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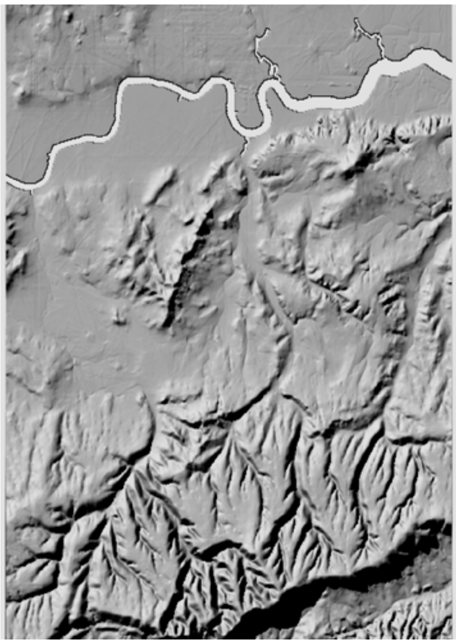
Top Chalk structure and Palaeogene stratigraphy in the Ravensbourne Catchment, South London

Integrated Geoscience Surveys South

Commissioned Report CR/02/250N



BRITISH GEOLOGICAL SURVEY

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Top Chalk structure and Palaeogene stratigraphy in the Ravensbourne Catchment, South London

A J Newell

Key words

South London; Chalk; Palaeogene.

Front cover

Shaded relief image of the Ravensbourne Catchment

Bibliographical reference

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Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

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1 Introduction

1.1 BACKGROUND

The Chalk aquifer in the Central London Basin is mainly well confined, with the Chalk cropping out in the Chilterns and the North Downs. Within this simplified hydrogeological framework, the Ravensbourne catchment in South East London is complicated by having;

- Unconfined Chalk;
- Significant areas where the London Clay is absent, and
- Significant areas where the Harwich Formation crops out.

The result is a hydrogeologically complex groundwater catchment within which there are many groundwater abstractions for public and private use. Understanding how these abstractions affect the groundwater system and water balance is important for future water resource planning and management (particularly for Thames Water the water undertaker).

This report provides the results of a 10-day study whose aim was to improve our understanding of the geological structure and stratigraphy of the Ravensbourne area. The report focuses on two main aspects:

- Top Chalk structure
- Palaeogene stratigraphy and its possible influence on aquifer properties

1.2 DATASETS AND METHODS

The work made use of the following datasets:

- British Geological Survey (BGS) 1:50 000 scale paper/digital geological maps (Figure 1)
- BGS digital 'Tectonic Map of the UK'
- 36 digital gamma-ray logs held in the BGS borehole geophysics database (WELLOG)
- High resolution (5 m cell) digital terrain model (DTM)
- Information on depth to Chalk from 1265 boreholes held in the BGS LOCUS (London Computerised Underground and Surface Geology) database (Figure 1)
- BGS South London Memoir (Dewey and Bromehead, 1921)

Data were manipulated and compiled using ArcView GIS, Surfer, CorelDraw, Excel and the BGS in-house geophysical log software WELLOG.

2 Geological structure

2.1 REGIONAL SETTING

The Ravensbourne Catchment lies on the southern limb of the 'London Basin', a broadly west-east trending structural basin developed to the north of the Weald Anticline (Figure 2). In the catchment area, the fold limb generally dips at a low angle (approximately 1°) toward the NNE. Chalk is exposed in the southern part of the area, dipping northwards beneath a cover of Palaeogene deposits (see Figure 4).

The London Basin is not a simple, laterally continuous syncline but is developed as two distinct troughs which are offset and separated by a relatively shallow 'bridge' which trends N-S under central London and includes the area of the Ravensbourne Catchment (Figure 2). On the elevated 'bridge' the top Chalk surface does not generally descend below –45 mOD, in contrast to the adjacent troughs where top Chalk plunges to –100 mOD (Figure 2). The bridge is characterised by minor fold structures and also normal faults, which are an unusual feature within the London Basin where the Palaeogene is generally unfaulted.

2.2 DETAILED STRUCTURE

Beneath the Palaeogene cover in the northern part of the Ravensbourne Catchment the geological structure is complex. Dewey and Bromehead (1921) identified two main sets of structures that are broadly orientated at right angles to each other (Figure 3):

The younger, and dominant set, trends roughly SW-NE and includes two faults and a major syncline:

- The **Greenwich Fault** downthrows to the NW and brings Woolwich Formation against Thanet Sand at Greenwich, Thanet Sand against Chalk at St John's and London Clay against Woolwich Formation at Brockley, it dies out near Dulwich (Dewey and Bromehead, 1921). In the St John's area, the Greenwich Fault has a downthrow of approximately 50 m to the NW at the level of top Chalk (Figure 4).
- The **Malden-Deptford Fault** extends from Raynes Park to Herne Hill and appears to die out toward Deptford. The fault downthrows to the NW. Its effect on outcrop is seen around East Dulwich where it brings London Clay against the Lambeth Group. In the Dulwich area, the fault has a downthrow of approximately 20 m to the NW at the level of top Chalk (Figure 8). Like the Greenwich Fault, the Malden-Deptford Fault is a large structure that extends from surface downwards into Palaeozoic basement, which underlies London at a depth of approximately - 400 mOD (British Geological Survey, 1998).
- The **Crystal Palace Syncline** is located to the southwest of the Greenwich/Malden-Deptford fault zone and has the form of an elongated closed basin (Figure 5). The syncline depresses the top Chalk surface to a maximum depth of -50 mOD under Crystal Palace (Figure 4).

A second, older and less pronounced, set of fold structures trends approximately NW-SE. The most important element is the **Lewisham-Chislehurst Anticline** which brings Chalk to the surface at Lewisham and Chislehurst (Figure 3). A number of smaller, similar trending fold structures occur to the west of this anticline (Figure 3).

The overall structural effect of intersecting the two orthogonal fold sets is to deform top Chalk into a series of low-relief basins and domes (Figure 5). On the solid geology map, the most conspicuous dome is the **Deptford Dome,** which appears as a circular outcrop of Chalk surrounded by Thanet Sand Formation. It might be expected that fold intersections are zones of high fracture density but this hypothesis is untested.

3 Stratigraphic framework

3.1 OUTCROP DISTRIBUTION AND THICKNESS

In the Ravensbourne Catchment, Chalk dips northward beneath a cover of Palaeogene sediments. In southern England, Palaeogene deposits locally reach 700 m in thickness and extend from the Palaeocene into the Early Oligocene. However, in the Ravensbourne Catchment, the Palaeogene succession is deeply eroded and is preserved only to the level of the Early Eocene London Clay. The maximum thickness of about 120 m of Palaeogene is preserved under Crystal Palace (Rockhill Reservoir, Figure 6). Over most of the catchment the Palaeogene does not exceed 40 m thick (Figure 6). The sediments comprise marine to marginal marine sands, silts, clays and shell beds and, because of their shallow burial, are mostly weakly consolidated.

3.2 RELATIONSHIP BETWEEN THE CHALK AND PALAEOGENE

The Chalk and Palaeogene are structurally conformable, but are separated by a time-gap of some 25 million years. The time-gap is made up from two separate components:

1. Chalk underlying the Palaeogene has been deeply eroded. The age of the sub-Palaeogene Chalk in the Ravensbourne Catchment is Santonian, indicating the probable removal of >150 m of Campanian and Maastrichtian chalks (Curry, 1992).
2. There is a 7 million year time gap at the base of the Palaeogene: the earliest deposits are Late Paleocene in age.

The major phase of erosion and non-deposition between the Chalk and the Tertiary is locally expressed by the development of strong erosional relief.

3.3 PALAEOGENE LITHOSTRATIGRAPHIC FRAMEWORK

The lithostratigraphical nomenclature used in this report (Table 1) is that established by Ellison et al. (1994).

THAMES GROUP	London Clay Formation	Claygate Member
	Harwich Formation (*Blackheath Beds*)	
LAMBETH GROUP	Reading Formation	Woolwich Formation
	Upnor Formation	
	Thanet Sand Formation	
CHALK GROUP		

Table 1. Palaeogene lithostratigraphy in South London

The oldest formation is the Thanet Sand Formation representing sandy inner shelf deposits. The Lambeth Group consists of the Upnor Formation, a generally thin transgressive unit of shallow marine to lagoonal facies, overlain by a complex interdigitation of continental facies (Reading Formation) and nearshore marine to lagoonal (Woolwich Formation). The Harwich Formation, which in the Ravensbourne Catchment, includes the locally incised 'Blackheath Beds' at its base, represents the re-establishment of shallow marine conditions throughout the area with the London Clay marking a further deepening of the sea.

3.4 THANET SAND FORMATION

Cored boreholes in central London show that the Thanet Sand consists of homogeneous fine-grained sands throughout (Ellison et al., 1994). The characteristic upwards-decrease in gamma-ray response probably results therefore from an upward decrease in glauconite content rather than clay (see Figure 9). The thickness of the Thanet Sand appears relatively uniform acoss the Ravensbourne Catchment, with an average thickness of 12 m. A layer of green-coated flints known as the 'Bull Head Bed' marks the contact of the Thanet Sand with the Chalk.

3.5 LAMBETH GROUP

The Lambeth Group consists of the Upnor Formation and the overlying Woolwich and Reading formations. It is generally around 12-15 m thick.

3.5.1 Upnor Formation

The Upnor Formation ranges up to 5 m thick and consists of medium-grained, glauconitic quartzose sands with a variable proportion of well-rounded flint pebbles. Cored boreholes in central London have shown that the most complete Upnor successions display a sharp two-fold facies division:

- The lower division is represented by glauconitic calcareous pebbly sandstones with a rich marine microfauna in the lower part.
- The upper division is represented by non-calcareous glauconitic sandstones and conglomerates with a restricted microfauna. Two conglomerate units are commonly present with the lower unit consisting of black pebbles in a glauconite matrix and the upper unit consisting of brown to cream coloured pebbles in a non-glauconitic sandy or muddy matrix. The upper conglomerate is probably continental and is thought to be related to the overlying Reading Beds (Ellison et al., 1994).

Gamma-ray logs of the Upnor Formation may show an upward decrease in values reflecting a change from glauconite-rich to glauconite-poor lithologies (see Figure 9).

3.5.2 Woolwich and Reading formations

The Woolwich and Reading formations represent an interdigitation of two contrasting sediment types:

Reading Formation: Clay is the dominant lithology and is red mottled due to pedogenic processes. The proportion of sand beds varies considerably and may constitute more than half.

Woolwich Formation: Highly variable lagoonal deposits consisting largely of interlaminated fine-grained sands, silts and clays. Plant debris is common and is locally concentrated into lignites. Shelly beds consist of brackish water shells in a dark clay matrix. Limestones occur locally.

In the Ravensbourne area, the typical vertical facies succession is:

- 2 m of red-mottled clay (lower Reading Formation)
- 5 m succession coarsening-upwards from clay to sand (lower Woolwich Formation), sometimes capped by red-mottled clay (upper Reading Formation)
- 1-2 m of grey shelly clays and thin limestones (upper Woolwich Formation)

3.6 HARWICH AND LONDON CLAY FORMATIONS (THAMES GROUP)

3.6.1 Harwich Formation

The Harwich Formation separates the Lambeth Group from the London Clay. In the Ravensbourne area, the Harwich Formation consists of loose, yellow and white, cross-bedded, coarse-grained sands and sandy pebble beds which are called the 'Blackheath Beds'. The pebbles are black, extremely well rounded flints which range up to 0.2 m in diameter. The associated sands are clean and contain very little glauconite. The beds contain a mixture of marine and estuarine shells. The pebble beds can range up to 10 m thick, but in the Ravensbourne area are generally 5 m or less. The base of the formation is an erosion surface which can cut deeply into underlying strata. The correlation presented in Figure 10 suggests that the Blackheath Beds thin toward the NW and pass into intercalated sands and clays.

The Ravensbourne Catchment broadly coincides with the western edge of the Blackheath Beds, which do not occur to the west of Croydon (Figure 7). In the subsurface, the northwestern limit broadly coincides with the point where they are truncated by the Malden-Deptford Fault (Figure 8).

The presence of the gravelly Blackheath Beds has an important impact on the topography of the Ravensbourne Catchment where the characteristic steep scarps and gently inclined slopes dipping into river valleys are capped by the Blackheath Beds (Figures 7 and 8). Where the gravels are absent west of Croydon the topography becomes more subdued and rounded (Figure 7).

3.6.2 London Clay

The Blackheath Beds pass abruptly into homogeneous dark bluish grey clay of the London Clay Formation. Gamma-ray logs show that 15-20 m above their base the clays coarsen-upwards into silts and sands which may form a minor heterolithic aquifer unit (Figure 9).

The NE-SW trending Crystal Palace ridge is capped by the Claygate Member of the London Clay Formation which comprises interbedded sands, silts and clays.

4 Lithostratigraphical control on aquifer properties

4.1 GAMMA-RAY LOGS AND AQUIFER CHARACTERISATION

Gamma-ray logs are widely used to locate the depth of key stratigraphic surfaces and to subdivide formations into units of sand and clay. The ability to run gamma-ray tools under any conditions - in air, any salinity fluid, openhole or cased wells - makes it one of the most popular and commonly available logs. The gamma-ray tool measures natural radioactivity of rocks in a similar way to a geiger counter. The sources of radiation are almost entirely from isotopes of thorium, uranium, and potassium. Although the radioactivity of most rocks is fairly low, it is sufficient to make a clear distinction between clean quartz sands or gravels (low radioactivity) and clays or clayey sands (higher radioactivity). Careful interpretation is required in sands rich in orthoclase feldspar or glauconite as their high levels of potassium can cause sands to have gamma count rates as high or higher than clay beds. The Palaeogene of the Ravensbourne area has two glauconite-rich intervals at the base of the Thanet Sand Formation and at the base of the Upnor Formation (Figure 9). Choosing a suitable cut-off value to delineate sands and clays provides a useful means of delimiting aquifer and aquitard layers within the Palaeogene succession. In this case of Figure 9, a value of 30 CPS is a satisfactory boundary to differentiate sands/gravels (below 30) and clays (above 30).

4.2 AQUIFERS

The gamma-ray cut-off log for Adenmore Road (Catford Station) shows that the Palaeogene is a multi-layered aquifer with three main units (Figure 9):

- Aquifer A: Thanet Sand and Upnor Formation (13 m thick)
- Aquifer B: Harwich Formation (5 m thick)
- Aquifer C: Sands within the London Clay (7 m thick)

4.3 AQUITARDS

The basal London Clay and Reading and Woolwich formations form the principal aquitards (Figure 9). The London Clay aquitard is a relatively uniform clay sequence 22 m thick at Adenmore Road. The Reading and Woolwich aquitard is 8 m thick and has a complex architecture with the following features that may reduce its effectiveness as an aquitard:

- The clay beds are generally thin (<2 m)
- Clays are intercalated with sands (Figure 10)
- Erosion at the base of the Harwich Formation can reduce the thickness of the Reading and Woolwich formations (e.g. see Bromley Reservoir on Figure 10) or even cut into the underlying Upnor/Thanet Sand formations.

However, correlation of gamma-ray logs across the catchment suggests that, although thin, the clay beds have extensive lateral continuity and probably represent a significant permeability barrier (Figure 10).

5 Conclusions

- The Ravensbourne area has complex geological structure produced by two intersecting sets of folds truncated by NW-SE trending faults.
- Palaeogene strata form a complex multi-layer aquifer.
- The development of the Harwich Formation as a highly permeable gravel deposit (‘Blackheath Beds’) may have an important influence on the hydrogeology of the catchment. The Blackheath Beds generally form extensive ‘dip slopes’ which incline toward valley bottoms.

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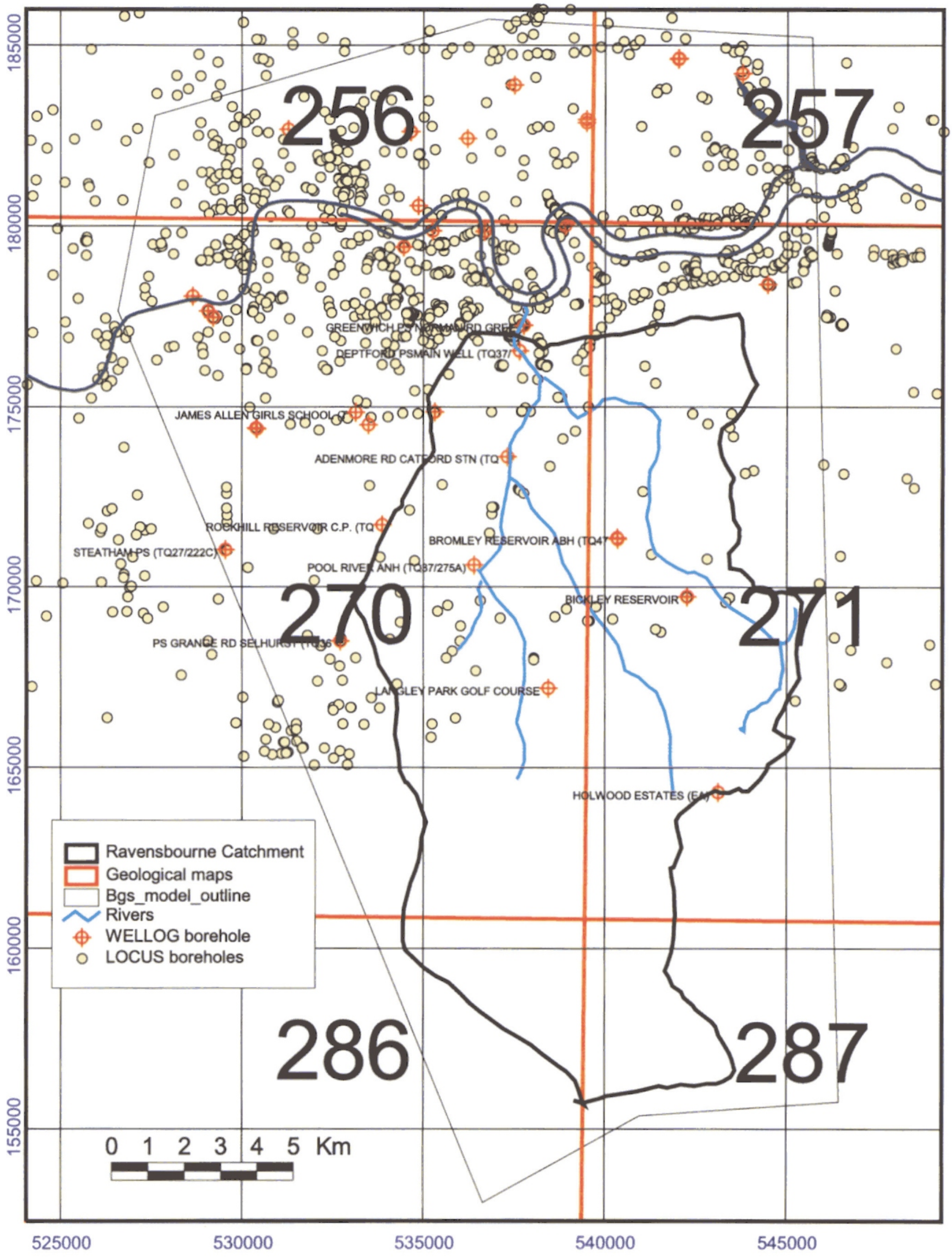

Figure 1. Map showing data coverage

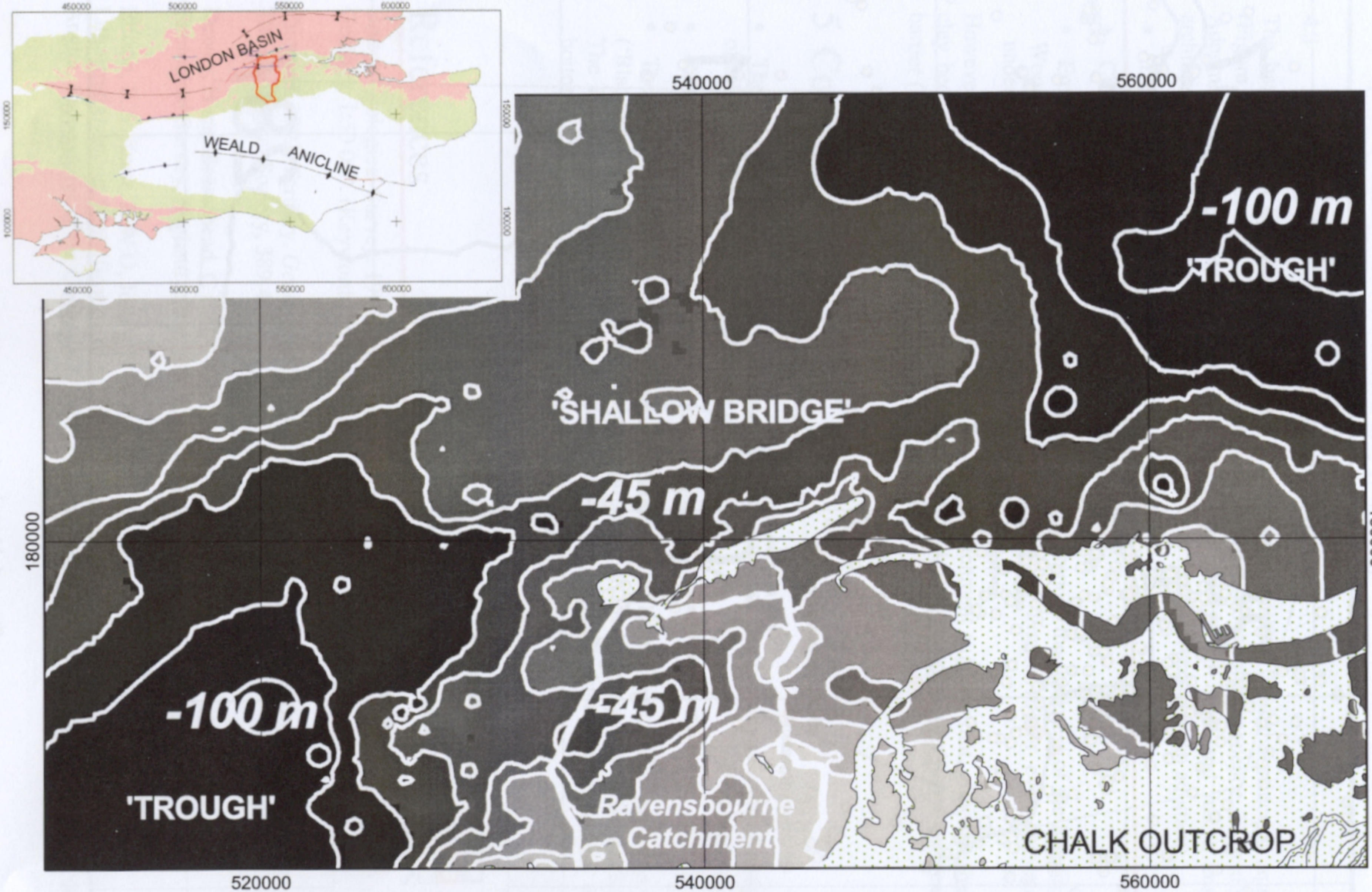

Figure 2. Regional geological setting (inset map) and contoured surface on top Chalk in the central London Basin

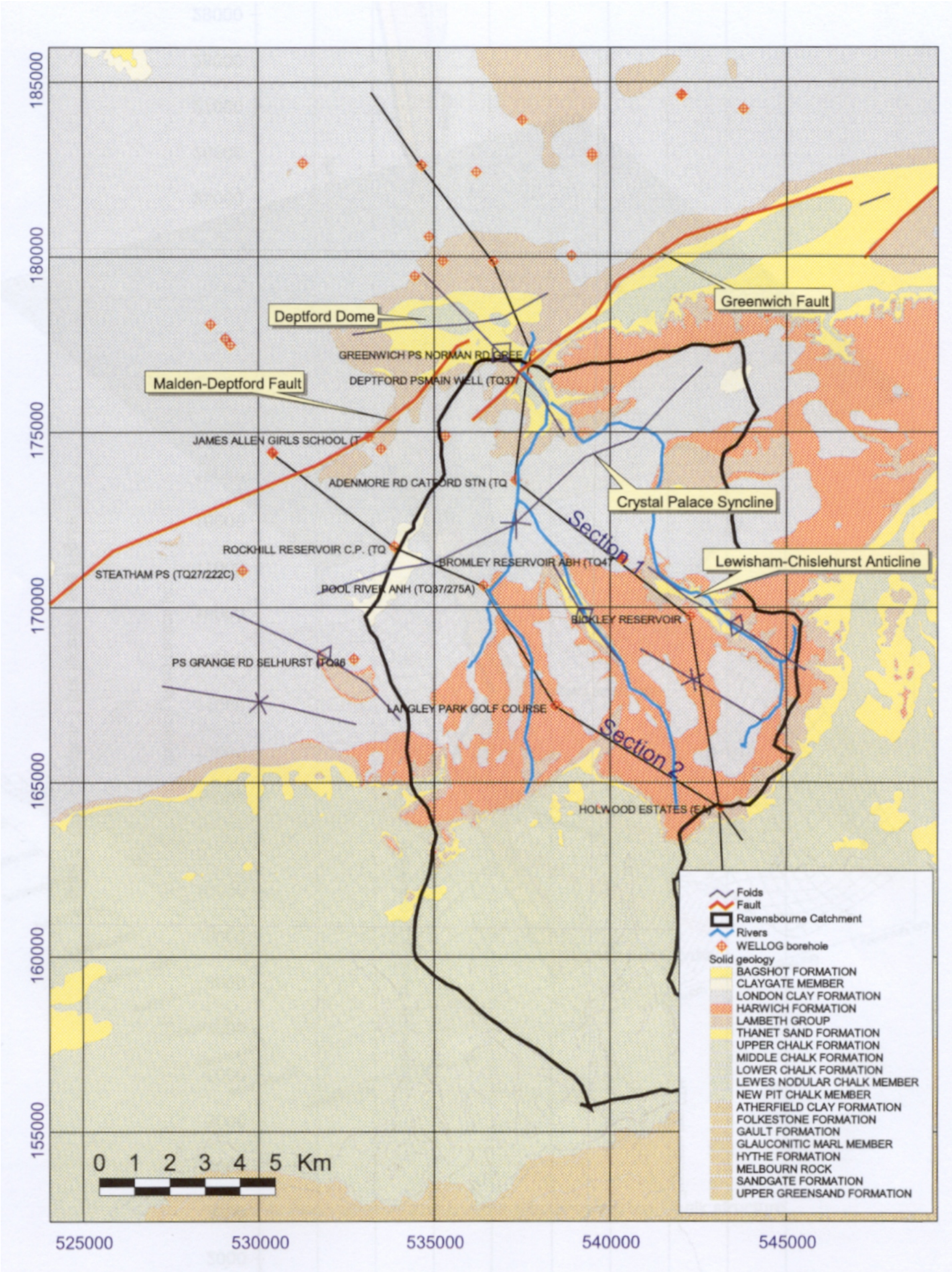

Figure 3. Geological map annotated with major structures

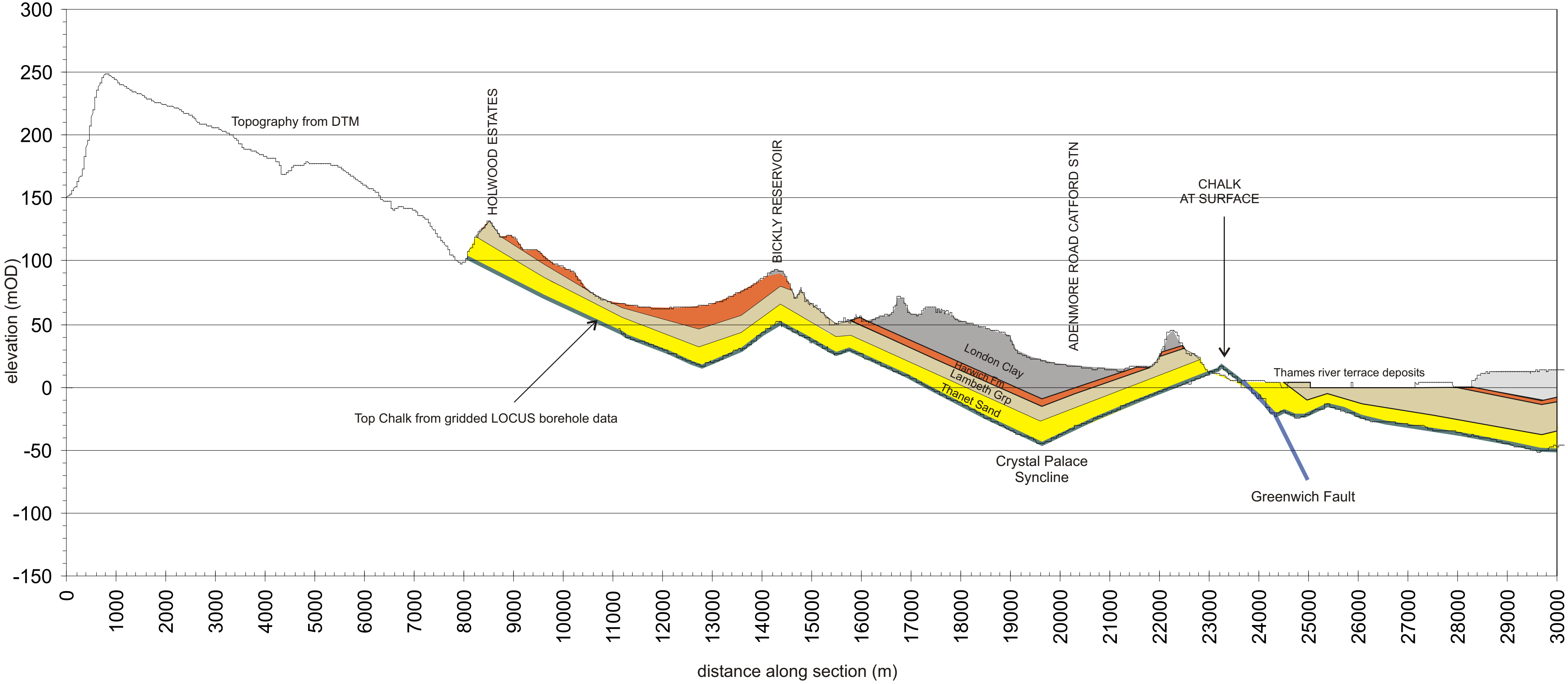

Figure 4. Cross-section 1 (for location see Figure 3)

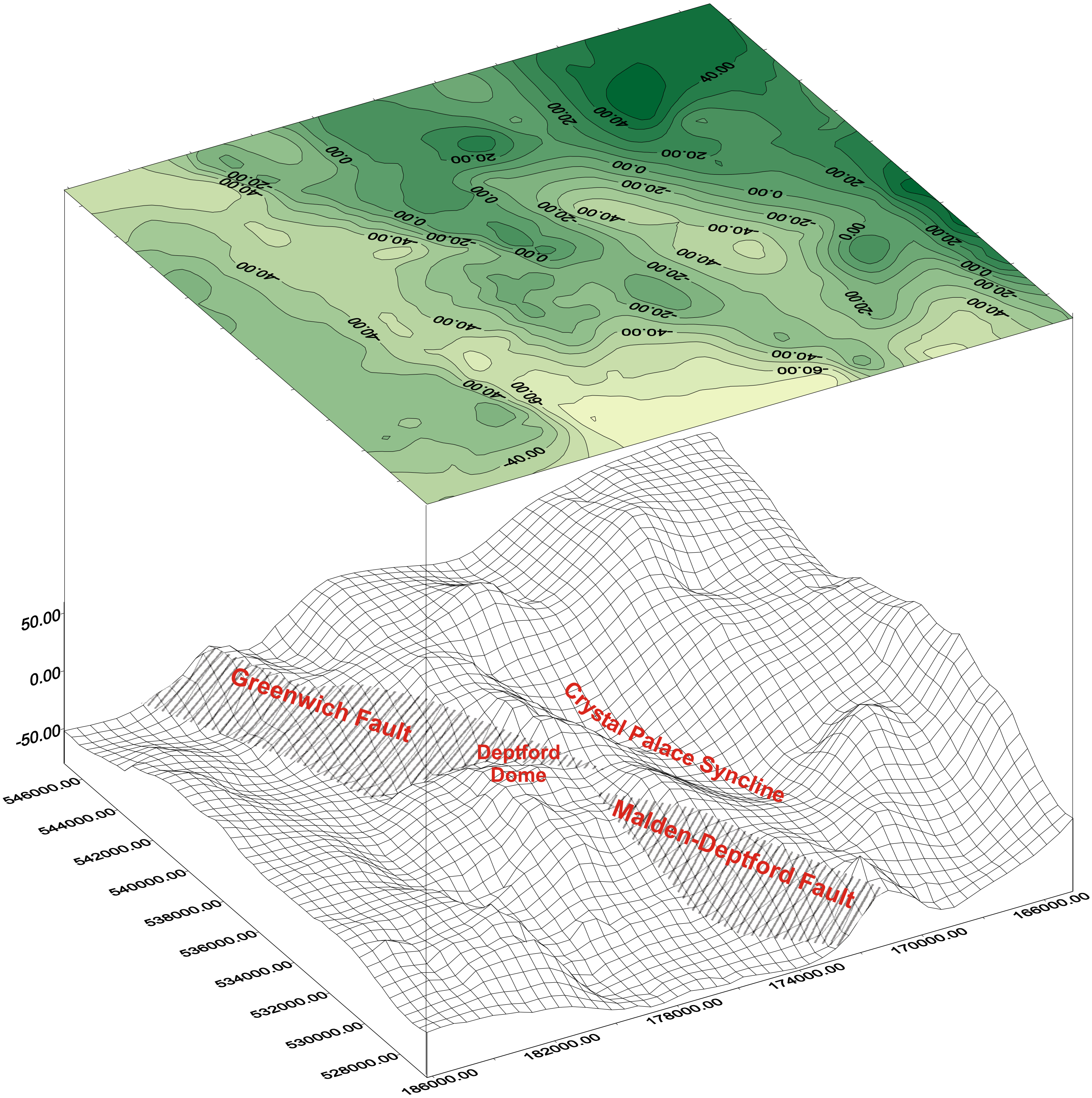

Figure 5. Mesh diagram and contour map showing top Chalk structure

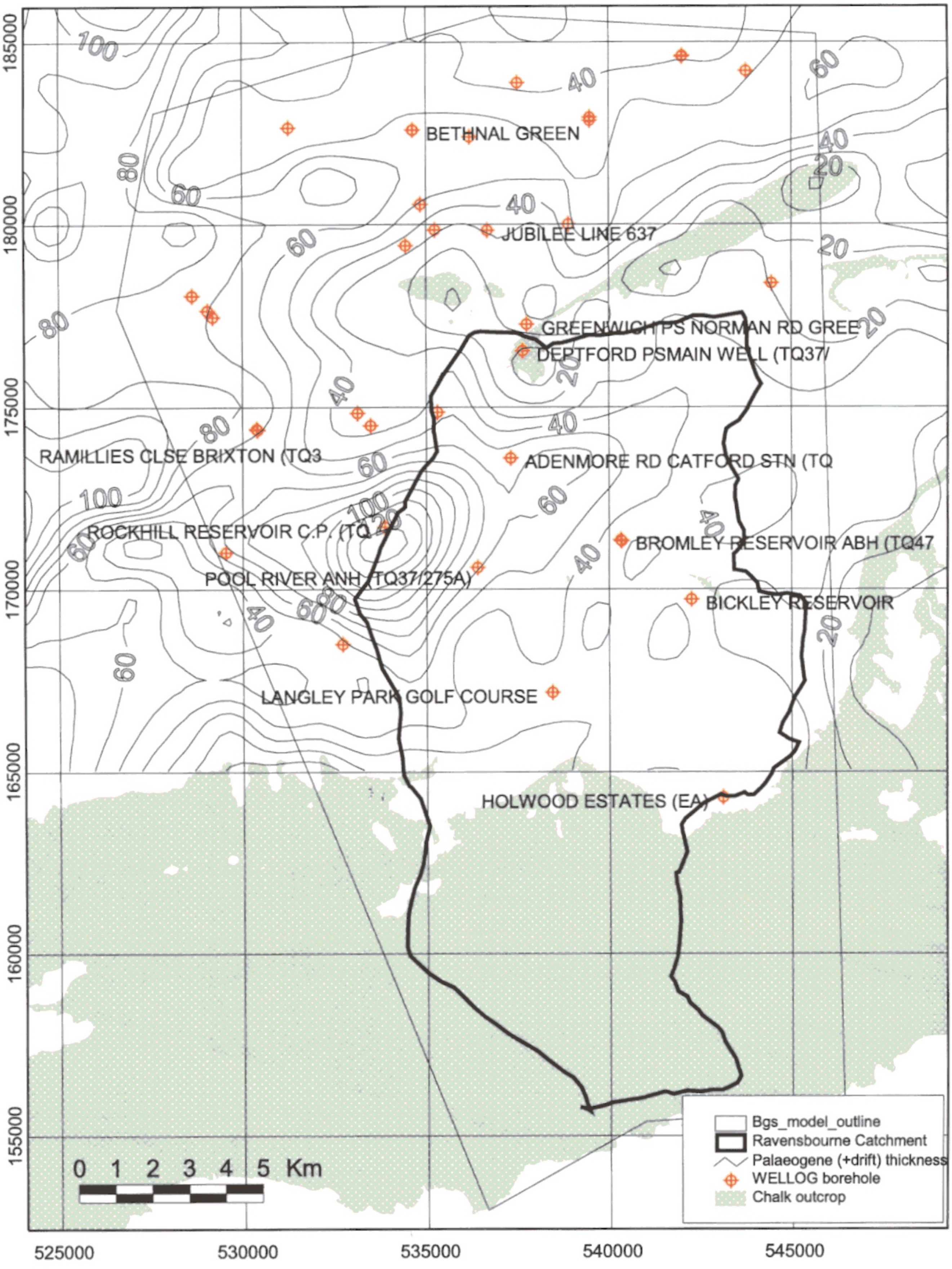

Figure 6. Map showing thickness of Palaeogene (+ drift where present)

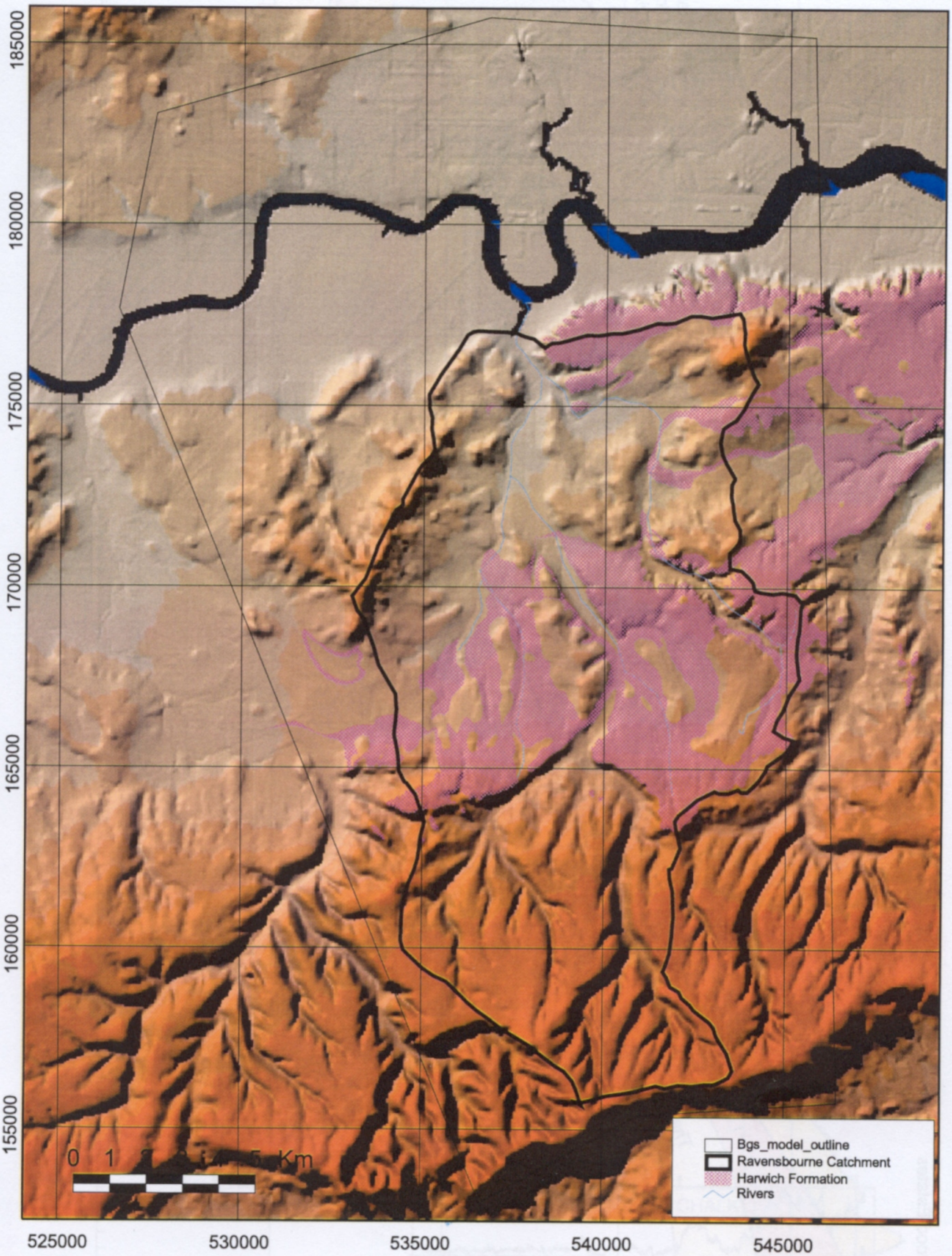

Figure 7. Harwich Formation outcrop overlain on DTM

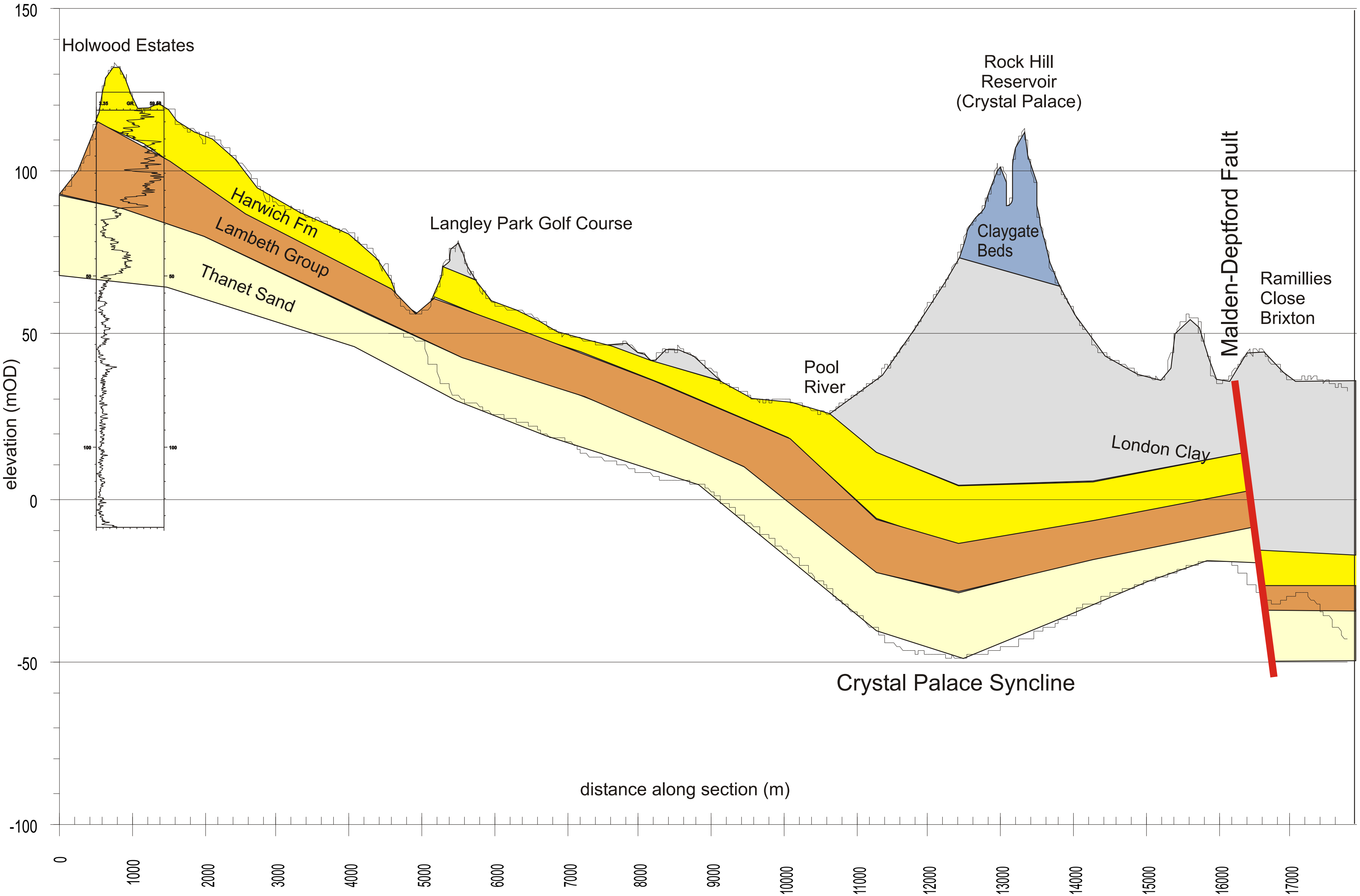

Figure 8. Section 2 (for location see Figure 3)

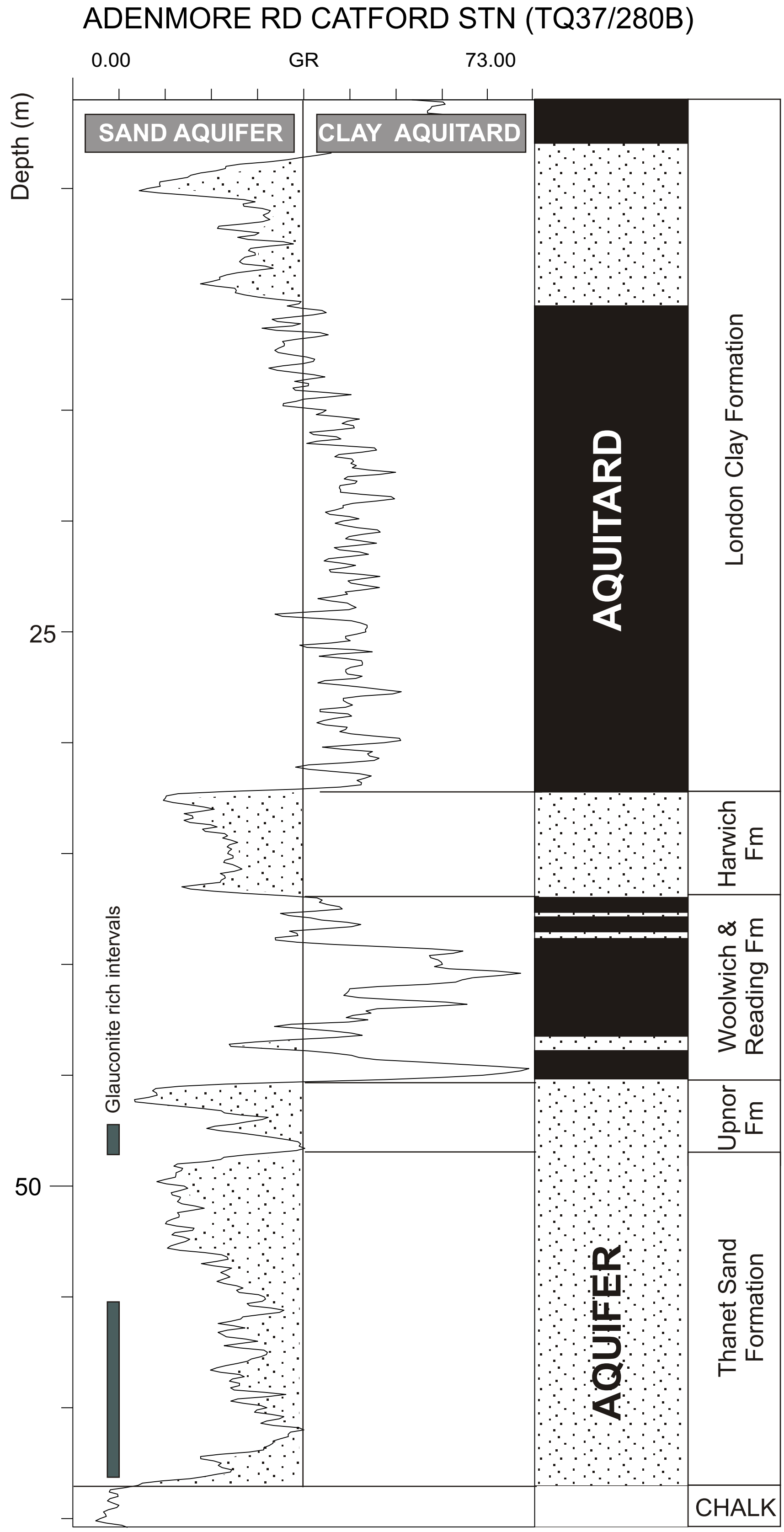

Figure 9. Palaeogene stratigraphy showing probable aquifer/aquitard zonation

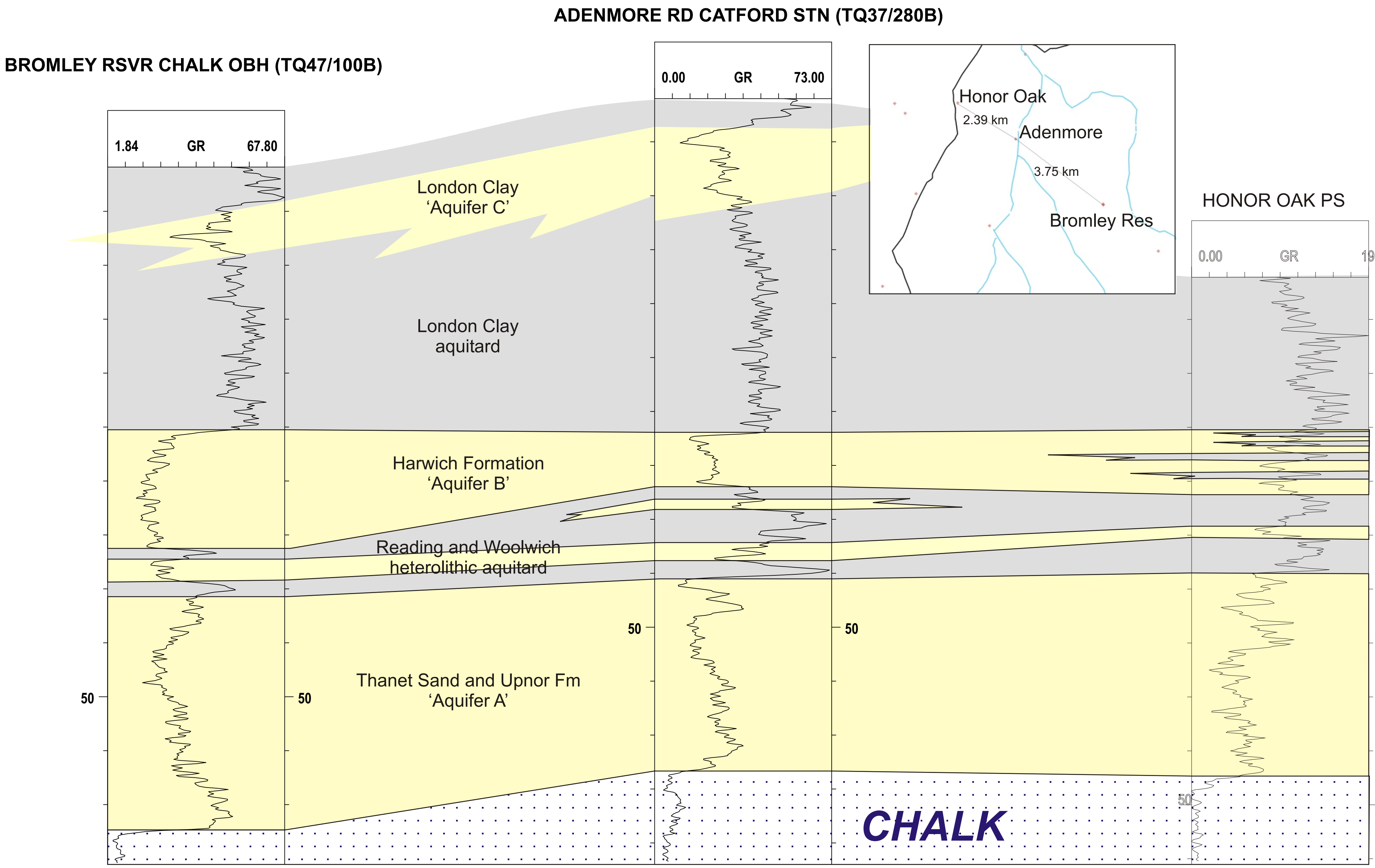

Figure 10. Correlation panel showing possible lateral variation of aquifer/aquitard zones