- Qualitative geotechnical assessment **completed mostly with core photos and underground mapping**
- Post-study mining advance rates to-date confirm the accuracy of the predictions.
- Prediction accuracy dependent upon drill hole spacing (mine experience demonstrates actual mining conditions more variable)
- Use as **general "barometer" rather than absolute forecast** of daily or weekly conditions
- Periodically update mining conditions and mining advance rate data
- Note changes in mining approaches and equipment
- Work to enhance this kind of investigation includes: standardized documentation of strata defects, qualitative assessment of overall rock mass quality, fracture spacing and Rock Quality Designation, CMRR parameters, implementation of the SMS, and many others.

General Recommendations

- Collect geotechnical data whenever possible
- Use available geotechnical data to enhance mine planning and operations
- **Take the time** to look for patterns and correlations in all available data
- Clues to enhance mine productivity or solve problems may be hidden in existing data!

Acknowledgement

Terry Hamrick, Senior Geologist

United Coal Company, LLC

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Thank you.