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Transitional geology and its effects on development and longwall mining in Pittsburgh Seam

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ABSTRACT

This paper presents the geologic and ground control challenges that were encountered by Consol Energy's coal mining operations in southwestern Pennsylvania, USA. Geologic encounters, such as sandstone-to-limestone geology transition, massive sandstone channels, shale channels, pyritic rich green claystone, laminated roof, and soft floor, have significantly impacted the development and longwall mining in Consol's Pittsburgh Seam coal mines. Experience from different mines shows that, in the sandstone-to-limestone geology transition zone, 1.83 m high-tension, fully-grouted primary bolts employed along with 4.88 m center cable bolts at every other strap greatly improved beam building and ensured proper anchorage into the competent roof. Hydraulic fracturing of the massive sandstone was often necessary to enhance caving of the massive sandstone behind the shields to relieve pressure at the face. The presence of soft floor coupled with presence of thick floor coal and deep cover, induced excessive headgate convergence during retreat of the first right hand longwall panel. In all, it is important to explore the roof and in-seam geology in detail to delineate normal and anomalous geologic conditions prior to and during development. With diligent geologic reconnaissance, geotechnical monitoring, and assessment, site-specific geotechnical solutions have been provided to mine operations to improve safety and productivity.

1. Introduction

The impact of anomalous geology on coal mining ground control, particularly within the Pittsburgh Seam, is well documented [1–3]. Anomalous and transitional geology often create zones or planes of weakness, the impact of which can be laterally extensive or confined in extent. Oftentimes, it is simply the unknown, unexpected, or erratic nature of these features that creates the greatest challenges.

Over the last two decades, Consol Energy has invested significant resources into development and enhancement of programs and methods to assess and address geologic challenges in its coal mines, of which underground reconnaissance, including systematic roof scoping and detailed entry mapping, is a major component [4–10].

More recently, Consol's Pittsburgh Seam mines have encountered a few challenging, and occasionally unique, geologic anomalies and transitional conditions that have impacted both development and longwall mining. In three separate case studies, this paper analyzes the characteristics of a few of these anomalies, their impact(s) on ground control, and the solution(s) to mitigate their impact.

2. Mine A

2.1. Geologic challenge

The geologic setting of Mine A is a transgressive roof sequence from a Paleo lake environment, otherwise known as a limestone to sandstone roof transition zone. In this case, the roof geology near mid-panel rapidly transitioned within a few gateroad pillar cycles from a sandstone-and-shale-dominated roof to limestone main roof with underlying claystone. Individually, neither of these roof geologies presented a significant challenge. However, the mixture of both roof types within the transition zone created a unique condition, such that, as the thinly bedded-to-laminated sandstone and shale roof thinned from top down, it was replaced by claystone that under laid the thickening limestone. Eventually, the overlying claystone encroached upon the anchorage zone for the 2.4 m resin-assisted point-anchor primary bolts at the same location where the roofline was still exposed to a highly-bedded mixture of shale and sandstone (Fig. 1). The resulting ground condition was an immediate roofline that was susceptible to high horizontal stress and an anchorage zone of lower than expected strength.

Although the transition zone was anticipated in general, this unique circumstance was not, and resulted in a roof fall. Analysis of the fall indicated that the heavily laminated immediate roof

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had likely sagged and eventually overwhelmed the primary support anchorage. Of particular note, is that the fall occurred within an entry, which was not only highly unusual, but also where supplemental cable bolts had not been installed.

From that time forward, and with the general trend already defined through corehole exploration, underground reconnaissance plans were tailored to better delineate the limestone-to-sandstone transitioning roof and to assess any exceptional circumstances that might develop.

2.2. Geotechnical solution

Detailed examinations of the roof fall area within the limestone-to-sandstone roof transition zone revealed that sandstone and shale strata delaminated and induced high bolt load that eventually overcame the anchorage capacity of the 2.44 m, point-anchor bolt at the claystone horizon. To improve anchorage capacity and to provide better beam building, 1.83 m, fully-grouted, high-tension bolts with alternating 4.88 m center cable bolts were employed in subsequent longwall developments.

Studies have shown that 1.83 m, fully-grouted bolts are more effective than the 2.44 m, partially-grouted bolts, especially in weak and laminated roof geology [11–14]. Su and Poland and Yassien used 2D FE models to evaluate the stress distribution within the bolted horizon for the fully-grouted bolt and the mechanical shell tensioned bolt. They found that the fully-grouted bolts “are about 2.5 times stiffer than the commonly used 2.44 m, partially-grouted, mechanical shell tensioned bolts”. Results from underground pull tests showed that the 1.83 m, fully-grouted bolt has higher stiffness and less bolt deflection than the 2.44 m, partially-grouted bolt (Fig. 2).

Roof movement and bolt load had also been monitored onsite with extensometers and load cells at development entry intersections bolted with 1.83 m, fully-grouted bolts and 2.44 m, partially-grouted bolts, respectively. Roof movement measurements within the 1.83 m, high-tension, fully-grouted bolt area showed much less movement (about 39.6 mm) than those within the 2.44 m partially-grouted bolt area (about 176.8 mm) over a 300-day monitoring period (Fig. 3). Load cell measurements (Fig. 4) also showed that the installed tension of the 1.83 m, fully-grouted bolt was much higher (about 10 ton) than that of the 2.44 m partially-grouted bolt (about 5.5 ton). Clearly, the 1.83 m, fully-grouted bolt, with its high stiffness and higher tension, built a much better beam than that of the 2.44 m, partially-grouted bolt.

In addition, the 4.88 m alternating center cable bolt employed with the 1.83 m, fully-grouted bolt system enabled the cable bolt to anchor at least-1.22 m into the competent limestone, thus providing a very effective tandem support system. As a result, no roof

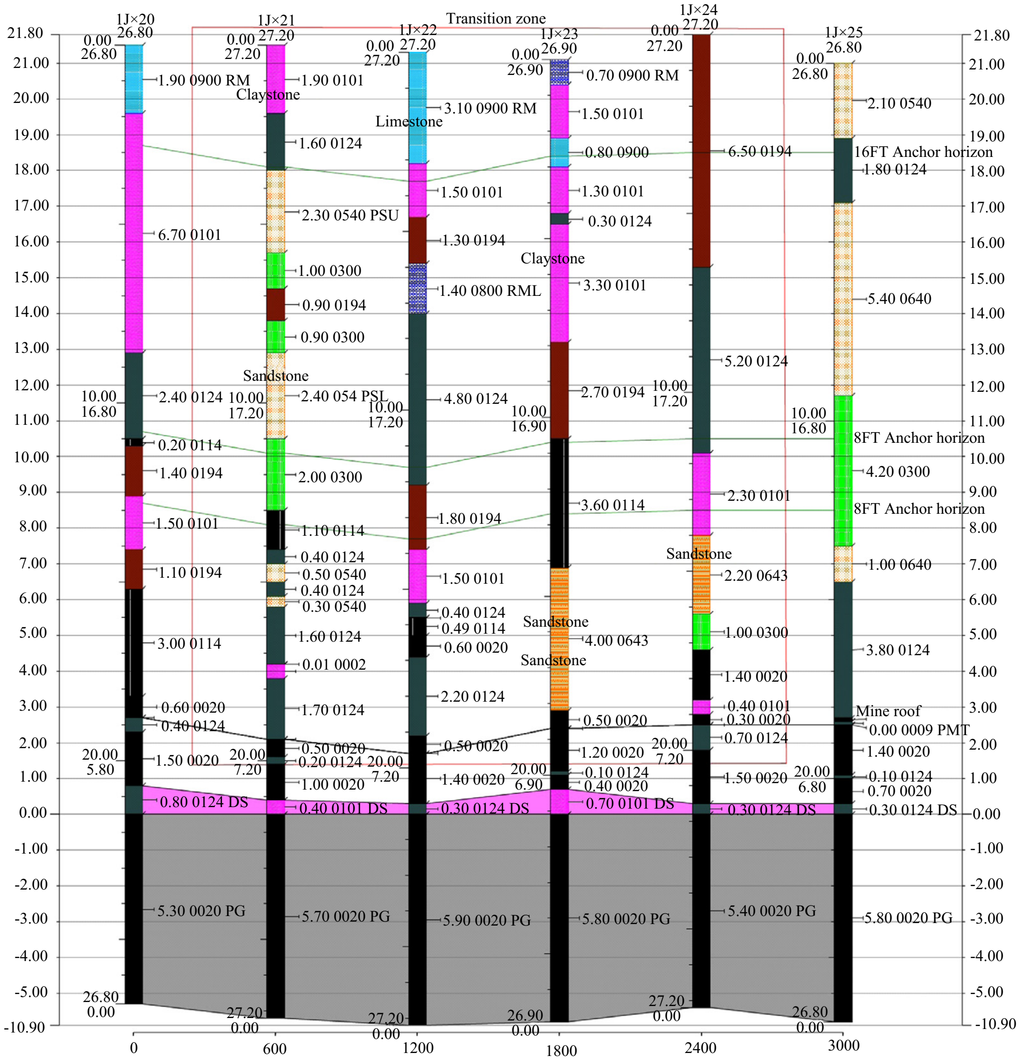

Fig. 1. Geologic cross section of the gate road.