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Stonehenge—a unique Late Cretaceous phosphatic Chalk geology: implications for sea-level, climate and tectonics and impact on engineering and archaeology

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ABSTRACT

Ground investigations for the A303 Stonehenge Tunnels revealed a unique and complex Chalk geology including the presence of the thickest (>20 m thick), and previously unknown phosphatic chalks in England, partly filling fault controlled erosional channels. The use of natural gamma-ray borehole logs to determine the presence and thickness of the phosphatic deposits is of particular value and combined with the lithostratigraphy, macrofossil and nannofossil biostratigraphy from cores has, for the first time, accurately constrained the Coniacian to Santonian age and the lenticular geometry of such deposits. Four phosphatic chalk events between 88.5–86.5 Ma are recognised associated with synsedimentary faulting. We suggest a causal link between tectonics, subsidence and channel-formation, phosphatisation events, pulses of oceanic upwelling on a frequency of about 0.5 million years to mantle-controlled plate tectonic episodes. The implications of this geology for construction of the A303 and the archaeology of the area are discussed.

1. Introduction

The A303 is a major trunk road between London and southwest England and traffic flows on the section between Amesbury and Winterbourne Stoke, Wiltshire (the section that includes Stonehenge) have been above the capacity of the road for some years. In 1995, Highways England put forward proposals to upgrade the A303 past Stonehenge. This included a cut-and-cover tunnel excavated in Upper Cretaceous Chalk. Rejection of a cut-and cover option led to new plans in 2002 for a 2.1 km (1.3 miles) bored tunnel with an estimated cost of £183 million. Ground investigations for the A303 Stonehenge Tunnels revealed a complex succession of phosphatic chalks >20 m thick (Figs. 1–3). This paper represents a benchmark total rock understanding of the ground in the area south of the A303 at Stonehenge based on surveys for design of a tunnel scheme being proposed in 2000 and taken to Public Inquiry in 2004 (with surveys in 2001–2003)—which failed to progress beyond this stage. This was the scheme option favoured at that time to mitigate some of the impacts of this scheme on the ecology, historic environment and landscape of this location.

Phosphatic chalks are rare in Europe, generally occurring as small outcrops or subcrops as local channel-fills in southern England and northern France (e.g. Jarvis, 1980, 1992, 2006; Mortimore and Pomerol, 1987). It was a complete surprise, therefore, to find the thickest phosphatic chalks in England during the 2001–2002 investigations (Mortimore, 2001) for the proposed A303 Stonehenge tunnels (Fig. 3). The nearest phosphatic Chalk deposits of a similar age to Stonehenge (Fig. 1) are at Boxford and Winterbourne north of Newbury in Berkshire and Taplow (South Lodge Pit) near Maidenhead, Buckinghamshire (Strahan, 1891,

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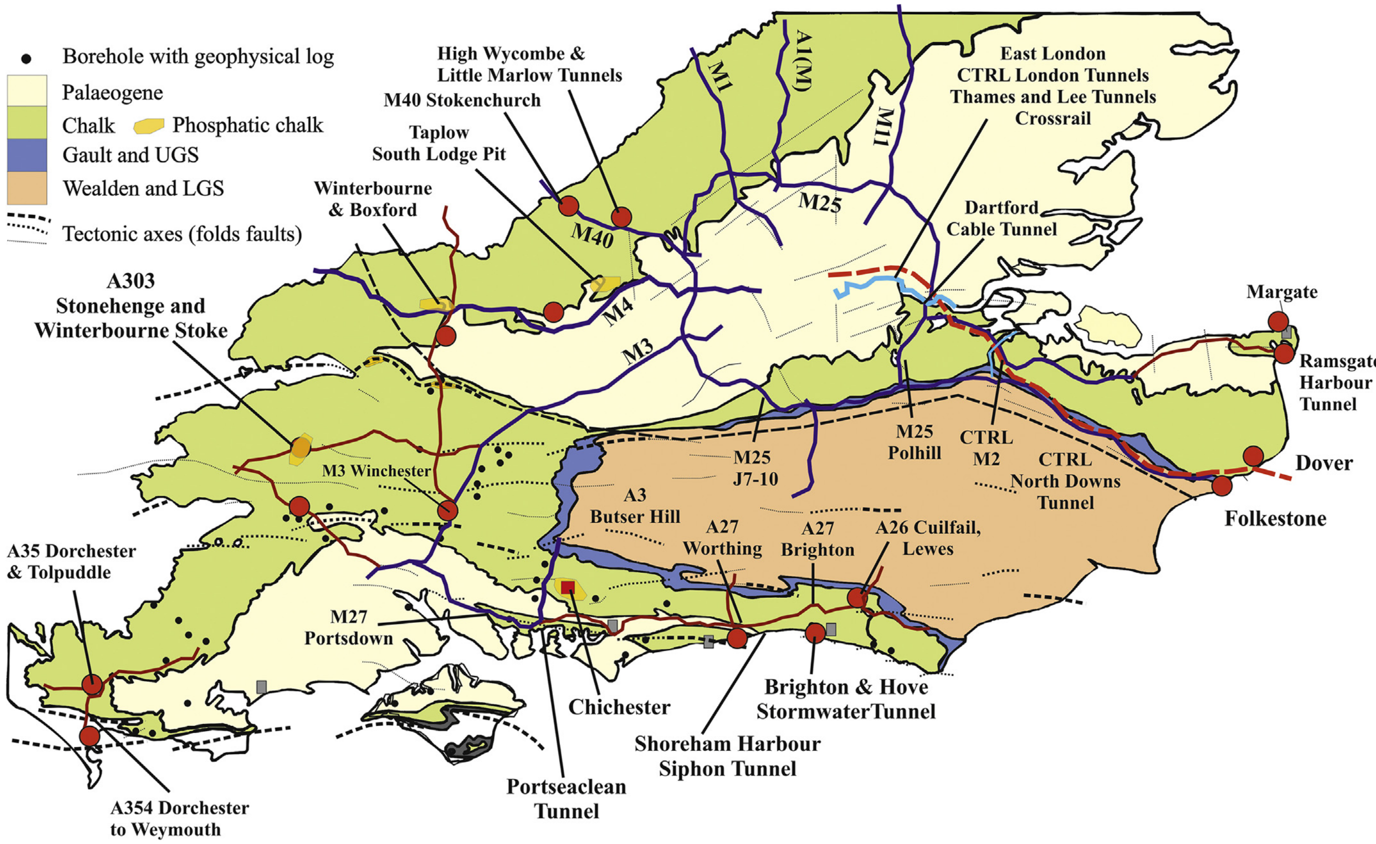

Fig. 1. Location of the A303 Stonehenge investigations in relation to southern England geology and other major Chalk engineering schemes.

1895; Hawkins, 1948; Jarvis, 1980, 1992; Jarvis and Woodroof, 1981). Limited exposure and no or few boreholes have made these other localities difficult to analyse and interpret. Many of these deposits also have little or no surface expression, making them very difficult to identify without excavations or boreholes. More extensive, mined deposits in the Somme Basin, northern France (Pomerol et al., 1980; Monciardini, 1989), have been used as analogues for the English deposits (Jarvis, 1980, 1992, 2006). At none of these localities has it been possible to completely reconstruct the total age range and sequence of geological events that formed these phosphatic chalks. The great number of cored boreholes and geophysical logs through the Stonehenge deposits are a first chance to provide a more complete geological setting for such deposits in Europe and assess the wider implications for Cretaceous marine environments. We argue that tectonic movements created the sea-bed setting and space for at least the thickest phosphatic chalk deposits at Stonehenge during a period of relative sea-level high which included oscillations and pulses of oceanic upwelling possibly related to mantle-controlled plate tectonics. In this respect the Stonehenge geological setting appears to have greater affinity with the fault-controlled phosphatic chalks of the Mons Basin, Belgium (Robaszynski, 1989; Robaszynski and Martin, 1988) rather than the submarine-channel formed deposits of northern France (Jarvis, 1992, 2006).

Cancellation of the original proposed A303 Stonehenge Tunnels and the Amesbury to Winterbourne Stoke improvements was in large part due to the unexpected geology and unexpected groundwater conditions around Stonehenge which led to construction costs more than doubling to £470 million in July 2005. Whether such geology also has implications for the archaeology of Stonehenge and location of flint mines is discussed.

2. Discoveries during the A303 Stonehenge ground investigation

Rotary cored boreholes drilled during the first A303 Stonehenge Amesbury to Winterbourne Stoke investigation improvements (Figs. 3 and 4) in 2001 identified 'normal' white chalk with flint bands. One borehole (BHR12, Fig. 4 section D), however, indicated the presence of an unusual deposit of phosphatic chalk (Mortimore, 2001). The surprise at finding previously unknown phosphatic chalks at Stonehenge was reinforced during the second ground investigation. This time, one borehole (BHR142, Fig. 4 section D) recorded the thickest known phosphatic chalk deposits in England (Mortimore, 2002, 2003). Other boreholes and trial pits were then checked and the phosphatic chalk deposits, comprising several 'events', appeared to be present over an area west of Stonehenge Bottom (Figs. 3–5). Evidence from lithological and fossil marker beds gave a clue to the age of these deposits and knowledge from other phosphatic deposits in southern England and northern France (e.g. Jarvis, 1980, 1992, 2006) provided clues to the chemistry of the sediments and the likely form of the sedimentary bodies.

2.1. Sorting out the stratigraphy, borehole correlations and geological long sections for the A303 Stonehenge Amesbury to Winterbourne Stoke route

Little specific geological information is available from the published literature along the proposed new route of the A303. The range of potential engineering (tunnelling, earthworks, foundations), required a geological framework, especially a detailed stratigraphy for the whole scheme. When ground investigations

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