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Lacustrine delta deposits and their effects on coal mining in a surface mine in Derbyshire, England

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ABSTRACT

Five late Carboniferous (Pennsylvanian) coal seams and associated inter-seam strata have been examined at Lodge House surface mine in the East Midlands Coalfield of England. Deposition of these coal seams and their accompanying inter-seam intervals occurred in an equatorial fluvio-lacustrine environment in an area approximately halfway between the depocentre and the southern margins of the Pennine Basin. Controls on the onset of inter-seam sedimentation and cessation of peat formation appear to have operated at two scales. Fourth order glacio-eustatic rises exerted the dominant control over formation of peats in laterally extensive mires. However, fifth order and smaller scale autocyclic mechanisms (specifically avulsion) are believed to have accompanied splitting of other seams close to, but beyond the confines of the mine.

A study of contrasting lacustrine delta deposits occupying two of the inter-seam intervals has enabled proximal, distal, wave-dominated and delta distributary channel sub-facies to be recognised. The lacustrine deltas prograded rapidly into shallow, but extensive, freshwater lakes and both delta lobe switching and avulsion of delta distributary channels were important mechanisms. The lower lacustrine delta sequence is characterised by mud-filled delta distributary channels near the top of the interval. The upper sequence is dominated by wave-formed structures and massive sandstone delta distributary channels, which formed during a period of episodic floods and strong winds.

Lacustrine delta deposits generally create good mining conditions, but delta distributary channels can present difficulties in underground mines. Mud-filled delta distributary channels subject to early compaction can give rise to 'swilleys' (elongate depressions) resulting in thickness changes and undulation of the overlying seam. When filled with strong, well-cemented, abrasive sandstone, delta distributary channel deposits can be hard to excavate. At Lodge House, the narrow width of the delta distributary channels meant that they were not detected by drilling prior to mining. Thus outcrop studies should be used to complement subsurface data as they can significantly enhance our understanding of small-scale features.

1. Introduction

The study of the sedimentary intervals between coal seams can provide insight into the controls on both the formation of these intervals and their associated coals, and yields critical information for mining. Five seams and four inter-seam intervals were recently exposed at the Lodge House surface mine in Derbyshire, England (British national grid reference SK 423 444; latitude 52° 59.7′ N, longitude 1° 22.2′ W). Coal was extracted from two areas in the mine, separated by a minor road, with a total extent of approximately 1 km by 1 km. This study examined the sequence exposed at the site concentrating on two inter-seam intervals containing lacustrine delta deposits. The mine is within the southern part of the East Pennine Coalfield (Fig. 1), and is operated by UK Coal. Five seams of Duckmantian age coal have been worked, from the Third Waterloo at the base up to the Bottom First Waterloo at the top (Fig. 2). The mine sits on the western flank of the Shipley Syncline (Fig. 3), which gives the sequence a gentle dip to the east, but faults are insignificant on the site. The shallow dip and lack of faults, together with generally soft and 'diggable' inter-seam strata (Scoble and Muftuoglu, 1984) have meant that mining of the coal has generally proved straightforward. Blasting has not been required, although sandstones above the Third Waterloo and Waterloo Marker seams have sometimes proved strong.

There has been a long history of coal mining in Derbyshire, in both deep (underground) and opencast (surface) mines (Farey, 1810), and numerous former opencast mine sites are situated close to Lodge House mine (Frost and Smart, 1979). Virtually no deep mines currently operate in Derbyshire, and exhausted opencast mines have been backfilled, restored and landscaped. Hence, few outcrops are available for study. Some data are available from geological records of former mine sites and exploration drilling but these have proved

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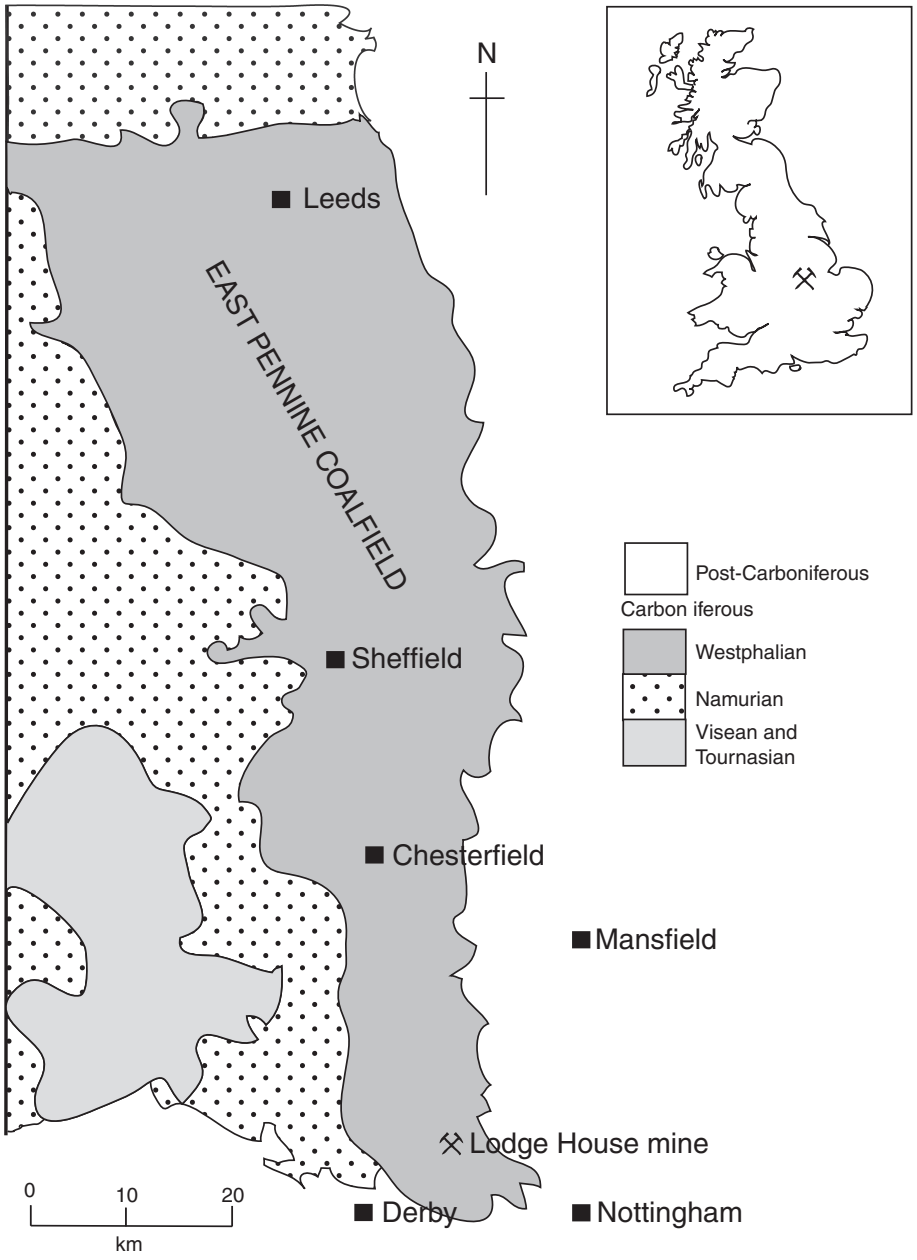

Fig. 1. Distribution of Carboniferous rocks and the extent of the East Pennine Coalfield, indicating the location of the Lodge House surface mine.

to be of variable usefulness. The Lodge House mine provided an opportunity to examine changing exposures created during the lifetime of the mine as faces advanced, allowing characteristics of the rock bodies to be documented. This study describes the facies exposed at the mine, discusses their genesis and considers the implications that they have for mining.

2. Geological background/study area

2.1. Stratigraphy

The Waterloo Seams exposed during working of Lodge House mine occur within the Pennine Middle Coal Measures Formation of Pennsylvanian (Upper Carboniferous) age (Fig. 2), in the Duckmantian European substage, which is part of the Westphalian European stage (Powell et al., 2000; Waters et al., 2007), dating to around 312 Ma (Heckel, 2008). The lowest of these seams is about 50–60 m above the Vanderbeckei (Clay Cross) Marine Band, which extends across Western Europe (Calver, 1968a), and marks the Langsettian–Duckmantian Boundary (Fig. 2). The seams are designated First to Fourth Waterloo in descending order. However, intermediate seams, laterally discontinuous seams, and complex patterns of seam splitting occur within the region (Fig. 2) (Frost and Smart, 1979; Smith et al., 1967). The seams mainly consist of bright and banded coal (vitrain and clarain), and are generally less than 1.0 m thick, with the exception of the Top Second Waterloo, which is up to 1.2 m. Some of the seams are overlain by mudstones containing bivalves such as *Anthracosia* spp. indicative of the *Anthraconaia modiolaris* Bivalve Zone. The Third Waterloo and Bottom Second Waterloo extend across the site. Although earlier surface mining has removed parts of higher seams, which formerly extended across the site, they were present in some areas of the mine and were examined during site visits.