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# UK Stratigraphical Framework Series: Kimmeridge Clay Formation

National Geoscience Programme

Open Report OR/26/001





BRITISH GEOLOGICAL SURVEY

NATIONAL GEOSCIENCES PROGRAMME OPEN REPORT OR/26/001

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*Keywords*

Kimmeridge Clay Formation,  
Ancholme Group,  
Lithostratigraphy,  
chronostratigraphy,  
biostratigraphy, geophysical  
logs, thickness maps, basin  
evolution

*Bibliographical reference*

BURREL GARCIA, L., WOODS, M  
A, NEWELL, A J. 2026  
UK Stratigraphical Framework  
Series: Kimmeridge Clay  
Formation . *British Geological  
Survey Open Report*,  
OR/26/001. 50pp.

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# UK Stratigraphical Framework Series: Kimmeridge Clay Formation

L Burrel Garcia, M A Woods, A J Newell

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# Foreword

This report is an overview of the stratigraphy of the Kimmeridge Clay Formation based on interpretations of borehole geophysical logs across its area of outcrop and subcrop in southern and eastern England. It is intended to provide a broad geological context on this stratigraphic unit for future investigations.

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# Summary

This report forms part of the UK Stratigraphical Framework Series (UKSFS) and provides an overview of the stratigraphy of the Kimmeridge Clay Formation of southern and eastern England. The work covers both outcrop and subcrop areas and is primarily based on new interpretations of borehole geophysical log and core sample data with reference to published materials and outcrop sections as required. The emphasis of the report is on regional structure, thickness and facies trends in the Kimmeridge Clay Formation. It should provide a framework for site-specific geological investigations that require understanding of the Kimmeridge Clay Formation.

# 1 Introduction

## 1.1 BACKGROUND TO REPORT SERIES

This report on the Kimmeridge Clay Formation forms part of the UK Stratigraphical Framework Series (UKSFS) which aims to generate new information on the structure, stratigraphy and facies (lithology) trends within UK bedrock geology units (formations or groups) of sedimentary origin. The emphasis of the report series is primarily (but not exclusively) on onshore UK geology and on stratigraphical trends across the entire areal distribution of the rock unit, at both outcrop and in the subsurface. The reports thus make extensive use of borehole data where these are available, for example, in the post-Devonian sedimentary basins of the UK where there has been a long history of exploration for groundwater, hydrocarbons, coal and other mineral resources.

The over-arching aim of the UKSFS is to create concise stratigraphical frameworks that can provide regional understanding of key UK stratigraphical units and can form the context and basis for further site-specific work where and when this is required. An emphasis on surface to subsurface correlations should make the reports and associated datasets applicable to many sectors where the subsurface understanding is important (e.g. hydrogeology, deep geothermal energy, geological containment of hydrogen, carbon dioxide and radioactive waste).

Where input datasets allow, the specific technical aims of the report series are to:

- Interpret borehole data and produce a robust set of stratigraphical markers using all available evidence (e.g. core, cuttings, biostratigraphy, chemostratigraphy and geophysical logs).
- Create structure maps of the stratigraphical unit fitted to verified borehole markers and other data (e.g. available depth-converted seismic picks and outcrop lines) where available.
- Create thickness maps of stratigraphical units and any key internal subdivisions using verified borehole markers and correcting for borehole inclination and structural dips where required. Attempt to understand trends within the thickness maps and the role of basin structure in controlling depositional trends.
- Classify boreholes for lithology (facies) using combinations of core, cuttings and geophysical logs and use this information to provide greater insight into patterns, trends, and subsurface heterogeneity of the rock unit.

The emphasis of the report series is on the concise delivery of new stratigraphical data and associated datasets at the UK scale. The reports do not aim to summarise all published information on a particular rock unit or specifically address issues around stratigraphical nomenclature which are covered in BGS stratigraphical formational reports (e.g. Barron et al. 2012), BGS Memoirs and in the BGS Lexicon of named rock units ([www.bgs.ac.uk](http://www.bgs.ac.uk)).

## 1.2 REPORT STRUCTURE AND ASSOCIATED DATASETS

This report is structured with text and tables at the beginning of the document and full-page figures at the end. The report includes a methodology section, an overview of the Kimmeridge Clay formation stratigraphic and tectonic context, and a discussion on structure, thickness trends and facies distribution. The data used and the structure and thickness maps generated are available as data files (Table 1).

Table 1 – List of data files associated with this report

File	Description	Projection
KCBoreholeLocations.txt	Point file with the location of the boreholes used for the Kimmeridge Clay study	OSGB 1936/BNG
KCWellMarkers	List of Kimmeridge Clay well markers for top and bottom for the formation	OSGB 1936/BNG

### 1.3 METHODS

The Kimmeridge Clay Formation crops out in southern England, the Cleveland Basin and across the East Midlands Shelf. In the subcrop the formation is transected by numerous deep boreholes with geophysical logs (Figure 1), which have been the main input data for generating stratigraphic surfaces and thickness maps in this study. The process of generating thickness and structural maps is described below:

1. Borehole data was loaded into 3D Geological modelling software Emerson SKUA-GOCAD 2019 using OSGB/British National Grid Projection. The elevations of the wells have been set at geophysical log datum (KB) or ground level. The wells have been identified using the borehole name, BGS SOBI identifier and BGS ID Number.
2. Borehole paths were created, either as vertical or deviated as required. Well deviation files were primarily sourced from UK Onshore Geophysical Library.
3. Geophysical logs (mostly gamma-ray and sonic) were extracted from BGS archives, cleaned, resampled at 0.15 m and loaded onto well paths.
4. Existing stratigraphical borehole markers from the BGS UK Stratigraphical Surfaces Database (SSD) were loaded onto the well paths and served as a starting point for verification and editing into a new project set. Geophysical log interpretations were guided by extensive outcrop and cored borehole data described in published literature and historical project work detailed in BGS technical reports. Stratigraphical markers were created using BGS Lexicon codes with the format – [unit below]\_[unit above]\_[type of contact].

The type of contact included normal (conformable) stratigraphical (N), unconformity (U) and faulted (F). A key to the stratigraphical markers created during the work is shown in Table 2.

5. The outcrop extent was extracted from BGS 1:50 000 scale geological maps (BGS Geology 50K) using all the lexicon codes that include the Kimmeridge Clay Formation (KC, Kimmeridge Clay Formation and AMKC, Ampthill Clay Formation and Kimmeridge Clay Formation undifferentiated). This has been used to limit the extent of the Kimmeridge Clay Formation’s outcrop during the horizon modelling stage. Ordnance Survey (OS) Terrain 50 (resampled at 200 m resolution) has been used as a terrain model.

Table 2 – List of stratigraphical markers created for the Kimmeridge Clay UKSFS report

Marker code	Unit Below	Unit Above	Contact	Number
-------------	------------	------------	---------	--------

CR_KC_N	Corallian Group	Kimmeridge Clay Formation	Normal	117
CR_KC_F	Corallian Group	Kimmeridge Clay Formation	Faulted	5
OXC_KC_F	Oxford Clay Formation	Kimmeridge Clay Formation	Faulted	1
AMC_KC_N	Amphill Clay Formation	Kimmeridge Clay Formation	Normal	1
FMB_KC_F	Forest Marble Formation	Kimmeridge Clay Formation	Faulted	1
MLI_KC_F	Middle Lias (Undifferentiated)	Kimmeridge Clay Formation	Faulted	1
KC_PL_N	Kimmeridge Clay Formation	Portland Group	Normal	77
KC_PL_F	Kimmeridge Clay Formation	Portland Group	Faulted	2
KC_PB_N	Kimmeridge Clay Formation	Purbeck Group	Normal	2
KC_PB_F	Kimmeridge Clay Formation	Purbeck Group	Faulted	1
KC_GTL_N	Kimmeridge Clay Formation	Gaythorn Limestone	Normal	2
KC_GTL_U	Kimmeridge Clay Formation	Gaythorn Limestone	Unconformity	4
KC_SAS_U	Kimmeridge Clay Formation	Sandringham Sands Formation	Unconformity	2
KC_JURU_U	Kimmeridge Clay Formation	Upper Jurassic Rocks (Undifferentiated)	Unconformity	1
KC_W_U	Kimmeridge Clay Formation	Wealden Group	Unconformity	1
KC_SPC_N	Kimmeridge Clay Formation	Speeton Clay Formation	Normal	1
KC_SPC_U	Kimmeridge Clay Formation	Speeton Clay Formation	Unconformity	6
KC_LGS_U	Kimmeridge Clay Formation	Lower Greensand Group	Unconformity	15
KC_LOCR_U	Kimmeridge Clay Formation	Lower Cretaceous Rocks (Undifferentiated)	Unconformity	1
KC_CK_U	Kimmeridge Clay Formation	Chalk Group	Unconformity	2
KC_SYS_U	Kimmeridge Clay Formation	Spilsby Sandstone Formation	Unconformity	7
KC_TRUNCATED	Kimmeridge Clay Formation	-		15
WWB_AMC_N	West Walton Formation	Amphill Clay Formation	Normal	1

Structural maps for the base and top of the Kimmeridge Clay Formation were created using implicit geological modelling methods from the Structure and Stratigraphy workflow in SKUA-GOCAD (Newell, 2018). The purpose of these maps was to show, in a highly simplified way, the relationship of boreholes to present structure. Input data were limited to borehole stratigraphic horizon markers, polylines defining the erosional boundaries for the formation, and major faults digitised from the BGS Tectonic Map of Britain, Ireland and adjacent areas (Pharaoh, 1996). Major faults that impacted the Kimmeridge Clay

Formation were modelled as simple vertical planes, an approach that was adequate for the simplified structure maps. In the SKUA-GOCAD workflow Table 3 summarises the main datasets used in the construction of structural grids.

Table 3 – Input data for structural grids

Data	Data source	Projection
OS Terrain 50	Ordnance Survey 50m digital terrain model (resampled to 200m)	OSGB36/BNG
Well markers	This project	OSGB36/BNG
Outcrop erosion lines	BGS Geology 50K	OSGB36/BNG
Faults	BGS Tectonic Map of Britain, Ireland and adjacent areas	OSGB36/BNG

6. Generation of thickness and structural maps for the Kimmeridge Clay Formation based on interpreted well markers and the modelled fault network. The colour map used is Lisbon from the Scientific Colour Maps project (<https://www.fabiocramer.ch/colourmaps>).
7. Creation of a simple facies analysis using cut-offs for the log electrofacies and k-means classification, described in section 4.3 and in Woods et al. (2021).

The interpretation of log data and the construction of horizons and thickness maps involved reference to numerous publications and reports. Key literature describing specific localities and boreholes is summarised in Table 4.

## 2 Kimmeridge Clay Formation: geological background

### 2.1 DEPOSITIONAL SETTING

The Kimmeridge Clay Formation (hereafter 'Kimmeridge Clay') is a mudstone dominated succession deposited during the Upper Jurassic (Kimmeridgian and Lower Tithonian; Figure 3). The nomenclature of the Upper Jurassic stages has been subject of discussion since the 19<sup>th</sup> century, where two interpretations for the Kimmeridgian stage were established: (1) *sensu anglico*, where the Kimmeridgian equates wholly with the Kimmeridge Clay Formation, and (2) *sensu gallico*, where the Kimmeridgian is restricted to the lower part of the Kimmeridge Clay, with the upper part corresponding to the Tithonian. Following international acceptance of the Tithonian as the terminal Jurassic stage, the Kimmeridgian should be understood in its *sensu gallico* version, with the Kimmeridge Clay corresponding to the Kimmeridgian and Lower Tithonian (Bailey to Fittoni ammonite zones) stages (Figure 3; see Cope (2006) for further detail on the discussion). Portlandian and Bolonian are secondary standard stages that correspond with the Tithonian, used for the terminal Jurassic in Britain due to its restricted ammonite provinces not quite fitting the global timescale definitions (Cope, 2006).

At the time of deposition of the Kimmeridge Clay, northwest Europe was part of a shallow sea – the Laurasian seaway – comprising a system of interconnected extensional basins (Figure 2). These formed from the post-Carboniferous subsidence of the NW European Shelf affected by several phases of extension that compartmentalised the basins in grabens and

half grabens (Chadwick, 1986). The Kimmeridge Clay was deposited in a shelf environment below the fair water wave base and close to the storm wave base (Macquaker and Gawthorpe, 1993).

Sedimentation of the Kimmeridge Clay took place in two main depocentres; the Wessex-Weald Basin and adjacent Channel Basin in southern England, and the Cleveland Basin (Yorkshire) and adjacent, East Midlands Shelf in northeast England (Figure 2). These two main depocentres underwent significant subsidence due to the extensional reactivation of basement compressional structures of Variscan and Caledonian age (Whittaker, 1985). This reactivation did not affect the Anglo-Brabant Massif, which lacked pre-existing Variscan structures. The Anglo-Brabant Massif went through minimal extension during the Jurassic and remained an uplifted area with variable marine inundation of its flanks associated with relatively thinner sediment accumulations (Pharaoh, 2018). Lower Cretaceous erosion caused extensive removal of Jurassic sediments from the Anglo-Brabant Massif with no preserved record of the Kimmeridge Clay Formation in this area.

South of the Anglo-Brabant Massif, the Wessex-Weald Basin is bounded by E-W trending extensional fault zones, active at the time of deposition of the Kimmeridge Clay (Chadwick, 1986). These faults developed under strong control from the reactivation of basement structures formed during the Caledonian and Variscan orogenies. The Pewsey Fault System and the London Platform Faults define the northern boundary of the basin area, where the stratigraphic thickness of the units thins towards the raised basement of the Anglo-Brabant Massif. The Central Channel High defines its southern boundary. The Hampshire-Dieppe High, bounded by the Purbeck-Isle of Wight Fault System divides the Channel Basin and Weald depocentres (Figure 2) (Underhill and Stoneley, 1998). The Kimmeridge Clay of southern England shows thickness variations related to variable subsidence, that in combination with eustatic sea level change, determined available accommodation space for sediment accumulation. The Kimmeridge Clay thins toward the basin margins and structural highs, where unconformities are more evident. In these areas, marginal facies of the Kimmeridge Clay are less organic rich, richer in carbonates, and sandier due to its proximity to sediment sources.

The East Midlands Shelf was a tectonically stable platform during the Late Jurassic and subsidence rates did not undergo drastic changes at a local scale. Thickening of the sedimentary cycles can be correlated with transgressive periods also identified in the Southern England basins (Penn et al. 1986). Across the East Midlands Shelf the lower part of the Kimmeridge Clay thins south-eastwards towards the Anglo-Brabant Massif. Towards the Humber and the Market Weighton High the upper part of the Kimmeridge Clay has been eroded beneath an unconformity (late Cimmerian Unconformity) developed at the base of the late Jurassic/Early Cretaceous Spilsby Sandstone Formation.

To the north, the Cleveland Basin (Figure 2) is a small extensional basin bound to the north-east by the Mid North Sea High, to the west by the Pennine High and to the south by the Market Weighton High against which the Kimmeridge Clay thins. Within the basin, intermittent fault reactivation associated with marked local thickness changes makes identification of the effects of eustatic sea level changes on sedimentation more difficult to understand compared to the East Midlands Shelf (Gallois, 2021).

Although clearly affected by variable syndepositional subsidence and post-depositional erosion, the Kimmeridge Clay nevertheless shows lateral continuity of lithostratigraphy and biostratigraphy across much of the outcrop and subcrop. This is consistent with interpretations of a low energy depositional setting with gentle depositional gradients,

resulting in aggradational stacking patterns of the strata during a period of high global sea level (Wignall, 1991; Taylor, 2001).

## 2.2 KEY OUTCROP REFERENCE SECTIONS AND BOREHOLES

The Kimmeridge Clay crops out across England from Kimmeridge Bay in Dorset to the Vale of Pickering in the Cleveland Basin, North Yorkshire. In the Vale of Pickering and further south around The Wash in East Anglia and south Lincolnshire, the formation is mainly known from boreholes. Inland exposures of Kimmeridge Clay across southern England (Wiltshire, Oxfordshire, Buckinghamshire) are limited, and most literature describing Kimmeridge Clay from this area relates to the type outcrop on the Dorset coast and nearby cored borehole records.

The key reference sections and boreholes are listed in Table 4. Many of these cores are held in the collections of sample material in BGS archives.

Table 4 – Key outcrop localities and cored boreholes for the Oxford Clay Formation lithostratigraphy

Locality	Kimmeridge Clay stratigraphy	Information Source(s)
Dorset type area, incl. Horrow Bay SY 955 790 to Chapman's Pool SY 955 771, Dorset	Composite logs ranging the entire KC succession	Cox and Gallois, 1981, Wignall, 1990, Morgans-Bell et al. 2001, Barton et al. 2011.
Meterhills 1 borehole, SY 9112 7911, Dorset	Lower KC, beds 1 to 32	Morgans-Bell et al. 2001, Taylor et al. 2001, Gallois 2000
Swanworth Quarry 1 borehole, SY 9675 7823, Dorset	Upper part of the Lower KC to top KC formation, beds 32 to 63	Morgans-Bell et al. 2001, Taylor et al. 2001, Gallois 2000
Brightling 1, BJ 5672 0121, Sussex	Entire KC	Ahmadi, 1997
Warlingham, BJ 5347 0157, Surrey	Mutabilis to Pallasioides	Ahmadi, 1997
Swindon borehole, SU 1413 8349, Gloucestershire	Lower KC, up to Pallasioides zone	Gallois, 1978, Gallois, 1979, Gallois and Cox, 1994
West Lavington borehole, ST 9898 5633, Wiltshire	Lower and lower part of the Upper KC. Baylei to Pallasioides zones	Gallois, 1979
Denver Sluice borehole, TF 591 011, Norfolk and other 19 boreholes in the area	Lower KC, beds 1 to 35	Gallois and Cox, 1976 Gallois (1979, 1994)
North Wootton borehole, TF 643 92457, Norfolk	Lower KC, beds 1 to 35	Gallois and Cox, 1976, Wilkinson 1983
North Runcton borehole, TF 6404 1624, Norfolk	Lower and lower part of the Upper KC. Baylei to Pallasioides zones	Gallois, 1978
Donington on Bain borehole, TF 2399 8188, East Midlands Shelf	From bottom KC, Bailey zone to Lower Upper KC, Pectinatus zone	Penn et al. 1986, Gallois, 1978, Gallois, 1979, Gallois 2021
Nettleton Bottom, borehole, TF 1252 9820, East Midlands shelf	KC beds 1 to 44	Penn et al. 1986

Golden Hill site composite section, Vale of Pickering, SE 7236 8294	From bottom KC to Upper KC, beds 1 to 53	Wignall et al. 1993
Marston 1 borehole, SE 7230 8285, Vale of Pickering	KC beds 19 to 46	Gallois, 2021
Ebberston borehole, SE 8921 8151, Vale of Pickering	KC beds 16 to 50	Gallois, 2021
Reighton borehole, TA 1465 7581, Vale of Pickering	Lower KC, beds 1 to 39	Gallois, 2021

## 2.3 STRATIGRAPHY

The Kimmeridge Clay is divided into 63 beds using a combination of lithological and biostratigraphic characteristics. The beds can be correlated across the whole depositional extent of the Kimmeridge Clay, and comprise coccolith limestones, micrite bands, sandstone packages and intervals of organic-rich mudstones. Some of the coccolith bands, especially outside the Dorset type section, can be thinner than 10 mm, so their correlation relies heavily on the identification of key ammonites (Gallois, 1979). Figure 4 highlights key marker beds used to identify stratigraphical intervals within the Kimmeridge Clay exposed in the Dorset type section at Kimmeridge Bay.

The division between Lower Kimmeridge Clay and Upper Kimmeridge Clay was introduced by Blake (1875). Although informal, it has significant value because of its correspondence with changes in ammonite zonation and wireline log responses. The boundary between the two subdivisions is the top *Autissiodorensis*/ base *Elegans* Zone.

### 2.3.1 Boundaries of stratigraphical units

The following features are used to define the upper and lower boundaries of the Kimmeridge Clay Formation and some of the most widespread marked beds:

#### Southern England

- Base of Kimmeridge Clay: The base of the Kimmeridge Clay and the Oxfordian/Kimmeridgian boundary in the Meterhills-1 borehole is marked by the Osmington Mills Ironstone and the *Inconstans* Bed, a mudstone with phosphatic nodules and shelly material (Morgans-Bell et al. 2001). The contact between the Kimmeridge Clay and underlying Corallian Group is marked by the transition from the *Evoluta* to the *Baylei* biozone. In the Dorset succession, the base of the Kimmeridge Clay Formation is composed of a rhythmic alternation of silty mudstone, dark grey mudstone and a very calcareous mudstone in the *Baylei* to *Eudoxus* zones.
- Lower/Upper Kimmeridge Clay contact in Southern England. The base of the Upper Kimmeridge Clay has been taken at a thin limestone band a little above the *Autissiodorensis*-*Elegans* contact, base of Bed KC36 (Gallois and Cox, 1976; Cox, 1981).
- Top of Kimmeridge Clay Formation: The top part of the Kimmeridge Clay has been named the Hounstout Marls (Morgans-Bell et al. 2001) and the Hounstout Silts and Clays (Gallois 1998 and 2000). The base of the Portland Sand Formation has been taken at the base of the Massive Bed, a 2 m thick bed of fine-grained calcareous sandstone (Arkell, 1947, Gallois, 2000). The top of the formation is taken at the transition between the *Fittoni* and *Albani* zones. Figure 5 shows the Kimmeridge Clay

outcrop at Chapman's Pool, where the upper part of the formation has been removed by erosion beneath the Portland Sand Formation.

Figure 6 shows the gamma-ray log of the Kimmeridge Clay in the Warlingham borehole [534760 0157190] correlated with the ammonite biozonation of the borehole. Upper and lower boundaries of the Kimmeridge Clay are clearly identifiable from the gamma log alone.

### **Eastern England (East Midlands Shelf)**

- **Base of Kimmeridge Clay Formation:** On the East Midlands Shelf the Kimmeridge Clay forms part of the Ancholme Group and overlies the Ampthill Clay Formation. The boundary between the Ampthill Clay and the Kimmeridge Clay is taken at a faunal and lithological change that occurs in a minor unconformity where pale grey and highly calcareous mudstones and thin limestones in the top of the Ampthill Clay pass upwards into the silty mudstones with phosphatic pebbles of the Kimmeridge Clay (Gallois and Cox, 1994). This boundary is seen in most wireline geophysical logs in the area, where the highest bed of the Ampthill Clay has lower gamma and higher sonic and the boundary is marked by the upward change to higher gamma and lower sonic in the overlying Kimmeridge Clay (Woods et al. 2022). The base of the Kimmeridge Clay is marked as a change from the *Regulare* zone to the *Baylei* biozones.
- **Top Kimmeridge Clay Formation:** The Kimmeridge Clay is overlain by the Sandringham Sands Formation at a strongly erosional boundary (Late Cimmerian Unconformity). This erosion surface has widely removed the higher part of the Kimmeridge Clay across the East Midlands Shelf, especially so in areas around The Wash and North Runcton (Gallois and Cox, 1994). This boundary is clearly identifiable in the logs as a sharp upward decrease of gamma log values.

### **North Yorkshire (Cleveland Basin)**

- **Base Kimmeridge Clay:** In the Vale of Pickering, the Kimmeridge Clay overlies calcareous sandstones of the Corallian Group, and the boundary is easily identifiable as a sudden downward reduction in gamma log values and an increase in sonic velocity.
- **Top of the Kimmeridge Clay:** Marked by an erosional unconformity that results in variable degree of loss of the upper beds in the Kimmeridge Clay. Above the unconformity, the base of the Speeton Clay is marked by a phosphatised basal bed. Because both lithologies are very similar, it is difficult to identify the contact from its gamma and sonic log signals.

## **2.4 BIOSTRATIGRAPHY**

The subdivision of the Kimmeridge Clay into biostratigraphical units is based on ammonites, comprising thirteen ammonite zones - *Baylei* to *Fittoni*. The formation also contains beds characterised by one or more distinctive fossils (e.g. ammonites, crinoids, bivalves, coccoliths) or abundances of a particular fossil, ranging from between a few millimetres to a few centimetres thick. These have been correlated in outcrops and cored boreholes across England. The standard biozonation of the Kimmeridge Clay is shown on Figure 3.

BGS reports and memoirs and published articles have compiled biostratigraphic logs from outcrop exposures and cored boreholes which can be used to correlate the Formation across depositional basins. Figure 7 and Figure 8 provide ammonite zone correlations for the Lower and Upper Kimmeridge Clay Formation based on these information sources.

For the Lower Kimmeridge Clay Formation, the thickest biozone intervals are found in the Wessex Basin, while there is significant thinning towards the Anglo-Brabant Massif, the Wash and the East Midland Shelf (Figure 7). The Lower Kimmeridge Clay of the Cleveland Basin ranges from the Cymodoce to Autissidorensis zones. The Eudoxus and Autissidorensis biozones are significantly thicker compared to the Southern England and the East Midlands Shelf while the Cymodoce and Mutabilis zones are notably thinner.

For the Upper Kimmeridge Clay, all the biozones are thicker in the Dorset boreholes and outcrops, thinning towards the Anglo-Brabant Massif (Figure 8). At the localities around the Anglo-Brabant Massif, The Wash, East Midlands Shelf and the Cleveland Basin, the higher part of the Upper Kimmeridge Clay succession has been removed by erosion, either at rockhead or beneath the Portland Limestone Formation (Southern England) or Speeton Clay Formation (Cleveland Basin). In these sections, the Rotunda and Pallasioides biozones are usually missing and the top of the Kimmeridge Clay is within the Pallasioides biozone. Locally, the base Cretaceous unconformity erodes down to the Wheatleyensis Zone, such as in the Hunmanby-1 borehole (Powell, 2010).

## 2.5 SEQUENCE STRATIGRAPHY AND BIOCHEMISTRY

Sequence stratigraphy is a useful tool to organize sedimentary successions into genetically related sedimentary packages, based on the identification of key boundaries and facies characteristics related to sea level change (Van Wagoner et al. 1990) and, in the Wessex-Weald basin more linked to cyclic changes on sediment supply (Huang et al. 2010). The first sequence stratigraphy studies on the Kimmeridge Clay included outcrop data and cored boreholes (Wignall, 1991 and Coe, 1992) and later also added wireline logs (Ahmadi, 1997). Melynck et al. (1994) proposed a sequence stratigraphy framework calibrated against GR log response. Taylor (2001) proposed a framework for sequence stratigraphy correlation across the Wessex-Weald Basin, which has been linked to astronomical cyclicity (Weedon et al. 2004 and Huang et al. 2010) and also correlated the previously existing frameworks (Figure 9). Most of these studies have been carried out in the Dorset Coast sections or in the boreholes of the Wessex and Weald basins, where the Kimmeridge Clay Formation is thicker, and the upper part of the succession is more complete. However, many of the marker beds and sequence boundaries identified have been successfully correlated to the Eastern England and Cleveland Basin sections (Gallois, 2021).

For the Lower Kimmeridge Clay, four sequence boundaries have been defined by Coe (1992) and Ahmadi (1997) which are associated with the presence of thin sand or silt bands with erosive bases and sometimes phosphatic nodules. These coarser-grained bands have been interpreted as the base of fining-upward transgressive cycles. Some of these correlate with the sequence boundaries identified by Taylor et al. (2001), which identify a total of seven sequence boundaries for the Lower Kimmeridge Clay based in erosive surfaces followed by a thin silt bed indicative of the base of the Lowstand System Tract.

For the Upper Kimmeridge Clay, Coe (1992) and Ahmadi (1997) also identify four main sequence boundaries, while Taylor et al. (2001) identify five. At the mid-Huddlestoni zone a decrease of pollen diversity and an increase in kaolinite abundance has been attributed to a change from humid to semi-arid conditions (Wignall, 1990). This change in climatic conditions also resulted in the deposition of two thick calcareous mudstone units (Ahmadi, 1997). In Southern England, the interval between the Wheatleyensis and Pectinatus zones, has been identified as a highstand associated with an increase in organic richness and carbonate content, related to plankton productivity (Taylor, 2001).

Huang et al. (2010) identify seven sequence boundaries during the deposition of the Kimmeridge Clay, most of them correlated with an increase in the accumulation rate and increase in Total Organic Content (TOC). In the lower part of the formation the correlation is not so clear probably due to hiatuses in the sedimentation or irregular sedimentation patterns.

## 2.6 GEOCHEMISTRY

### 2.6.1 Stable Isotopes

A Carbon 13 isotope curve has been correlated to ammonite zonation and to global climate curves (Morgans-Bell et al., 2001; Turner et al., 2018). Although the sedimentary basins were quite restricted in the Late Jurassic, distinct Carbon isotope events allow the correlation of Kimmeridge facies across the northern Tethys domain at a higher resolution than the ammonite biostratigraphy. Turner (2018) identifies three distinct isotopic events within the Kimmeridge Clay sedimentation: a positive shift and two peaks within the Eudoxus Zone, possibly representing a widespread increase in organic carbon content (Morgans-Bell et al. 2001), a short-term negative shift in the Huddlestoni zone, linked to the 'Huddlestoni Event' (Wignall and Ruffell, 1990), an abrupt shift from humid to arid conditions, and a negative excursion in the Pallasioides zone.

Matthews et al. (2004) studied the fractionation of  $^{57}\text{Fe}/^{54}\text{Fe}$  in the organic-rich mudstones and dolomite bands of the Kimmeridge Clay in Dorset. The study provides evidence of how iron isotopes are recycled during the sedimentation and diagenesis of the sediments.

Molybdenum alongside other trace metals serve as a proxy for the redox conditions of the depositional environment of mudstones. Pearce et al. (2010) provide  $^{98}\text{Mo}/^{95}\text{Mo}$  variation on the Kimmeridge Clay type section in Dorset, identifying a variable redox regime between the *Autissodorensis* to the *Pectinatus* biozones, ranging from mildly reducing to strongly reducing. These variations can be correlated to global redox conditions. Flooding of continental margins during highstand periods are interpreted to promote reducing conditions. Variations in trace metal abundance are strongly linked to TOC content, detrital abundance and facies types.

### 2.6.2 Bulk Rock Geochemistry

The potassium content for the Kimmeridge Clay remains fairly constant, around 3% across the entire formation. The most prominent potassium lows are recorded in the stone bands, which are micritic limestones or coccolith limestones (Cox, 1981). The uranium curve shows more variation, with the lowest uranium content recorded in the Basalt Stone band and other calcareous mudstones. The highest uranium readings are recorded in the oil shales and bituminous mudstones (Ahmadi, 1997). Uranium is generally associated with organic content, so when limestone bands have high uranium values it is usually because they are interbedded with organic-rich mudstones. Depositional stone bands, for example coccolith mudstones, have higher uranium content than those with a diagenetic origin, which typically have a very low organic content (Ahmadi, 1997). The Thorium curve for the Kimmeridge Clay generally coincides with the potassium curve, although it has a slightly wider range of values. Thorium lows are associated with the stone bands, which are poor in the clay minerals with which thorium is typically associated (Ahmadi, 1997).

Potassium and thorium levels are closely correlated in mudstones and can be a useful tool to determine its clay mineral composition. Clay minerals represent between 30 to 65% of the mudstones in the Kimmeridge Clay Formation (Ahmadi, 1997). The most abundant clay

minerals are illite and kaolinite with minor presence of chlorite and smectite. Kaolinite and smectite tend to increase the Th/K ratio and illite will tend to decrease it (Myers and Wignall, 1987). The clay mineral trends of the Kimmeridge Clay are very similar in the Wessex basin and the Cleveland basin, suggesting shared detrital sources. Late Jurassic clay mineralogy indicates an alternation of arid and humid phases. Kaolinite depleted intervals, indicating arid climate conditions, occur in the Cymodoce-Mutabilis zones and the Huddlestoni-Lower Pectinatus zones. Eudoxus-Autissiodorensis zones and Pallassioides were relatively humid and the Rotunda-Fittoni zones marked a return to relatively arid conditions (Hesselbo et al. 2009).

## 2.7 GEOPHYSICAL LOG SIGNATURES

Ahmadi (1997) linked the interpretation of wireline logs from the Kimmeridge Clay Formation to its biostratigraphical and sequence stratigraphical classification. Taylor (2001) followed the same approach for the correlation of logs across the Wessex-Weald Basin. Gamma-ray is considered the most useful wireline log for the correlation of these Upper Jurassic sediments because it is available for most boreholes, can be used for both borehole and outcrop characterisation, and its signal is not affected by fluid content in the rock. Resistivity and sonic logs have also been useful to identify siltstone beds, which have higher porosity values than the mudstones. The density log can be useful to pick out phosphatic nodules, iron ooids or siderite, which have a higher density signature than mudstones lacking these cements but can have similar values for the gamma log.

It is generally considered that high gamma log readings indicate a high content of clay rich in uranium, thorium or potassium and low gamma log readings correspond to coarser, quartz-rich lithologies with a lower proportion of clay. However, this general assumption needs to be treated with caution because a number of other factors other than grain size and clay content can affect the radioactivity measurements (for example the presence of phosphate, pyrite and organic matter).

Gamma log trends can be used to correlate the alternations of clay materials with coarser lithologies and thus deduce the presence of sequence stratigraphy cycles. Progradation cycles can be identified from a decrease in gamma ray readings, indicative of an increase in grain size, which can be interpreted as a shallowing upwards cycle; for example, in the Upper Kimmeridge Clay (Ahmadi, 1997). Retrogradation of facies can be inferred from an increase of gamma log readings, indicating a deepening upwards interval. Irregular trends in gamma log readings through the Kimmeridge Clay Formation represent the aggradation of small-scale fine-grained lithologies, typical of low energy environments (Wignall, 1991).

Appendix 1 is a correlation panel of gamma-ray and sonic logs across the outcrop and subcrop of the Kimmeridge Clay Formation from the Dorset Coast to the East Midlands Shelf. A higher resolution image of this correlation panel can be found within the associated data for this report. In the following sections, correlation panels of key transects across the Southern England basins will be presented alongside the discussion of the different structural maps and thickness maps.

Stratigraphical control for the main correlation panel (Appendix 1) is provided by cored boreholes in the Wessex Basin (Swanworth Quarry & Metherhills boreholes; Gallois, 2000; Morgans-Bell, 2001), Weald Basin (Warlingham Borehole; Worssam & Ivimey-Cook, 1971; Callomon & Cope, 1971), and East Midlands Shelf (Denver Sluice, North Runcton, North Wootton & Nettleton Bottom boreholes; Gallois, 1979; Penn et al., 1986). The data from these boreholes includes biostratigraphical classification and detailed lithostratigraphical subdivision according to the bed number system of Cox & Gallois (1981) and Gallois (2000).

The common datum for the geophysical log correlations in the Wessex-Weald basins is a laterally persistent low gamma/low interval transit time sonic inflection, that in the cored successions in Dorset corresponds with a level at the base of KC 35 (Autissiodorensis Zone) (Gallois, 2000) and likely represents the paired Maple Ledge and bituminous stone bands. Although logs from boreholes on the East Midlands Shelf region share a similar inflection pattern, they less easily compare with logs in the Kimmeridge Clay of the Wessex-Weald basins. This contrast in log character potentially suggests a broad difference in the physical properties of the Kimmeridge Clay on the East Midlands Shelf compared to the Wessex-Weald basins. However, it is also apparent that some geophysical log features are laterally persistent, for example, the Huddlestoni Zone in all regions is coincident with a distinctive interval of low gamma log values.

## 3 Structural and thickness trends in the Kimmeridge Clay Formation

### 3.1 STRUCTURAL TRENDS

Figure 9 shows a depth map of the base of the Kimmeridge Clay Formation in Southern England and the main basin-bounding structures. Figure 10 is a depth map of the top of the formation. The base of the formation occurs approximately between 190 m OD and -1671 m OD in the Southern England basins (Wessex-Weald Basin and the Channel Basin). The base of the Kimmeridge Clay Formation is deepest at the western part of the Weald Basin and eastern part of the Wessex Basin, corresponding with areas of intense flexural and normal fault driven subsidence during the Jurassic and Early Cretaceous. Later Cenozoic exhumation was limited in these areas and the Kimmeridge Clay Formation remains relatively deeply buried. To the north, the depth of the base Kimmeridge Clay shallows towards the Anglo-Brabant Massif paleo-high and towards the eastern part of the Weald Basin. The base of the formation is also shallower towards the crest of the Weald anticline, which experienced significant exhumation through the Cenozoic.

Across the East Midlands Shelf and in the Cleveland Basin, the base of the Kimmeridge Clay Formation is between 146 m OD and -1395 m OD (Figure 11). The base of the Kimmeridge Clay progressively deepens from W to E towards the Sole Pit Trough in the Southern North Sea. Between the East Midlands Shelf and the Cleveland Basin, the Market Weighton High marks an area of reduced deposition and increased erosion, towards which the base of the Kimmeridge Clay rises and the top of the formation is lost to erosion (Figure 12). The Cleveland Basin is affected by the narrow E-W oriented graben systems of the Flamborough Head Fault Zone, which developed as extensional structures during the deposition of the Kimmeridge Clay and influencing its thickness distribution in this region (Kirby and Swallow, 1987).

### 3.2 TOTAL KIMMERIDGE CLAY THICKNESS

Figures 13 and 14 show thickness maps of the Kimmeridge Clay of southern England and the combined East Midlands Shelf and Cleveland Basin region. Thickness values are given as True Vertical Thicknesses (TVT) and there is no correction for the (generally low) bedding dips. Figure 15 is a W-E wireline log correlation across the Wessex and Weald basins, with the Kimmeridge Clay showing notable thinning towards the basin margins. For southern England the mean thickness of the Kimmeridge Clay is 166 m, with a maximum of 712 m penetrated at the Holtye-1 well, in the deep grabens of the Weald Basin, where the thickest

values for the formation are reached (Figure 16). For the East Midlands Shelf and Cleveland Basin, the mean thickness is 121 m with a maximum thickness of 349 m penetrated at the Caythorpe-1 well in the Cleveland Basin and 260 m penetrated at the Biscathorpe-1 well on the East Midlands Shelf.

The thickness distribution of the Kimmeridge Clay is heavily influenced by the pre-Permian structural configuration, when the Wessex-Weald Basin and the East Midlands Shelf/Cleveland Basin were separated by the London Platform and the Anglo-Brabant Massif.

### **3.2.1 Wessex-Weald Basins**

Deposition of the Kimmeridge Clay in both the Wessex and Weald basins was associated with significant syn-depositional normal fault movement, and the development of thick successions in the hanging walls of major normal fault systems during a phase of Jurassic crustal extension (Chadwick, 1985). In the Wessex Basin, this is reflected by the successions in the Swanworth and Metherhills boreholes (Appendix 1), deposited on the down-thrown side of the Purbeck – Isle of Wight Fault Zone (Barton et al., 2011). In contrast, deposition of Kimmeridge Clay was more restricted across the footwall of these structures, seen for example in the Marchwood Borehole, located on the Hampshire – Dieppe High. Here, the pinching together of geophysical log inflections provides evidence of condensed sedimentation. In the Weald Basin, the thick Kimmeridge Clay seen in the Warlingham borehole reflects the syn-depositional influence of faults that run along the southern margin of the Anglo-Brabant Massif (immediately to the north). These structures, like those controlling sedimentation in the Wessex Basin, were initiated as compressional features during the end Carboniferous Variscan Orogeny and later re-activated as extensional faults in the Jurassic (Barton et al., 2011).

The Weald basin depocenter is bounded by the London Platform to the north and the Potsdown-Middleton fault to the south. Towards the margins of the basin the Kimmeridge Clay Formation thins and gets condensed, displaying several unconformities (Taylor et al. 2001) (Figure 15, Figure 16 and Figure 17).

### **3.2.2 Relationship between present-day structure and thickness**

The area of maximum thickness of the Kimmeridge Clay Formation does not coincide exactly with the area of maximum depth for the base of the formation at present day, which is located to the west in the Wessex basin (Figure 17). This is due to the Alpine inversion uplifting the Weald Basin, forming the wide structure of the Weald anticline, which has an axial relative uplift of more than 1000 m (Chadwick, 1986). The structural highs were also more prone to later (Early Cretaceous, Late Cimmerian) erosion (Chadwick & Evans, 2005), further thinning or locally completely removing Kimmeridge Clay from these regions.

The thickness of the Kimmeridge Clay Formation decreases towards the Wessex Basin and Pewsey sub-basin, with localized thickening in the grabens of the Portland-Wight sub-basin and the westernmost part of the Wessex Basin (Figure 13). In the Portland-Wight sub-basin, south of the Middleton-Wight normal fault, the Kimmeridge Clay thickens up to 579 m in the 98\_13\_1 offshore well, SW of the Isle of Wight. Thickness progressively decreases towards the Anglo-Brabant Massif and the London Platform, which were areas of limited subsidence during the Upper Jurassic (Figure 13).

### 3.2.3 East Midlands Shelf

North-eastwards, across the East Midlands Shelf, the preserved thickness of the Kimmeridge Clay is affected by significant Early Cretaceous erosion cutting into and removing much of the higher part of the Kimmeridge Clay (Upper Kimmeridge Clay). The log trends in the Lower Kimmeridge Clay indicate significantly condensed sedimentation in the Denver Sluice Borehole, where deposition is potentially influenced by its location close to the flooded margin of the Anglo-Brabant Massif. In The Wash, the Kimmeridge Clay Formation is notably thin, ranging from 65 -130 m (Gallois, 1979) (Figure 14). Further north, there is progressive thickening and expansion of geophysical log markers towards the succession in the Nettleton Bottom Borehole. The logs suggest a progressive trend of increased sediment accommodation space towards the Nettleton Bottom Borehole, but without the significant influence of syn-depositional structure that affects thicknesses preserved in the Wessex and Weald basins.

### 3.2.4 Cleveland Basin

The Cleveland Basin is separated from the East Midlands Shelf by the Market Weighton High (Figure 2). The Kimmeridge Clay covered this structural high and no significant thinning towards the structure has been inferred (Wright, 2022). Lower Cretaceous uplift of the Market Weighton High eroded the formation originally deposited across this structure in the Market Weighton area, where the formation is entirely absent (Wright et al. 2022, Figure 7c).

In the Cleveland Basin the Kimmeridge Clay shows marked thickness changes due to fault reactivation during the deposition of the unit. Still, there is good lateral continuity of carbonate-rich marker beds and faunal zonation, so sedimentary cycles can still be identified from logs and correlated with the Southern England succession (Gallois, 2021). Subsidence of the Cleveland Basin was initiated during the Late Triassic and continued until the Cretaceous, forming a distinct depocentre north of the Market Weighton High from the Late Jurassic when the region experienced high rates of basin subsidence (Herbin et al. 1995; Penn et al. 1986).

In the Cleveland Basin the top part of the Kimmeridge Clay Formation is eroded beneath the base Cretaceous Unconformity. The thickness of the preserved Kimmeridge Clay succession has been estimated around 155 m for the Fordon-1 borehole and 102 m for the Hunmanby-1 borehole which are 730 m apart (Gallois, 2021), a good example of how Kimmeridge Clay thickness can drastically change over a short distance within a region affected by synsedimentary faulting (Figure 14).

## 4 Facies variation in the Kimmeridge Clay Formation

### 4.1 FACIES DISCRIMINATION USING GEOPHYSICAL LOGS

Geophysical logs are a useful tool for facies determination when there is no direct record of lithology and grain size from cored rock.

For this study on the Kimmeridge Clay Formation gamma-ray and sonic logs were available. Organic rich mudstones –the predominant facies in the formation– and marls have a higher gamma ray response than the interbedded siltstones, sandstones, and limestones, which can be identified as gamma troughs in the log (Table 6). Where the interbedded siltstone beds have phosphatic nodules gamma-ray values can be higher (Penn et al. 1986). The

sandstone, siltstone, limestone and dolostone interbed present moderate to high sonic values as opposed to the low sonic values of the organic rich mudstones.

Cross plots of gamma and sonic logs can be used to isolate clusters representative of the different rock facies (Newell et al. 2021). This approach was used for the Kimmeridge Clay Formation using gamma-ray and sonic logs, but the result was a scatter of points with no identifiable clusters that could be directly linked to the main Kimmeridge Clay facies types. Based on cut-offs for the gamma ray and sonic values the scatter of points has been divided in four quadrants, which has produced four broad electrofacies that can be used as a guide to map lithofacies. This approach was used by Woods et al. (2021) to discriminate four facies types for the Oxford Clay Formation. For the Kimmeridge Clay Formation there is good correspondence between the electrofacies groups discriminated with the cut-offs and the lithofacies described in the logs (Figure 19).

The clearest correspondence is between low gamma-ray values/ low interval transit times and limestone/carbonate-rich siltstone and sandstone bands. These hard bands are used as marker beds and together with ammonite biostratigraphy has allowed the correlation of the Kimmeridge Clay formation sequences across the Southern England basins and the East Midland Shelf (Gallois and Cox, 1976, Gallois, 1979 and Penn et al. 1986) and the Cleveland basin (Gallois, 2021).

High-gamma log readings correspond to organic-rich mudstones which have a variable sonic velocity response. For the organic rich mudstones, large scale variations in the carbonate and the organic content are superimposed on smaller scale rhythmicity, giving the gamma log a serrated appearance (Penn et al. 1986).

Classification of electrofacies in the Kimmeridge Clay shows strong regional variations across the basins of Southern England. In the central part of the Weald Basin, where the Kimmeridge Clay Formation is thickest, the carbonate-rich bands are well developed, reaching thicknesses around 30 m (Rogate-1, Ashour-1 and Detention-1 boreholes, Figure 15). As the formation becomes more condensed towards the margins of the Weald Basin and the Wessex Basin, the carbonate-rich bands thin out (Chilworth-1 and Cranborne-1, Figure 15) to a point where they pinch out and all the Kimmeridge Clay succession is mudstone (Hewish-1 and Winterborne-Kingstone-1, Figure 15).

Table 5 – Principal facies in the Kimmeridge Clay, Total Organic Content (TOC) and characteristic response on wireline logs

<b>Principal facies</b>	<b>Facies sub type</b>	<b>TOC</b>	<b>Likely response on wireline log</b>	<b>Principal sources</b>
Mudstone	Clay-rich not laminated mudstones	1 to 1.6%	High gamma, low sonic	Cox and Gallois, 1981; Penn et al., 1986; Wignall, 1989; Macquaker and Gawthorpe, 1993
	Laminated mudstone	High TOC values 8-15% Morgans-Bell et al. 2001, 23-42.4% MacQuaker and Gawthorpe, 1993	Very high gamma, low sonic	
	Silty mudstone	0.4-10%	Moderate gamma,	

			moderate sonic
	Coccolith mudstone	2.6-15.8%	
Marl		1-3%	High gamma, low sonic
Siltstone		<2%	Moderate gamma, moderate sonic
Sandstone		<2%	Moderate to Low gamma, moderate sonic
Limestone	Coccolith limestone		Low gamma, high sonic
Dolostone			Low gamma, high sonic

#### 4.2 KNOWN STRATIGRAPHIC AND SPATIAL TRENDS

- (1) Towards the margins of the basin the Kimmeridge Clay Formation becomes sandier, richer in carbonates and has a lower proportion of organic matter.
- (2) Reworked phosphatic pebbles within the siltier beds in the Bailey to early Mutabilis Zone indicate that the basins across southern England were sediment starved at that time (Wignall and Hallam, 1991).
- (3) Highstand conditions from Wheatleyensis to Pectinatus zones, are reflected in an increase of carbonates and organic richness (Taylor et al. 2001).
- (4) Eudoxus Zone sediments reflect deepening of the basin and associated sea level rise, beds become thicker and organic rich mudstones/ oil-shales become widespread (Taylor et al. 2001). From Eudoxus to Pallasioides zones organic rich mudstones were deposited in five intervals with interbedded micrite beds, the latter corresponding to minor level sea level falls (Morgans-Bell et al.2021).
- (5) The Pallasioides Zone has an increase of silt and sand material related to a major sea level drop that continues into the Early Cretaceous. The Rotunda and Fittoni zones are predominantly silty. recognisable in wireline logs as a progressive decrease in gamma log values.
- (6) Sand-rich units in the Weald Basin related to sea level falls thin westwards. In the Wessex Basin the equivalent beds are silts (Taylor et al. 2001).

## 5 Conclusions

- The Kimmeridge Clay thickens from NE to SW across its onshore outcrop and subcrop distribution.
- Persistent distribution of sedimentary marker beds, biozones and geophysical markers indicates limited variation in the depositional environment across Southern and Eastern England. This allows stratigraphic correlation across the entire outcrop-subcrop area.
- The structurally deepest part of the Kimmeridge Clay is in the Wessex Basin, which does not correspond to the thickest succession, found in the Weald Basin. This is due to Cenozoic uplift of the Weald depocentre.
- The Wessex-Weald Basin was tectonically active at the time of deposition of the Kimmeridge Clay. Faulting-controlled deepening events are reflected in the thickening of the stratigraphic succession.
- Lateral changes in the lithofacies distribution correspond to the shallowing of the basin towards the shelf.

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# 7 Figures

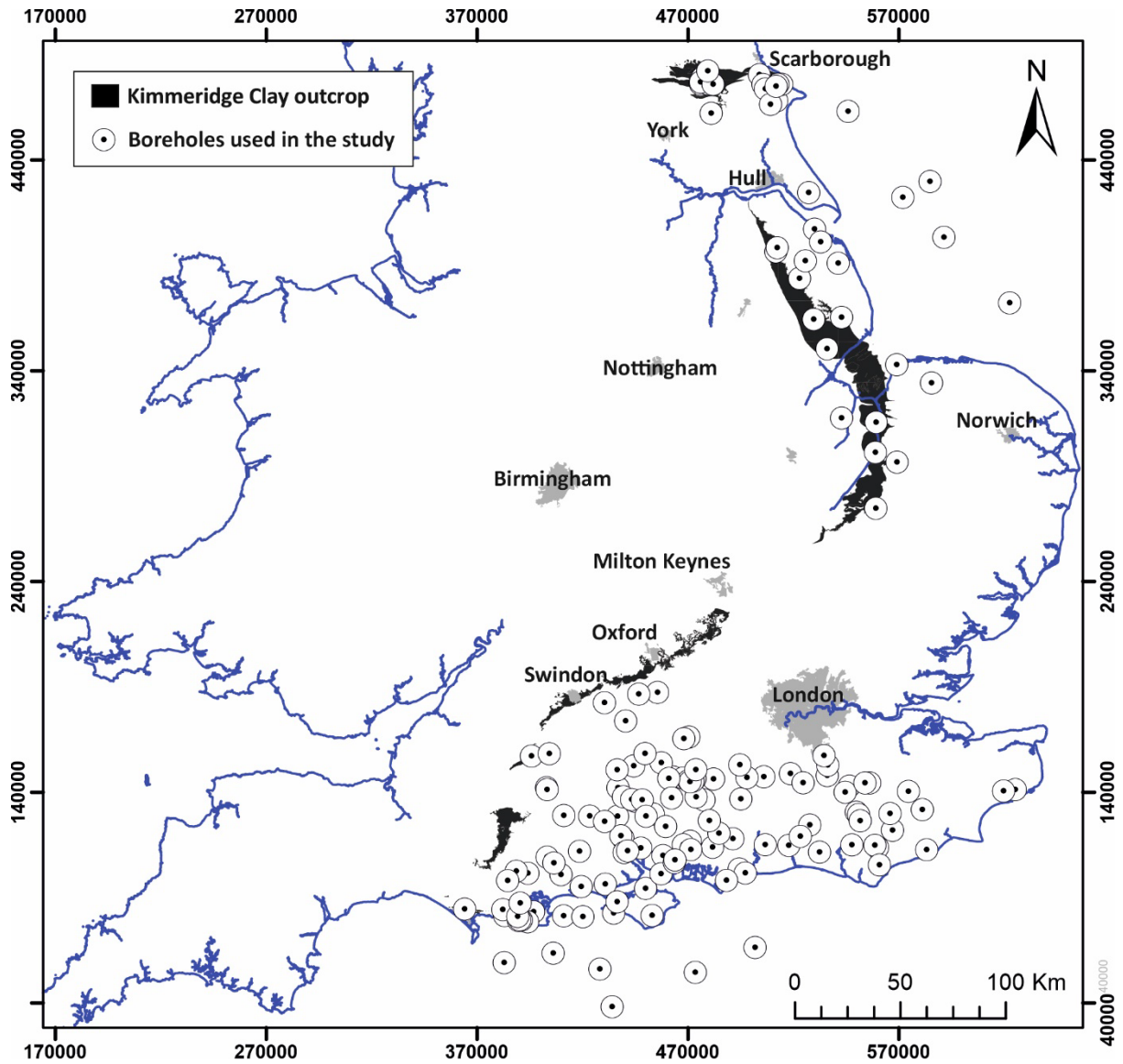


Figure 1 – Map of the Kimmeridge Clay formation outcrop and location of the boreholes used in this report  
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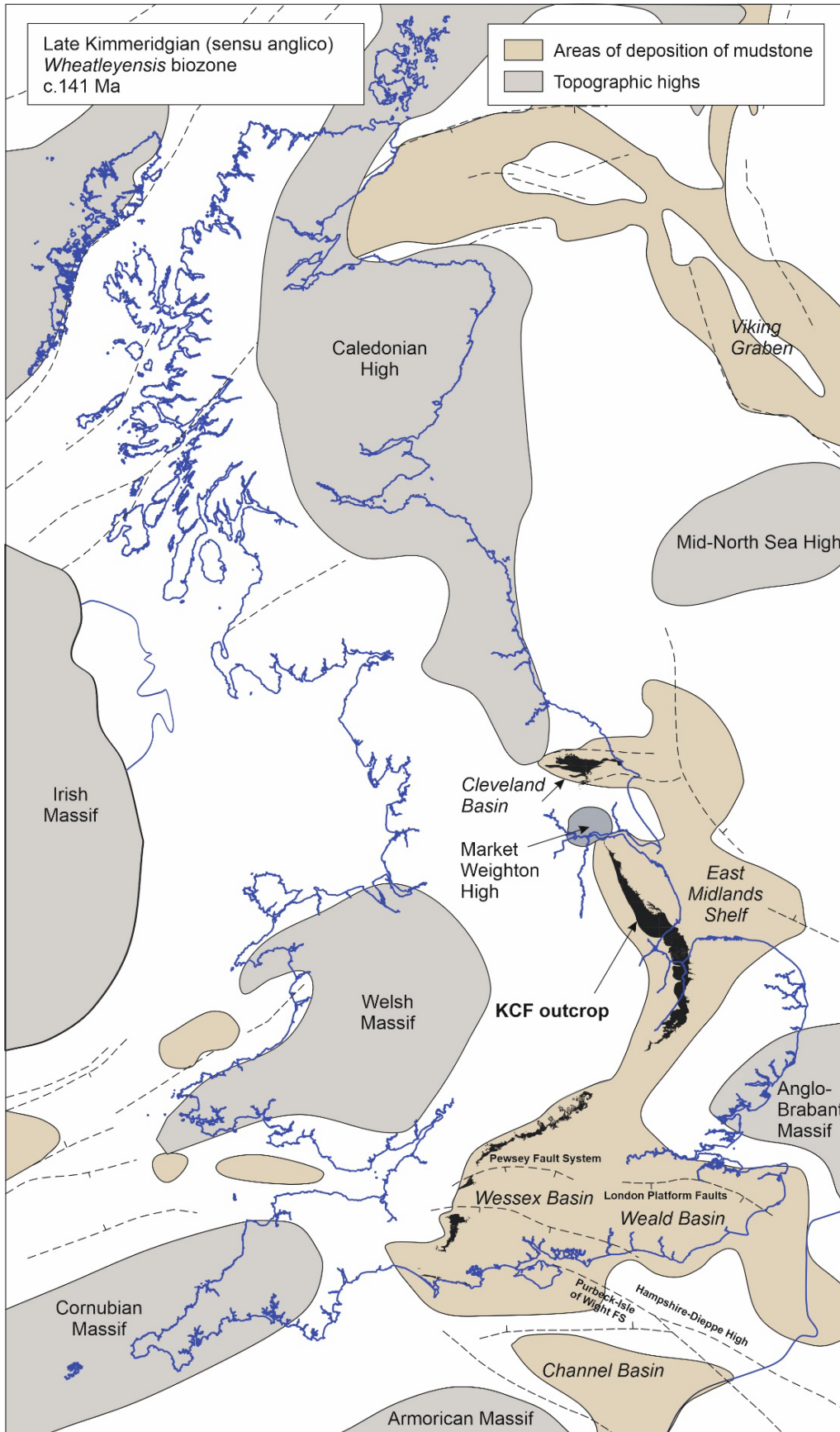


Figure 2 – Map of the present-day outcrop of the Kimmeridge Clay Formation and paleogeographic highs and mudstone depocentres at the time of the unit sedimentation. Modified from Bradshaw et al. 1992 and Gallois 2021. Contains OS data © Crown copyright and database right (2025) OS AC0000824781 EUL Geological data British Geological Survey © UKRI 2026

Stage	Lithostratigraphy	Bed Nos (Morgans-Bell et al., 2021)	Zone	
Tithonian	Kimmeridge Clay Formation	Upper Kimmeridge Clay Formation	KC 58	Virgatopavlovia fittoni
			KC 55-58 (pars)	Pavlovia rotunda
			KC 51 (p)-54	Pavlovia pallasioides
			KC 46 - 51 (pars)	Pectinatites pectinatus
			KC 42 (pars) - 45	Pectinatites huddlestoni
			KC 41-42 (pars)	Pectinatites wheatleyensis
			KC 37 - 40	Pectinatites scitulus
			KC 36	Pectinatites elegans
			KC 33 - 35	Aulacostephanus autissiodorensis
			KC 24 - 32	Aulacostephanus eudoxus
			KC 15 - 23	Aulacostephanus mutabilis
			KC 5 - 14	Rasenia cymodoce
			KC 1 - 4	Pictonia baylei

Figure 3 – Stratigraphic log of the Kimmeridge clay formation with the biostratigraphic ammonite zones correlated with the lithostratigraphic bed groups. © UKRI 2026



Figure 4 – Photograph of the Kimmeridge Bay outcrops with key marker beds can be easily identified. British Geological Survey © UKRI 2026

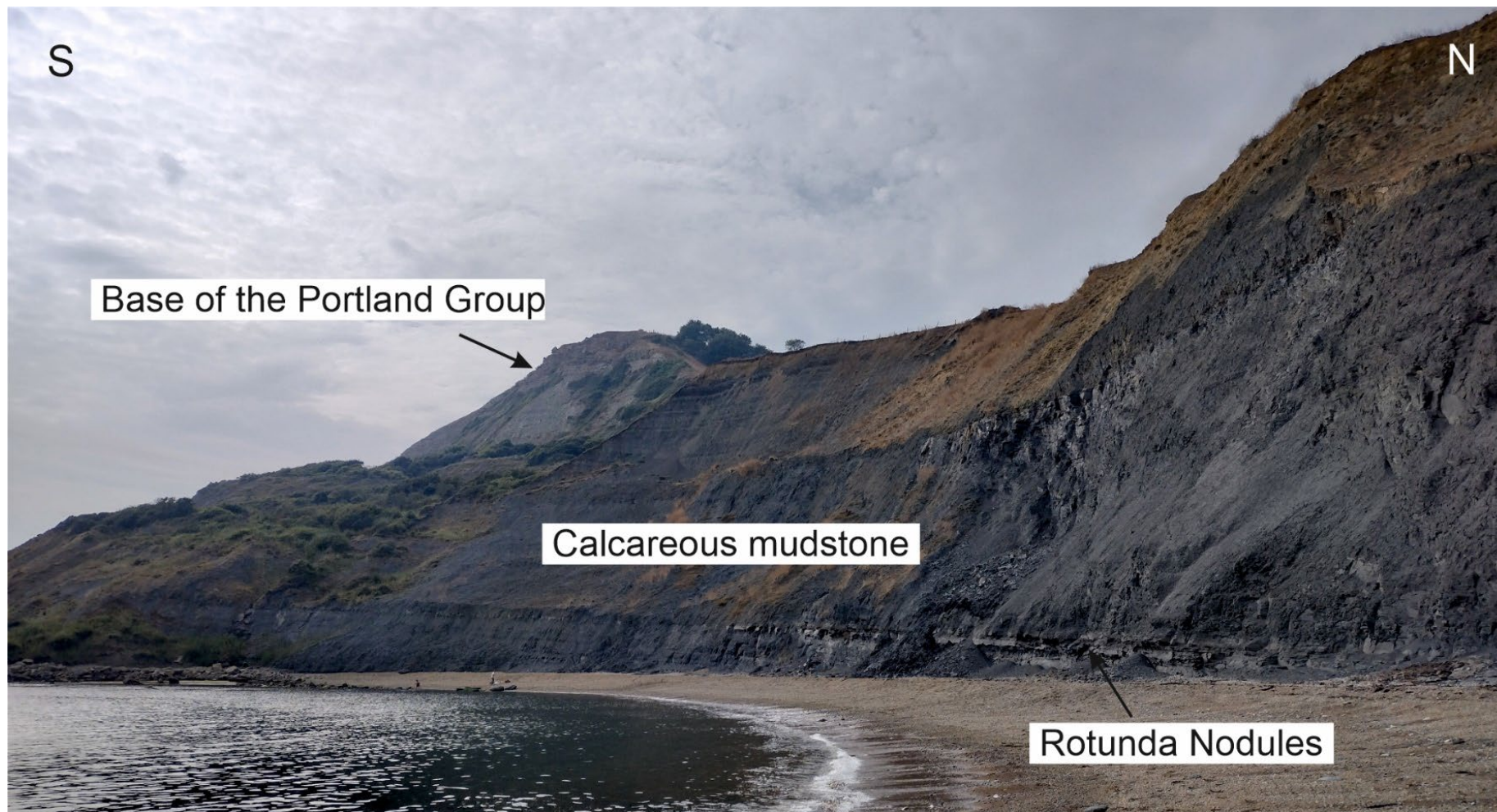


Figure 5 – Top of the Kimmeridge Clay Formation at Chapman's Pool outcrops. The upper part of the formation is lost to erosion under the Portland Group. British Geological Survey © UKRI 2026

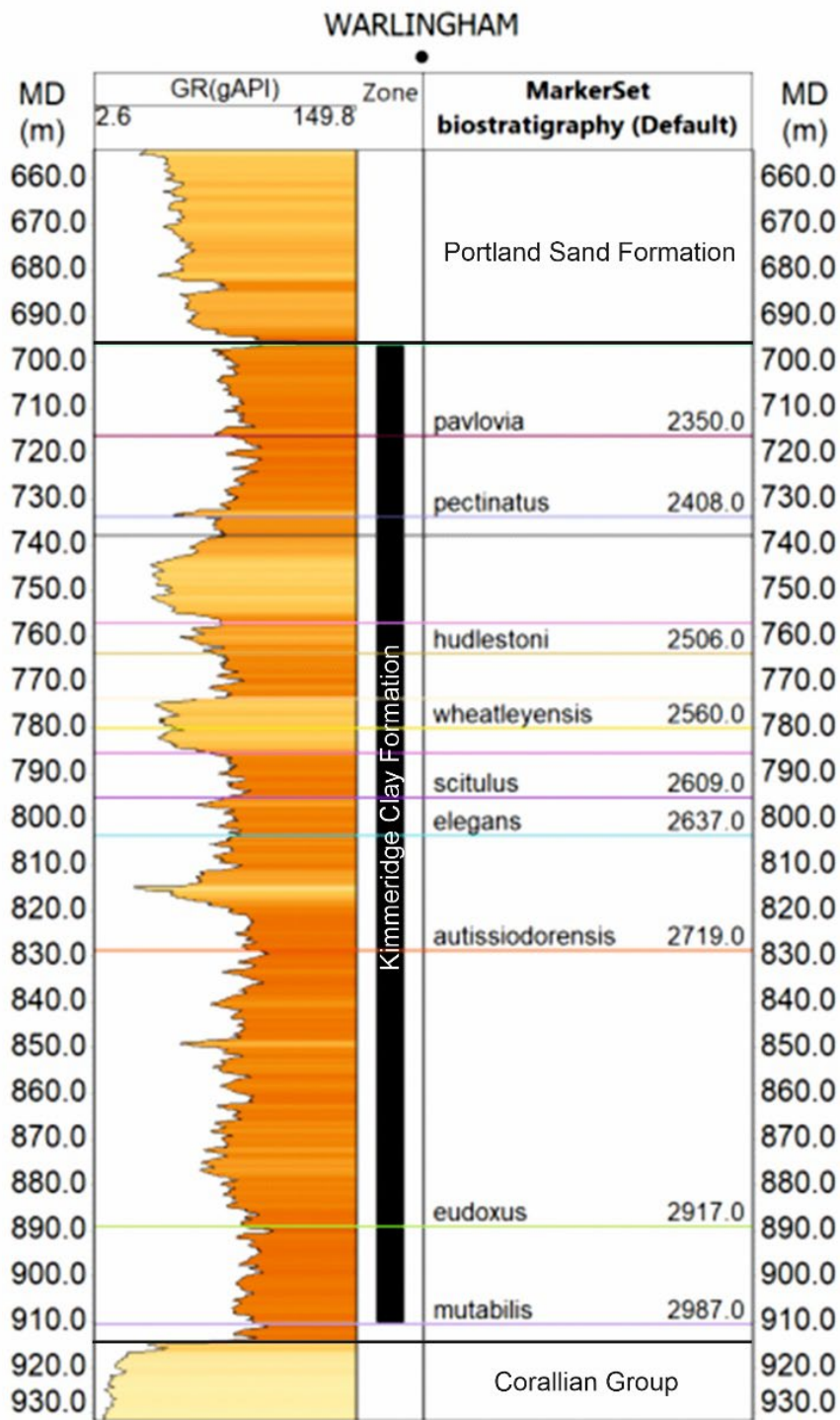


Figure 6 – Gamma Ray log of the Warlingham-1 borehole [534760 0157190] and biostratigraphic markers correlated from Ahmadi, 1997.

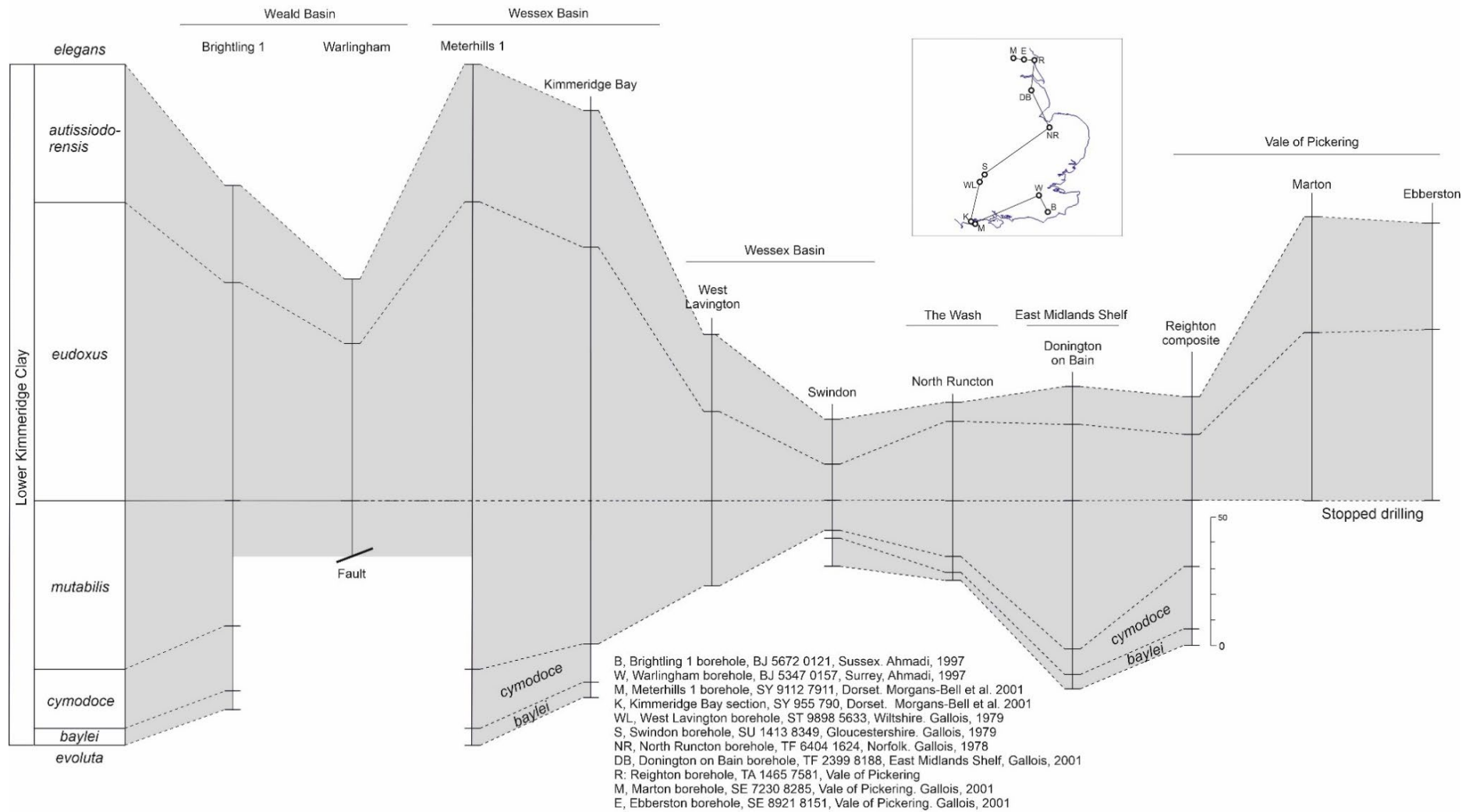


Figure 7 – Correlation of the ammonite zones of the Lower Kimmeridge Clay across southern and eastern England. See references for each borehole within the figure. British Geological Survey. Contains OS data © Crown copyright and database right (2026) [OS AC0000824781 EUL](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/107141/OS_AC0000824781_EUL.pdf) © British Geological Survey UKRI 2026

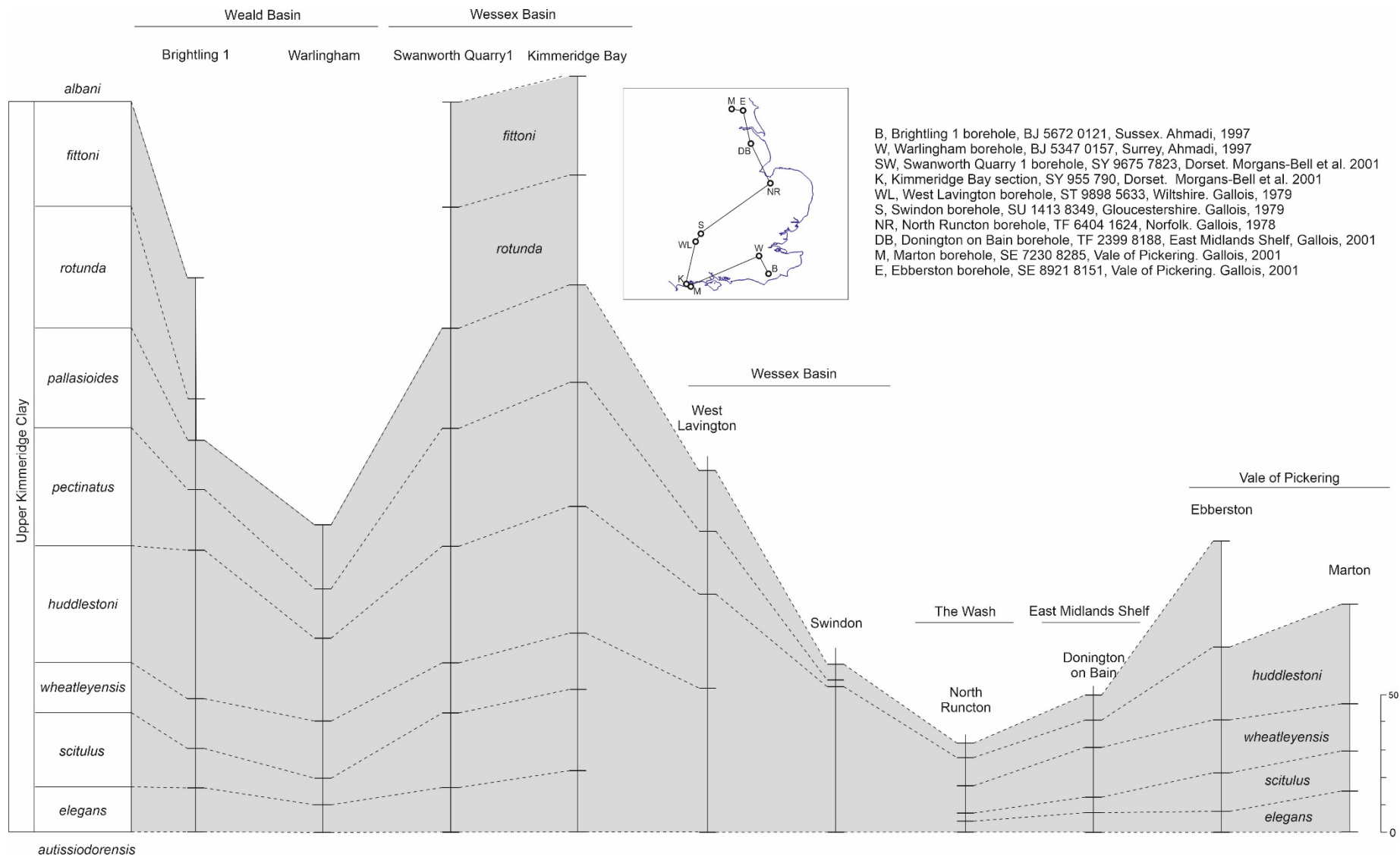


Figure 8 – Correlation of the ammonite zones of the Upper Kimmeridge Clay across southern and eastern England. See references for each borehole within the figure. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026



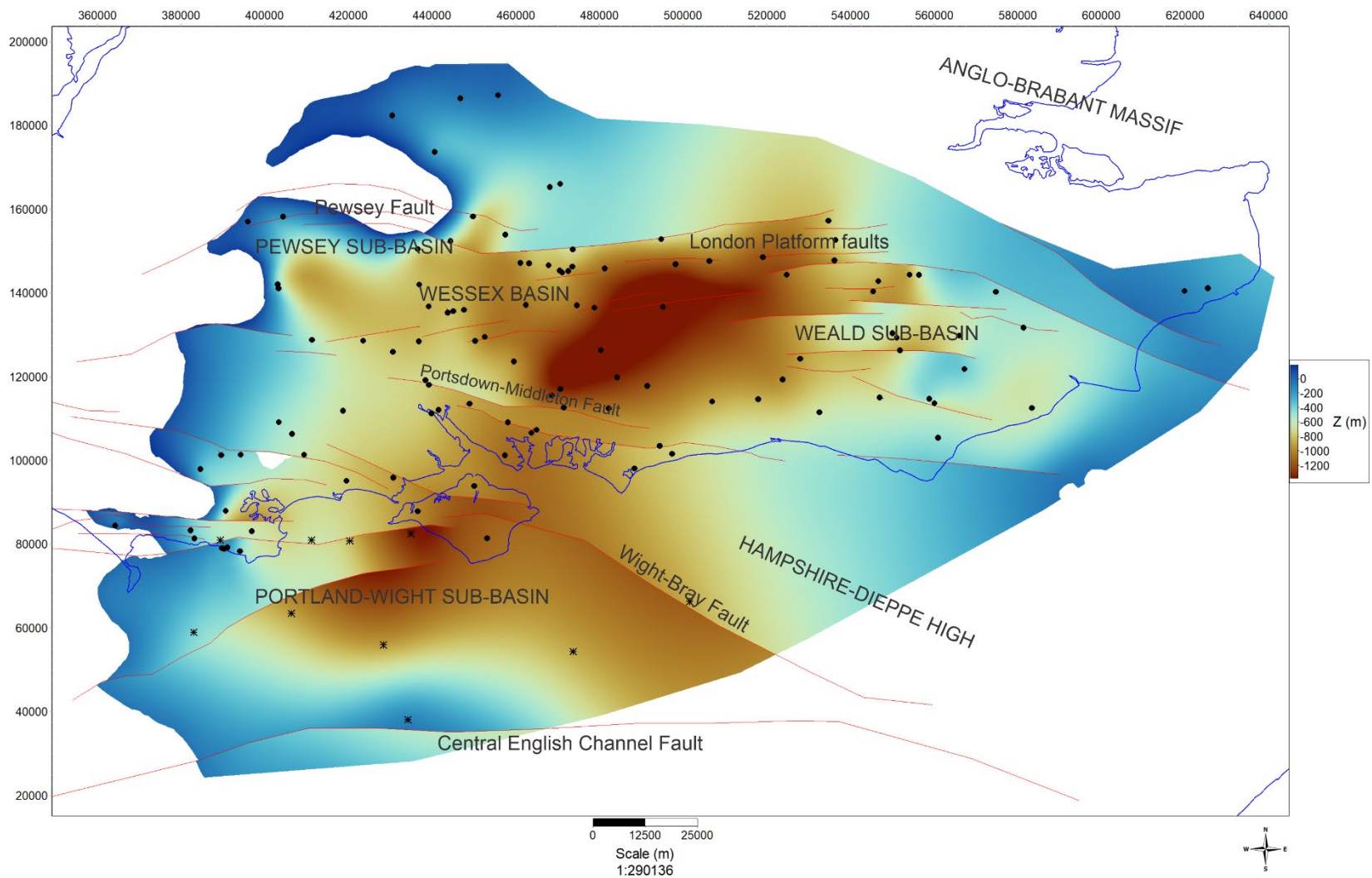


Figure 10 – Elevation map of the Kimmeridge Clay Formation base in Southern England with the main basin-bounding faults represented. Black dots refer to onshore boreholes and black dots with an x refer to offshore boreholes. Contains OS data © Crown copyright and database right (2026) [OS AC0000824781 EUL](#). British Geological Survey © UKRI 2026

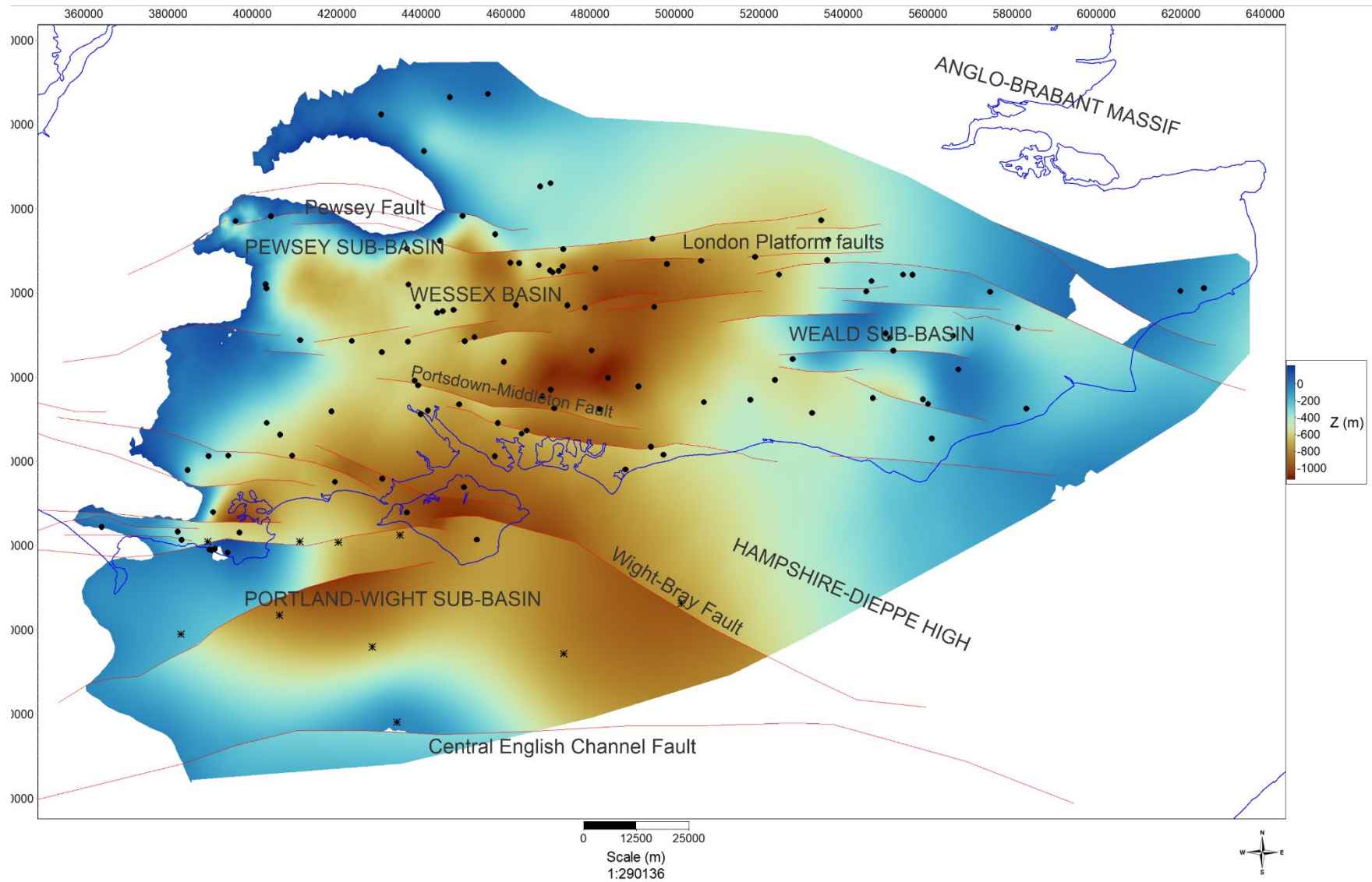


Figure 11– Elevation map of the Kimmeridge Clay Formation top in Southern England made from borehole data. The main basin-bounding faults are represented. Black dots refer to onshore boreholes and black dots with an x refer to offshore boreholes. Contains OS data © Crown copyright and database right (2026) [OS AC0000824781 EUL](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/100000/OS-AC0000824781-EUL.pdf). British Geological Survey © UKRI 2026

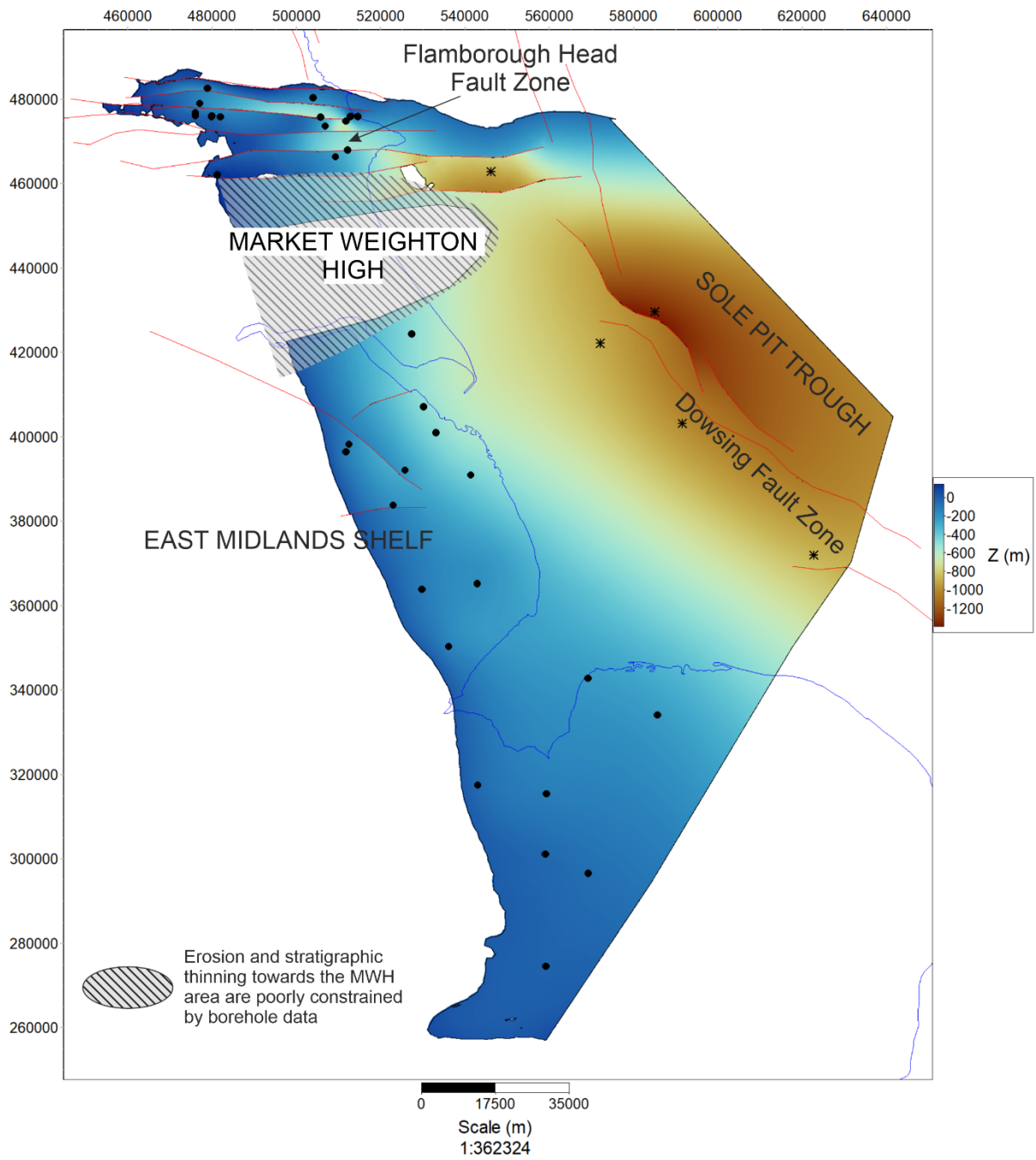


Figure 12 – Elevation map of the Kimmeridge Clay Formation base in the East Midlands Shelf and Northern England made from borehole data. The main faults are represented. Black dots refer to onshore boreholes and black dots with an x refer to offshore boreholes. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

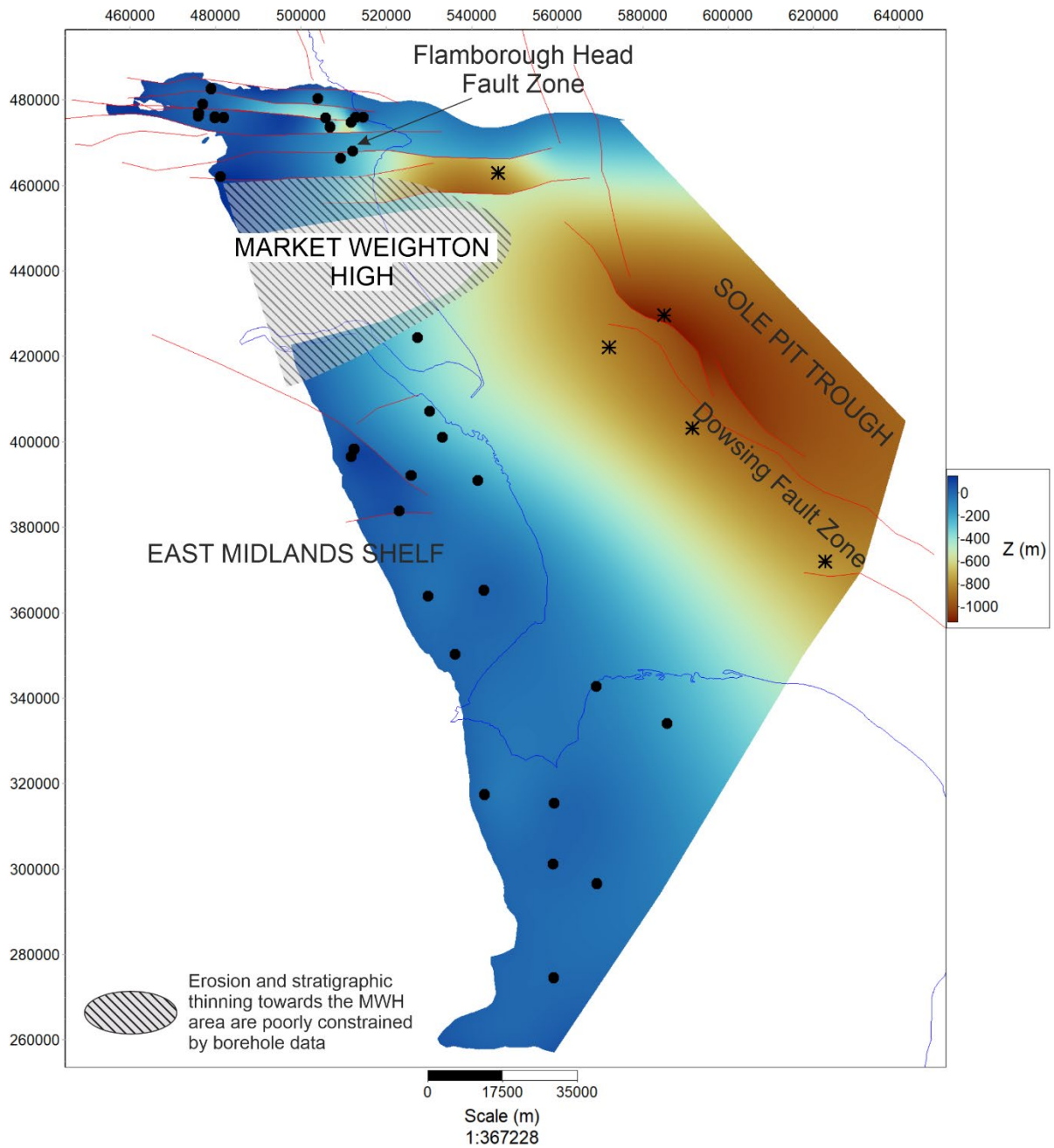


Figure 13– Elevation map of the Kimmeridge Clay Formation top in the East Midlands Shelf and the Cleveland Basin made from borehole data. The main faults are represented. Black dots refer to onshore boreholes and black dots with an x refer to offshore boreholes. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

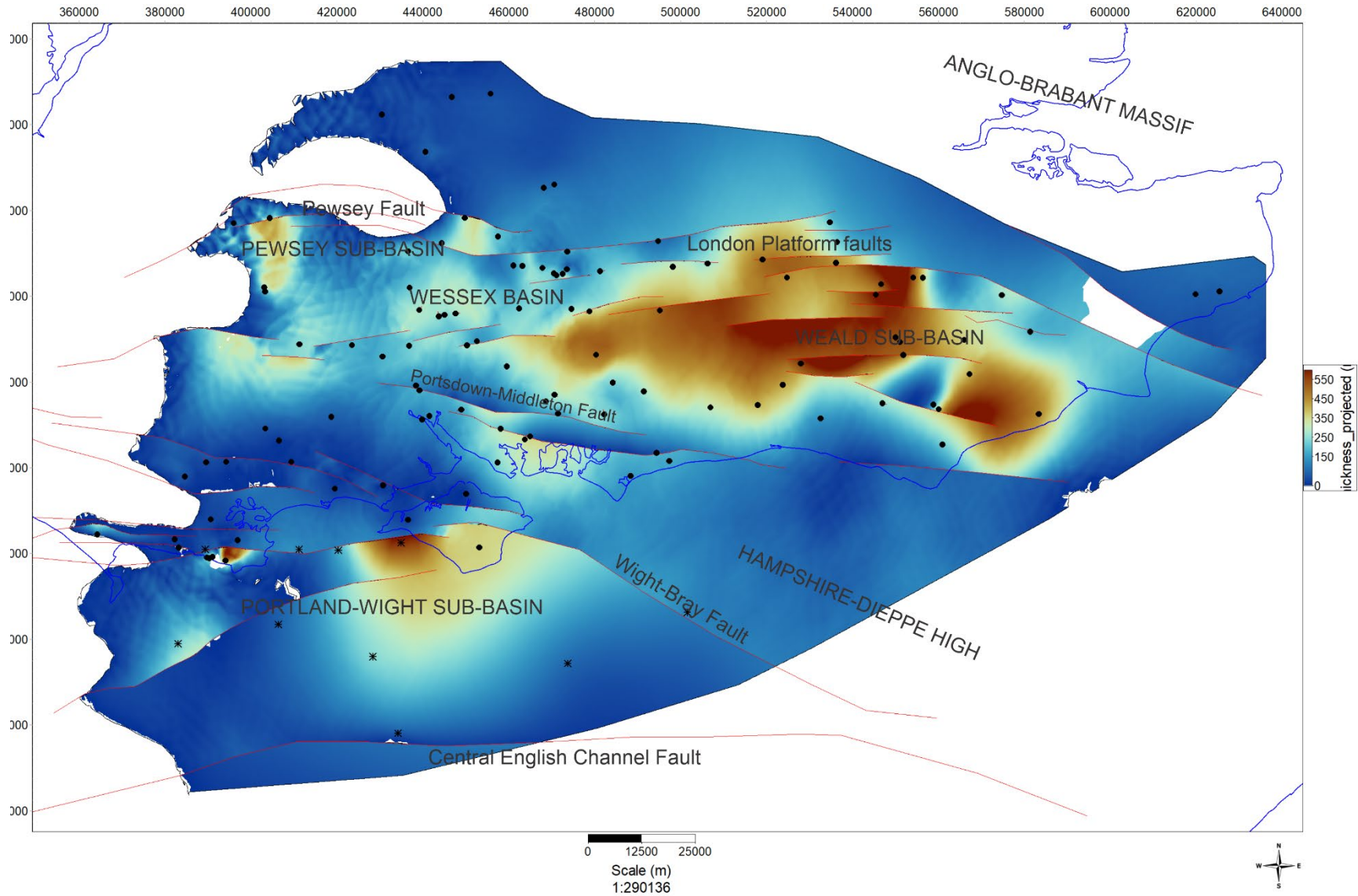


Figure 14– Thickness map of the Kimmeridge Clay Formation in Southern England made from borehole data and including the main faults affecting the formation. Black dots represent onshore borehole locations and black dots with a cross represent offshore boreholes. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

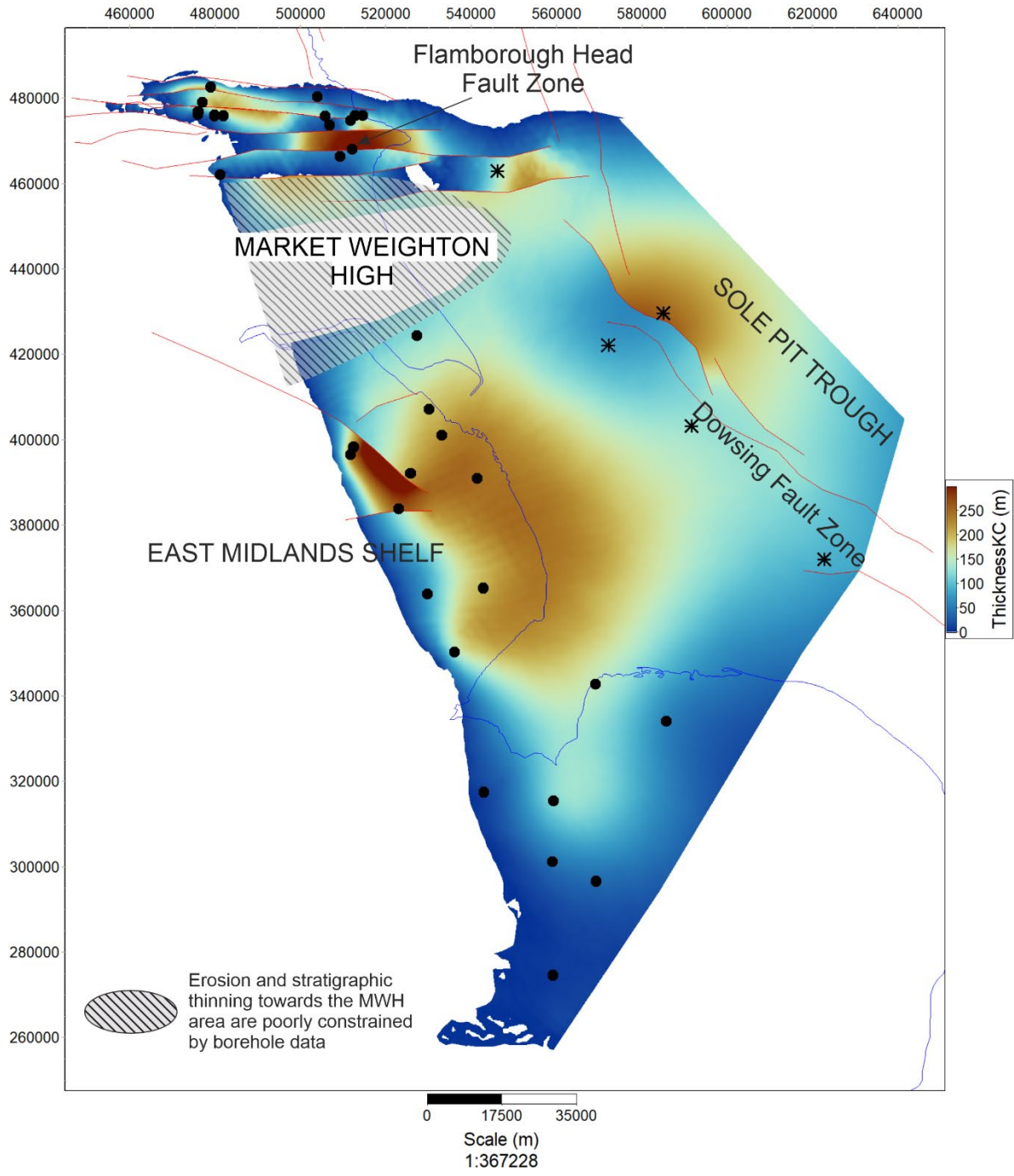


Figure 15 – Thickness map of the Kimmeridge Clay Formation in the East Midlands Shelf and the Cleveland Basin made from borehole data and including the main faults affecting the formation. Black dots represent onshore borehole locations and black dots with a cross represent offshore boreholes. The sudden termination of the KC against the highs is an artifact of the modelling methodology which takes thicknesses values from boreholes and is not constrained by seismic data. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

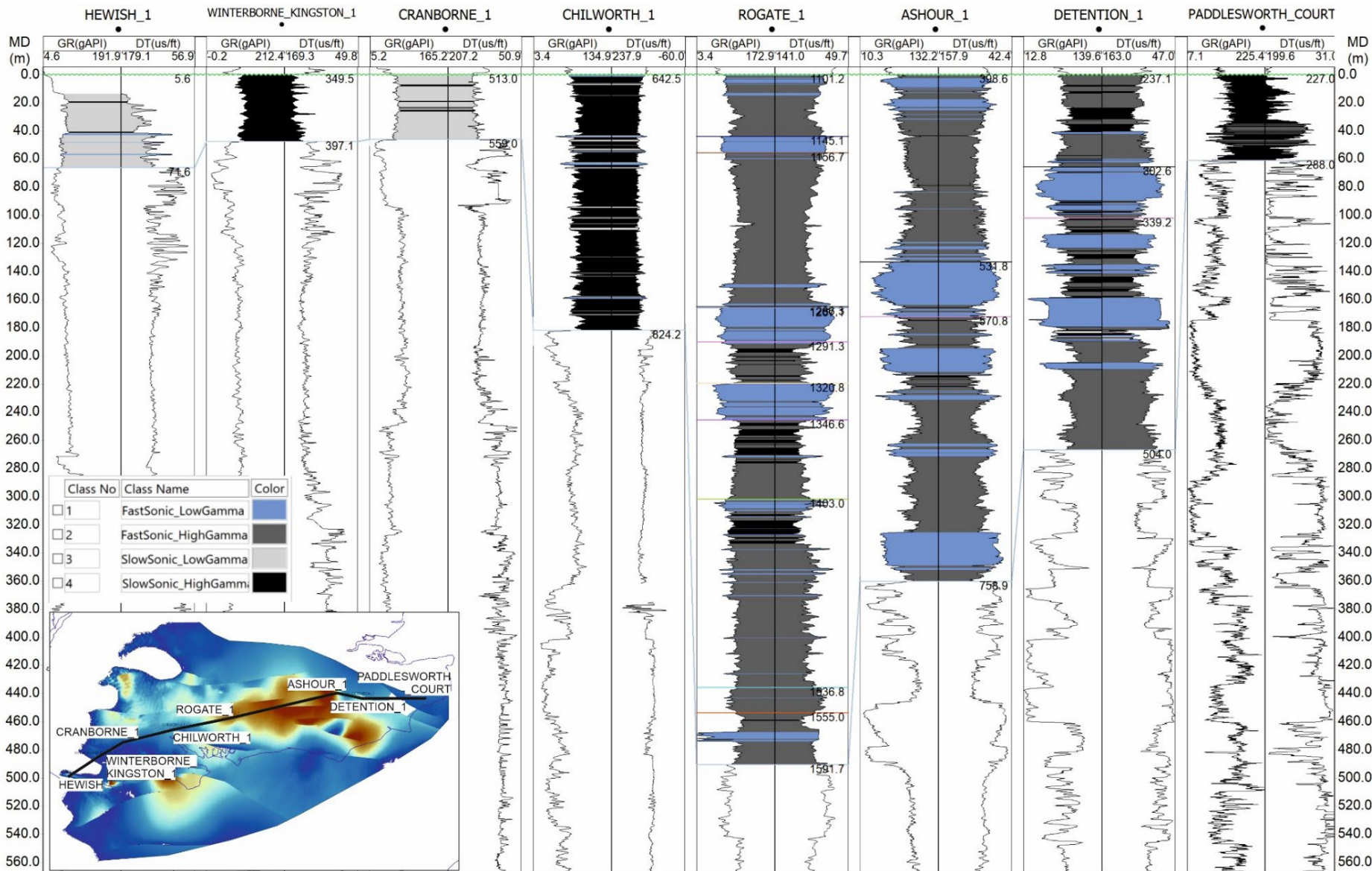


Figure 16 – Wireline log correlation across from the western edge of the Wessex Basin to the edge of the Anglo-Brabant massif, showing the formation thickening towards the Wessex and Weald depocentres. The colour coding of the log track refers to the four electrofacies groups established through cut-offs explained in section 4.1 of this report. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

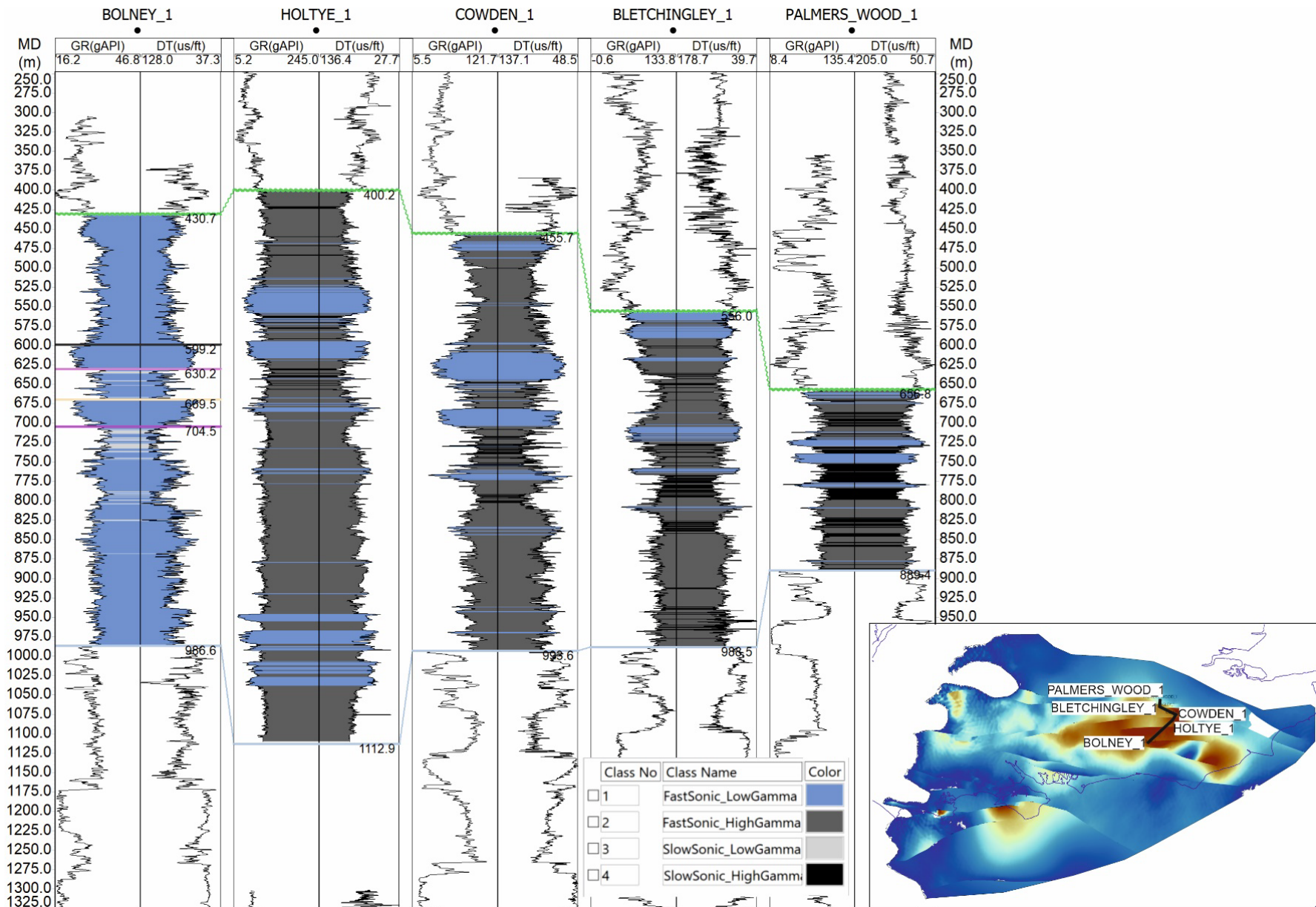


Figure 17 – Wireline log correlation across the thickest part of the Weald Basin depocentre. The colour coding of the log track refers to the four electrofacies groups established through cut-offs explained in section 4.1 of this report. British Geological Survey © UKRI 2026

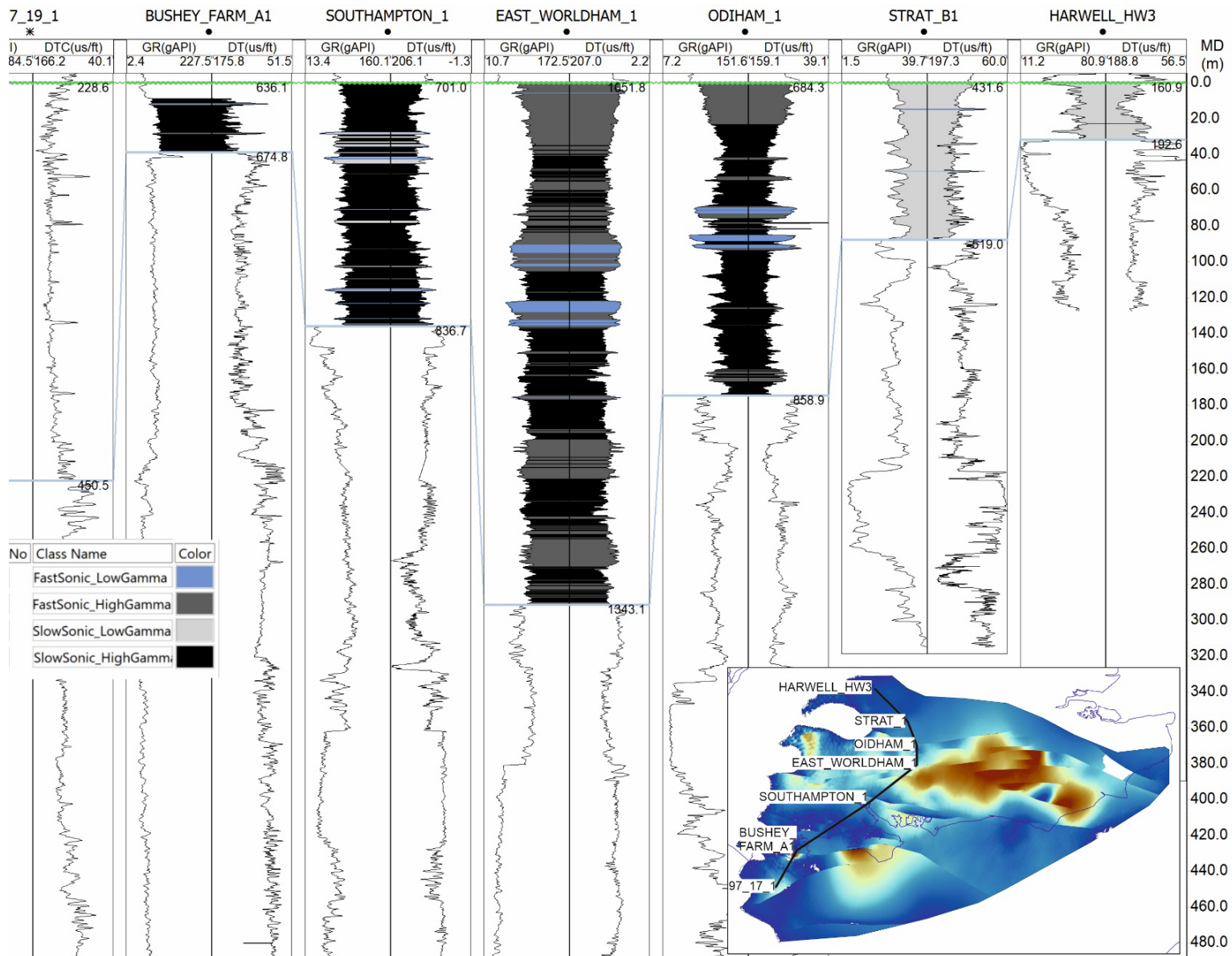


Figure 18 – Wireline log correlation across the western Wessex basin, showing notable thinking of the formation towards the basin margins. The colour coding of the log track refers to the four electrofacies groups established through cut-offs explained in section 4.1 of this report. Contains OS data © Crown copyright and database right (2026) OS AC0000824781 EUL. British Geological Survey © UKRI 2026

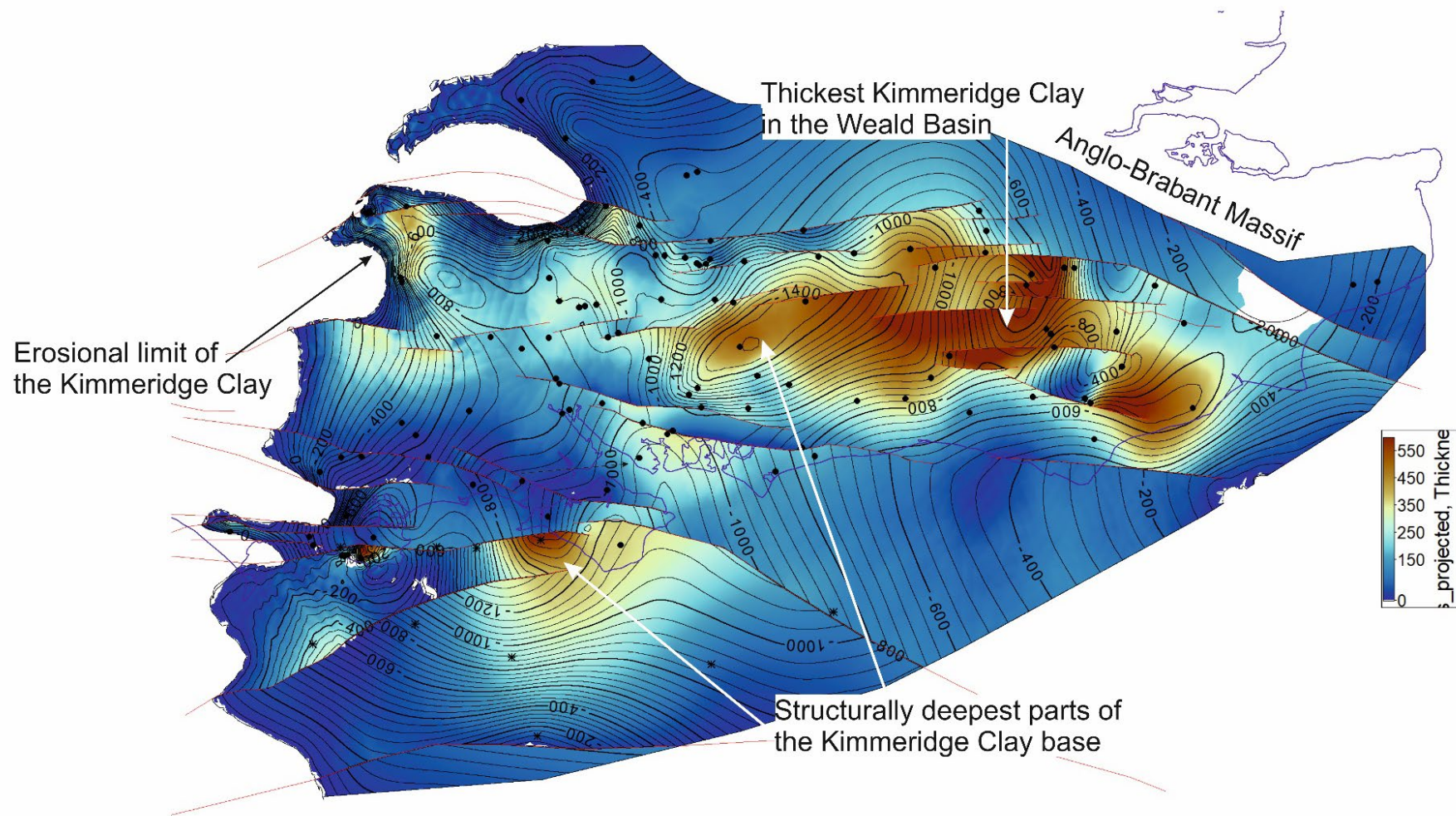


Figure 19 – Thickness map of the Kimmeridge clay in Southern England from borehole data. The main faults affecting the formation are represented. Black dots refer to onshore boreholes and back dots with an x refer to offshore boreholes. Contains OS data © Crown copyright and database right (2026) [OS AC0000824781 EUL](#). British Geological Survey © UKRI 2025

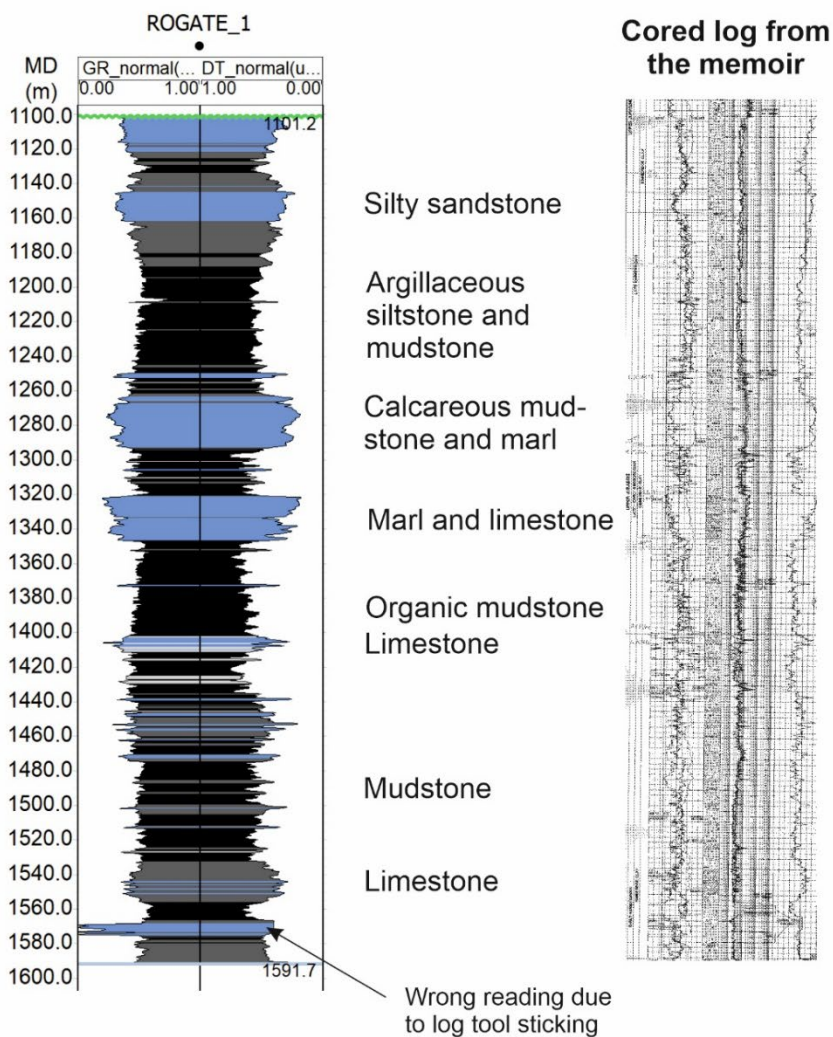
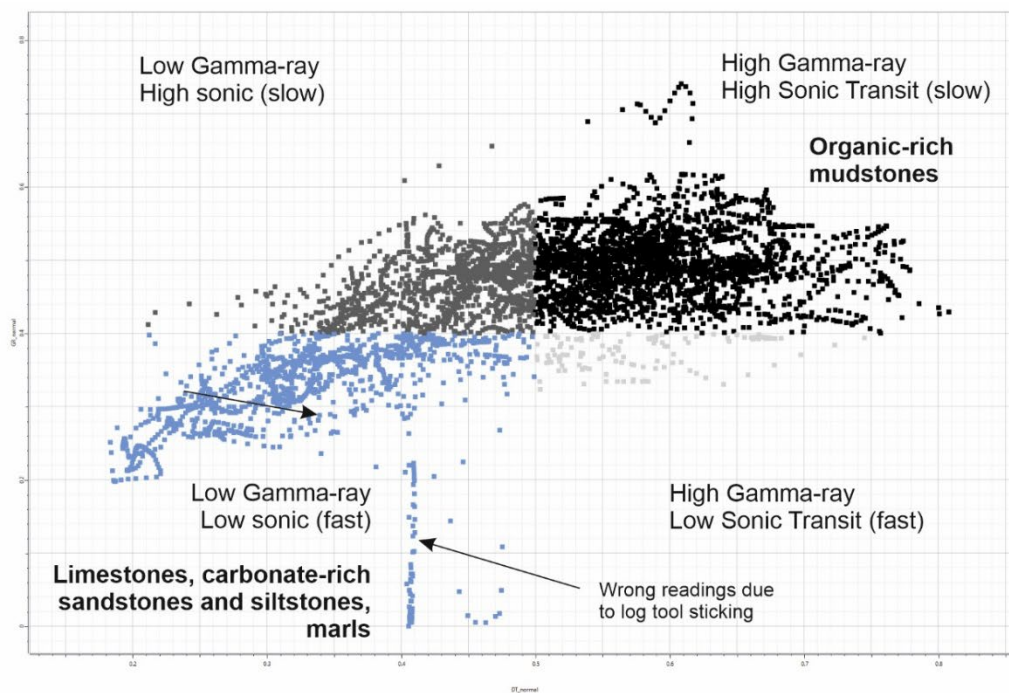
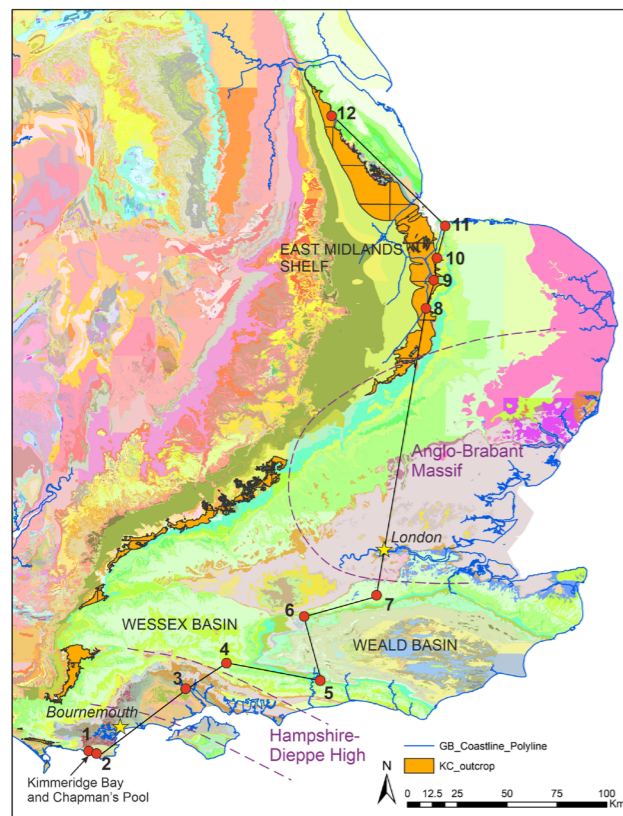
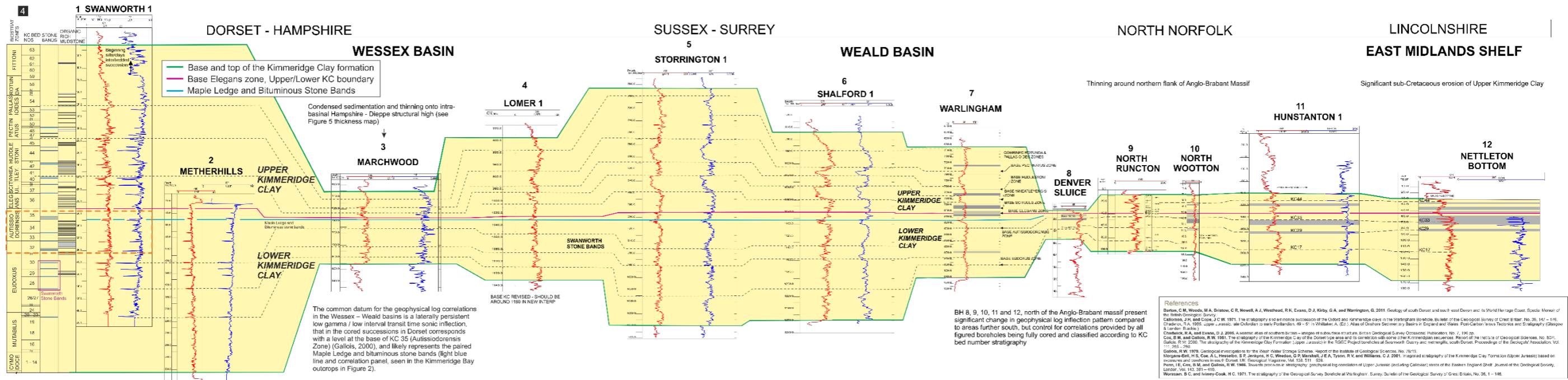


Figure 20 – Above, plot of gamma-ray vs sonic to differentiate four electrofacies using cutoffs (see explanation in text). Below, Electrofacies at Rogate-1 borehole [480342 0126314] next to corresponding annotations from the core-logging memoir. British Geological Survey © UKRI 2026

# 8 Appendix



Appendix 1. Wireline log correlation across the Kimmeridge Clay outcrop and subcrop from the Dorset Coast to the East Midlands. A high-resolution version of this correlation can be found in the associated data of this report. Contains OS data © Crown copyright and database right (2026). British Geological Survey © UKRI 2026