Geoscience Frontiers 7 (2016) 273–286

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Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research paper

High-resolution geological maps of central London, UK: Comparisons with the London Underground

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ARTICLE INFO

Article history:
Received 31 March 2015
Received in revised form
14 May 2015
Accepted 21 May 2015
Available online 25 June 2015

Keywords:
London
London Underground
London Clay
Lambeth Group
Chalk
Tunnelling
Boreholes

ABSTRACT

This study presents new thickness maps of post-Cretaceous sedimentary strata beneath central London. >1100 borehole records were analysed. London Clay is thickest in the west; thicker deposits extend as a narrow finger along the axis of the London Basin. More minor variations are probably governed by periglacial erosion and faulting. A shallow anticline in the Chalk in north-central London has resulted in a pronounced thinning of succeeding strata. These results are compared to the position of London Underground railway tunnels. Although tunnels have been bored through the upper levels of London Clay where thick, some tunnels and stations are positioned within the underlying, more lithologically variable, Lower London Tertiary deposits. Although less complex than other geological models of the London Basin, this technique is more objective and uses a higher density of borehole data. The high resolution of the resulting maps emphasises the power of modelling an expansive dataset in a rigorous but simple fashion.

1. Geological background

The centre of London, the largest city in the EU with a population approaching 15 million, is located approximately on the axis of an E–W-trending syncline that constitutes the greater part of the London Basin. This structure formed during late-Oligocene to mid-Miocene times in response to the Alpine orogeny (Ellison et al., 2004). Cretaceous chalk is the major aquifer: in central London, the Chalk is covered by a thick (up to 70 m) blanket of Cenozoic sediments. These sediments include the Eocene-aged London Clay Formation, though which much of the London Underground network was bored, and the more varied underlying strata collectively termed the Lower London Tertiary deposits (Sumbler, 1996; Ellison et al., 2004).

Attempts to model or map the sub-surface geology of the London Basin initially focused on a limited number of heavily simplified cross-sections through the entire basin (Whittaker, 1872, 1889; Dewey and Bromehead, 1921). Indeed, the geological structure of the Cretaceous and Palaeogene sediments that overlie the Palaeozoic basement (the London Platform) has been described as "relatively simple" (Ellison et al., 2004). Only two faults—between Wimbledon and Streatham, and at Greenwich—are currently shown on the largest-scale geological maps. However, minor faults and folds superimposed on this simple synformal structure have been known for nearly a century (Wooldridge, 1923, 1926). Currently, there is a growing body of evidence for a considerably greater degree of complexity in the structure of the Chalk and the succeeding stratigraphy, localised swarms of sub-vertical faults, and Pleistocene-aged periglacial erosive features (Berry, 1979; Newman, 2009; Newman et al., 2010; Royse, 2010; Royse et al., 2012).

Such discoveries have largely arisen due to a major leap forward in our collective computational ability to model the sub-surface in three dimensions. 3D block models have typically been applied to the entire London Basin (Royse, 2010; Mathers et al., 2014), or to discrete localities with implications for major civil engineering projects (e.g. Aldiss et al., 2012). This study focuses upon an intermediate scale: central London, as approximately delineated by the central Travel Zone 1 of Transport for London (Fig. 1). Surfaces and isopachs of the Palaeogene sedimentary succession are computed and discussed with reference to the position of deep London Underground railway tunnels. 1122 records from the British Geological Survey (BGS) borehole scan archive were extracted and processed (available in the Supplementary Materials attached to this article).

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Peer-review under responsibility of China University of Geosciences (Beijing).

http://dx.doi.org/10.1016/j.gsf.2015.05.004
1674-9871/

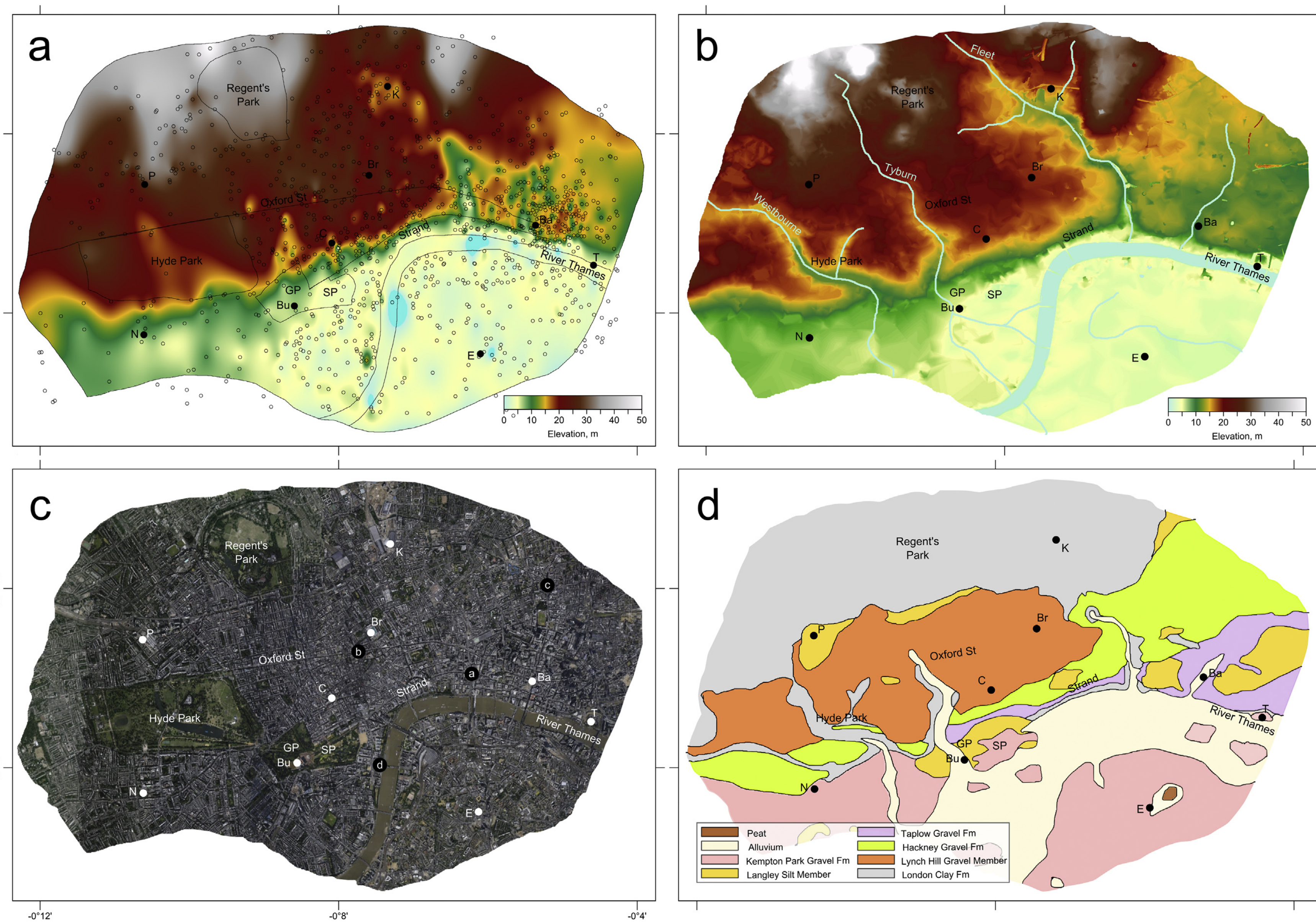

Figure 1. (a) Topographic map of central London, based on borehole elevation data. Open circles = 1122 boreholes used in this study. GP = Green Park; SP = St James's Park; Ba = Bank of England; Br = British Museum; Bu = Buckingham Palace; C = Piccadilly Circus; E = Elephant and Castle; K = King's Cross railway station; N = Natural History Museum; P = Paddington railway station; T = Tower of London. (b) Topographic map based on OS Terrain 5, a 5 m-resolution Digital Elevation Model (DEM). Anomalous linear features in NE = railway cuttings. Blue lines = subterranean rivers (Barton, 1992; Paul and Blunt, 2012). (c) Landsat satellite image. Lettered black circles = location of photos in Fig. 3. (d) Superficial and bedrock geology, digitised from the BGS DiGMapGB geological dataset.