Feature

Geological evolution of the Hampshire Basin (southern England) during a global climate transition from 'hothouse' to 'coolhouse' in the Palaeogene

Palaeogene sediments of the Hampshire Basin were a sensitive recorder of fluctuations in climate and eustatic sea level as Earth's climate transitioned from the global early Eocene 'hothouse' to the early Oligocene 'coolhouse', accompanied by the first permanent continent-scale glaciation of Antarctica at the Eocene/Oligocene boundary. A study of the Palaeogene sediments of the Hampshire Basin is not only interesting from a palaeoclimate perspective, but the marine middle Eocene formations are renowned for containing some of the most abundant and diverse Palaeogene fossil assemblages in the world. In this article, I take you on a tour of the geological evolution of the Hampshire Basin from the end of the Paleocene through to the Pleistocene. I highlight some of the best exposures where sediments can be studied at outcrop and representative fossil assemblages can be collected, along with the economic and archaeological significance of these Palaeogene sediments.

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The Hampshire Basin encompasses much of southern Hampshire, south-eastern Wiltshire and Dorset, south-western West Sussex and the northern half of the Isle of Wight, in southern England, comprising a succession of latest Paleocene, Eocene and early Oligocene predominantly unconsolidated clastic sediments (Fig. 1). These sediments were deposited in an interplay of fluvial, lacustrine, deltaic, estuarine, lagoonal and shallow marine environments. The soft sediments of the Hampshire Basin are easily weathered, forming the modern-day 'basin' of low topography with gentle slopes, surrounded by higher and steeper chalk hills around its uplifted perimeter. Palaeogene sediments of the Hampshire Basin (along with the London Basin to the north-east) represent the preserved remnants of sediments deposited across a broad coastal plain bordering the North Sea, which once occupied a large portion of south-eastern Britain. These sediments have been preserved within synclinal depressions between large anticlinal and monoclinal fold structures, which developed to their full extent during Miocene structural inversion (Fig. 2).

Tropical England during the latest Paleocene–early Eocene 'hothouse'

During latest Paleocene–early Eocene times, sediments were widely deposited across a broad coastal plain bordering the North Sea and far beyond their current preservational limits within the Hampshire and London basins. This is evidenced by a patchy cover of residual deposits of this age known traditionally as the 'clay-with-flints' across the chalk downlands bordering the Hampshire and London basins, extending as far west as eastern Devon, southern Somerset and Wiltshire, and as far north as Berkshire, Oxfordshire and Hertfordshire. Within the Hampshire Basin, latest Paleocene–early Eocene sediments comprise marine, marginal marine and continental sediments of the Lambeth Group (Upnor and Reading formations), Thames Group (Harwich and London Clay formations) and lower part of the Bracklesham Group (Wittering Formation). They were deposited during an extreme greenhouse ('hothouse') climate, characterized by global temperatures ranging from 10°C to 20°C hotter and eustatic sea level up to 90 m higher than today, along with little or no ice at the poles. As a result, southern Britain was characterized by a tropical hot and humid climate, situated at a palaeolatitude of ~40° N.

Within the Hampshire Basin, sedimentation commenced at the end of the Paleocene with deposition of the Upnor Formation, comprising shallow marine glauconitic sands containing oyster beds. The Upnor Formation records the first shallow marine transgression across the Hampshire Basin from the east but is poorly exposed and absent from the southern part of the basin, hampering reconstructions of this latest Paleocene marine transgression.

The Upnor Formation is overlain by distinctive colour-mottled red, purple, orange, brown and grey clays and silts of the Reading Formation, containing laterally discontinuous sand beds. The Reading Formation was deposited across an extensive muddy floodplain under a humid tropical climate at the start of the Eocene (~56–55 Ma). Discrete horizons preserving plant fragments and fossil wood (lignite) provide evidence for an extensive cover of swamp palm vegetation across this waterlogged floodplain, through which drained fluvial channels depositing isolated sand bodies. A large quantity of zircons within sands of the Reading Formation suggests that clastic material was sourced from the erosion of metamorphic and felsic igneous rocks in the Armorican massif of NW France, metamorphosed and intruded during the late Carboniferous Variscan Orogeny (~300 Ma). It is therefore possible to reconstruct a series of large rivers flowing to the north-east, from the highlands of the Armorican massif across a broad coastal plain covering a large portion of south-eastern Britain, transitioning to estuarine and then shallow marine environments further east towards or within the North Sea basin (Fig. 3). The lower part of the Reading Formation may have been deposited during the Paleocene-Eocene Thermal Maximum (PETM; ~55.9 Ma), a transient 'hyperthermal' event when temperatures spiked to some of the hottest values of the entire Cenozoic and as much as 20°C warmer than today. The Reading Formation is best exposed in the steeply dipping cliffs at Alum Bay and Whitecliff Bay (Isle of Wight) along the southern margin of the Hampshire Basin. Elsewhere in the basin, it has only been studied in boreholes and temporary quarries where sands within the formation were extracted for the construction industry, such as the Brickworth Sand Pit near Whiteparish. Sarsen stones, widely distributed across the chalk downlands of Salisbury Plain and Marlborough Downs in Wiltshire, represent residual silicified sandstone blocks of the Reading Formation. Large tall-standing sarsen stones were used in the construction of Neolithic archaeological sites such as Stonehenge and Avebury Rings in Wiltshire. The sarsen stones of Stonehenge on Salisbury Plain were transported ~25 km southward by Neolithic people from their original source in West Woods on the southern edge of Marlborough Downs.

Following a period of erosion, long-term global warming associated with the onset of the Early Eocene Climatic Optimum (EECO) resulted in a major eustatic sea level rise and marine transgression across the coastal plain of south-eastern Britain. Initially, fine-grained glauconitic sands and silts of the Harwich Formation were deposited, but these were quickly succeeded by richly fossiliferous marine clays and silts of the London Clay Formation. The marine Harwich and London Clay formations comprise the Thames Group and were deposited during the early–middle Ypresian (~55–51.5 Ma). The marine transgression of the London Clay sea spread far and wide across the former extensive low-lying muddy floodplain of south-eastern Britain, depositing marine sediments as far west as Dorset and Wiltshire, and as far north as Berkshire, Hertfordshire and East Anglia (Fig. 4).

The London Clay Formation is named after the London Basin, where it is widely exposed at the surface or at shallow depth beneath superficial Neogene or

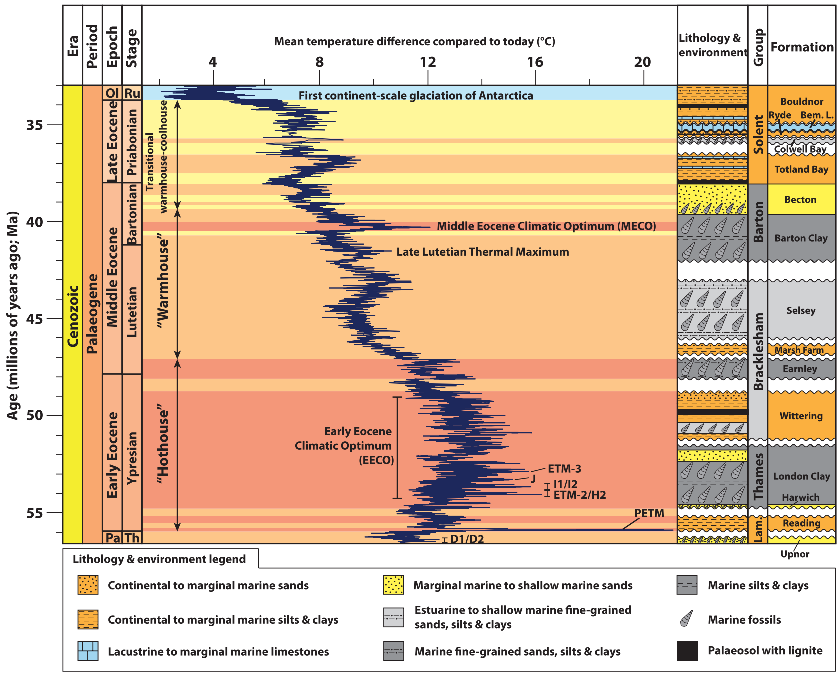


Fig. 1. Correlation of the stratigraphy and depositional environments of the central-eastern Hampshire Basin to global climatic evolution based on the stable oxygen isotope ratios ($\delta^{18}O$) of deep sea benthic foraminifera from the Atlantic and Pacific oceans (data from Westerhold et al., 2020). The main fossiliferous horizons/formations are indicated, along with key global climatic events. Correlation between the Hampshire Basin stratigraphy and global climate evolution is based primarily on magnetostratigraphy, integrated with calcareous nannofossil biostratigraphy for the marine formations. PETM = Paleocene-Eocene Thermal Maximum. ETM-2 = Eocene Thermal Maximum 2. ETM-3 = Eocene Thermal Maximum 3. Bem. L. = Bembridge Limestone Formation.

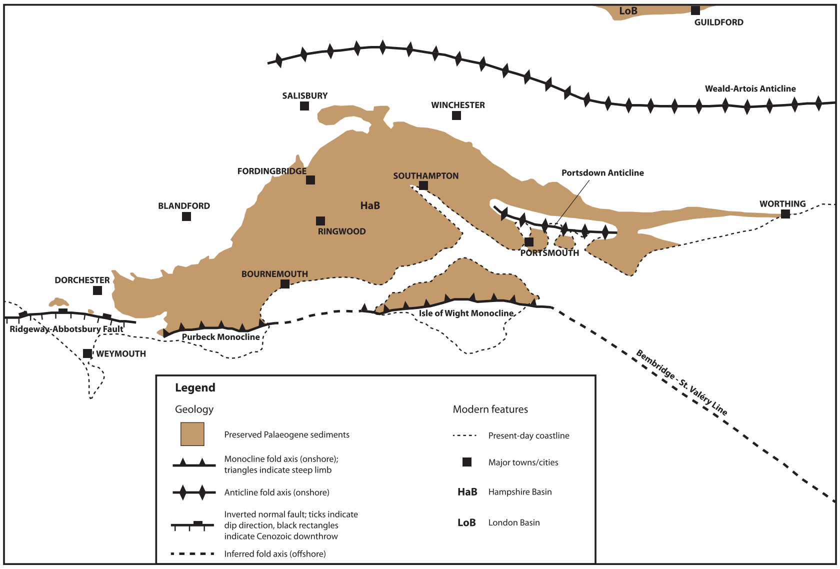


Fig. 2. Simplified geological map of the Hampshire Basin, illustrating the distribution of preserved Palaeogene sediments and the principal geological structures.

Quaternary strata. Fossiliferous foreshore and cliff exposures abound along the east coast from Kent to Suffolk, yielding a diverse suite of bivalves, gastropods, corals, crustaceans, foraminifera and fish remains. These sites are particularly famous for their abundance of shark's teeth. The formation contains a greater proportion of sand and was deposited within a shallower marine environment further westward within the Hampshire Basin, closer to the basin margin and sources of sediment input. It also becomes sandier upward through the succession, containing some well-developed silty and fine-grained sand units such as the Nursling Sand, Portsmouth Sand and Whitecliff Sand within the upper part of the formation. Some of these sand units have been quarried along with those in the underlying Reading Formation for building, concreting and plastering sand.

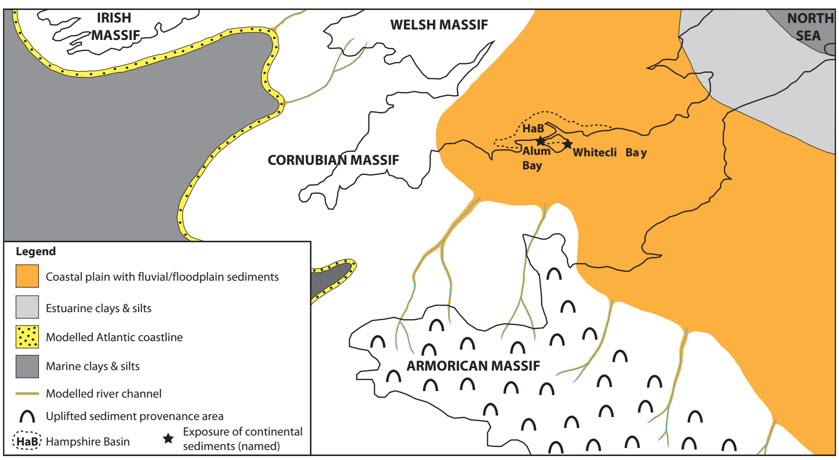
The tropical London Clay sea was connected to the North Atlantic Ocean through both the North Sea and English Channel, fringed by extensive mangrove forests where palms such as the *Nypa* swamp palm flourished. The *Nypa* swamp palm is found today in mangroves along the coastline of the tropical and subtropical Indian and Pacific oceans, where the large ripe nuts detach and float in the water, aiding their dispersal. As a result, wood and nuts of the *Nypa* swamp palm and other tropical vegetation travelled far offshore across the surface of the London Clay sea, with pyritized fossils found throughout the marine London Clay Formation within the London and Hampshire basins. Within the Hampshire Basin, the London Clay Formation is once again best exposed in the steeply dipping cliffs at Alum Bay and Whitecliff Bay on the Isle of Wight. However, fossiliferous foreshore exposures also occur around Bognor Regis in West Sussex, which are particularly famous for their fossil insects.

Late Ypresian marine regression from south-eastern Britain facilitated the return of a broad coastal plain, where clays, silts and fine-grained sands of the Wittering Formation were deposited in predominantly lagoonal and tidal flat environments. Although generally poorly fossiliferous, a shallow marine interval preserving calcareous fossils is found in the lower part of the formation in the south-eastern Hampshire Basin, as far west as Gosport. By contrast, there is evidence that the sea regressed completely from the entire Hampshire Basin during deposition of the overlying 'Whitecliff Bay Bed' (~50 Ma), allowing lush tropical vegetation to flourish. The 'Whitecliff Bay Bed' comprises a well-developed rooted fossil soil (palaeosol), which represents a distinctive marker within the Wittering Formation and can be correlated throughout the Hampshire Basin.

The Wittering Formation was deposited during peak 'hothouse' conditions of EECO (~51.5–49 Ma), supporting the development of extensive tropical vegetation across the landmasses of southern Britain. The appearance of tourmaline and kaolinite within sediments of this age suggests a shift in provenance to the granites of the Cornubian massif (Cornwall and west Devon) to the west. As a result, sediment input to the Hampshire Basin was focused into the south-west of the basin around the northern Purbeck, Poole and Bournemouth area, where a vast delta system informally known as the 'Poole Delta' formed. Generally sandier sediments of the Poole Formation were deposited across the Poole Delta in a complex interplay of alluvial, fluvial, estuarine and deltaic environments during the early–middle Eocene, although extensive lake basins and swamps developed during periods characterized by a wetter climate or sea level rise. Within these lake basins, a specific type of kaolinite-rich clay known as ball clay was deposited. The kaolinite is likely to have been derived from chemical weathering of exposed granites on Dartmoor (Cornubian massif) under the tropical and humid climate. This ball clay is commercially mined for the production of pottery, tiles, bricks and pharmaceutical uses between Corfe Castle and Wareham in Dorset.

The Wittering Formation outcrops at the surface across a significant part of the northern and eastern

Fig. 3. Depositional environments and palaeogeography across southern Britain and NW Europe during deposition of the Reading Formation (early Ypresian, early Eocene; ~56–55 Ma).



Hampshire Basin, such as within the Southampton area and across the northernmost part of the New Forest National Park. However, it typically forms a belt of low topography with poor exposure. The formation is best exposed in cliffs at Whitecliff Bay on the eastern coast of the Isle of Wight and as foreshore exposures at the western end of Bracklesham Bay in West Sussex.

The richly fossiliferous marine sediments of the middle Eocene

A long-term cooling trend subsequently commenced during the middle–late Eocene, following peak greenhouse climates associated with EECO. Small ice caps started to erratically form and grow across Antarctica, leading to a stepwise fall in global sea level. This long-term cooling trend was briefly interrupted at the end of the Ypresian (early Eocene) and start of the Lutetian (middle Eocene) by two abrupt warming events or 'reversals'. These facilitated eustatic sea level rise and transgression of a shallow subtropical sea westward across the broad coastal plain of south-eastern Britain, leading to deposition of marine fossiliferous fine-grained glauconitic sands and sandy clays of the Earnley Formation (~48–47 Ma). The Earnley Formation represents one of the most fossiliferous successions within the eastern Hampshire Basin as far west as Southampton, thinning and eventually pinching out further to the west. As a result, it is possible to reconstruct a roughly north–south trending coastline, extending from the westernmost tip of the Isle of Wight northwards through the New Forest to the west of Lymington, Brockenhurst and Lyndhurst (Fig. 5). The marine fossiliferous Earnley Formation is best exposed as foreshore exposures in Bracklesham Bay, just to the south-east of Bracklesham car park, or in cliffs at Whitecliff Bay. Particularly interesting and spectacular fossiliferous units include the '*Cardita* Bed', which is packed with the giant thick-walled bivalve *Venericor* (*Cardita*) *planicosta* (Fig. 6), the '*Turritella* Bed', containing the abundant gastropods *Turritella imbricataria* and *T. sulcifera*, the 'Palate Bed' which contains well-preserved eagle ray palates, and the '*Nummulites laevigatus* Bed', packed full of giant nummulites (benthic foraminifera) as large as a coin, now known as *Nummulites britannicus* (Fig. 7a).

A pronounced global cooling and fall in eustatic sea level resulted in the return of lagoonal, deltaic and estuarine environments across much of the Hampshire Basin during deposition of the overlying Marsh Farm Formation (~47–46 Ma). The Marsh Farm Formation comprises predominantly clays and silts, although sands fill erosional channels incised into the upper part of the formation. It is generally poorly fossiliferous across the central-eastern Hampshire Basin, although a marine unit exposed at Whitecliff Bay contains abundant nummulites. This formation and correlative sediments (Parkstone Clay Member of the Poole Formation) are best known for their abundance of lignite and plant fossils across the western part of the basin, deposited across the former Poole Delta. Fossiliferous exposures occur along the coastline of Brownsea Island in Poole Harbour and at Alum Bay, signifying the return of swampy environments and lush subtropical vegetation across the western Hampshire Basin during this time.

The Bracklesham Group is capped by fossiliferous marine glauconitic clays, silts and fine-grained sands of the Selsey Formation, deposited during middle–late Lutetian marine transgression (~46–43 Ma). The Selsey Formation contains a particularly abundant and diverse array of marine gastropods due to the development of a thriving shallow subtropical seagrass community (Fig. 8). The formation takes its name from Selsey Bill at the south-eastern end of Bracklesham Bay, where it is exposed on the foreshore. The formation also outcrops as foreshore exposures

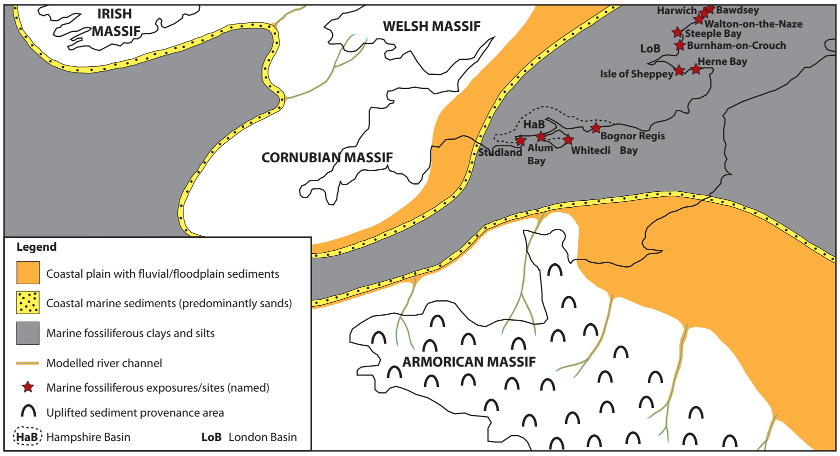


Fig. 4. Depositional environments and palaeogeography across southern Britain and NW Europe during deposition of the London Clay Formation (early–middle Ypresian, early Eocene; ~54.5–51.5 Ma).

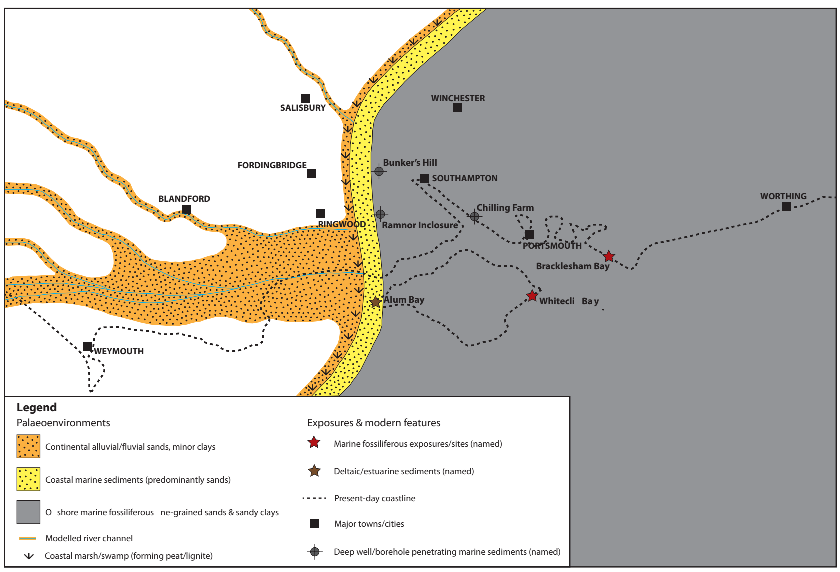


Fig. 5. Depositional environments and palaeogeography across the Hampshire Basin and surrounding area during deposition of the Earnley Formation (latest Ypresian–early Lutetian, latest early–middle Eocene; ~48–47 Ma).

Fig. 6. Large bivalves (*Venericor planicosta*, formerly called *Cardita planicosta*) from the lower Earnley Formation at Bracklesham Bay ('*Cardita* Bed'; ~48–47.5 Ma). This species also occurs within the upper Selsey Formation at Brook, Bramshaw and Lee-on-the-Solent, as well as the lower Barton Clay Formation (Elmore Member) at Studley Wood and Stokes Bay. White scale bar represents 10 mm.

around Hill Head, Lee-on-the-Solent and Stokes Bay in Hampshire, as well as within the beds and banks of deeply cut streams around Brook and Bramshaw in the northern New Forest. In addition to gastropods, the formation also yields bivalves such as *Venericor planicosta* (Fig. 6) and *Lentipecten corneus*, abundant shark and ray teeth, and small nummulites such as *Palaeonummulites variolarius* (Fig. 7b). These nummulites are significantly smaller than the giant *Nummulites britannicus* found in the underlying Earnley Formation, although they can still be identified with the naked eye. There is evidence for the initial onset of structural inversion and uplift of the Sandown Pericline (south-eastern Isle of Wight) during this time, with possible coeval uplift of the Weald-Artois and Portsdown anticlines to the north-east of the Hampshire Basin. Unlike most of the other marine formations, the Selsey Formation transgression cannot be easily correlated with a major climatic event or eustatic sea level rise. Therefore, this transgression may reflect the onset of gentle subsidence within the Hampshire Basin between the uplifting fold structures

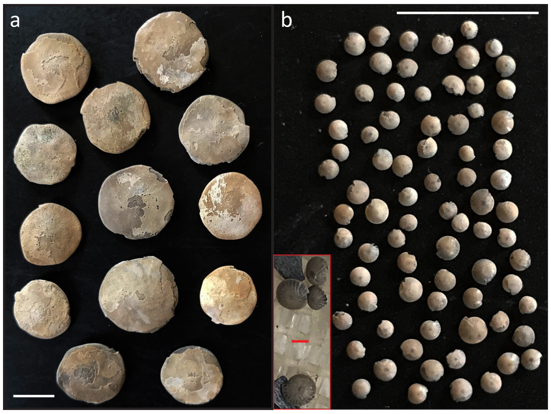


Fig. 7. Nummulites (benthic foraminifera) of contrasting sizes from two distinct horizons within the Bracklesham Group. **a**. *Nummulites britannicus* from the upper Earnley Formation at Bracklesham Bay ('*Nummulites laevigatus* Bed'; ~47.5–47 Ma). **b**. *Palaeonummulites variolarius* from the upper Selsey Formation at Bramshaw ('Shepherd's Gutter Bed Unit 4'; ~44 Ma). White scale bars represent 10 mm; red scale bar on inset image of *Palaeonummulites variolarius* represents 1 mm.

around its periphery. Palaeogeographical reconstruction for the Selsey Formation is hampered by the magnitude of Miocene erosion across these inversion structures, destroying evidence of the formation's depositional limits outside of its preservational limits within the Hampshire Basin and western part of the London Basin. However, there is evidence for a western coastline separating marine environments from sandier deltaic and estuarine environments of the Poole Delta across the western tip of the Isle of Wight, extending north-westward to the west of Lymington towards Ringwood (Fig. 9).

Following an erosional hiatus, the sea transgressed into the Hampshire Basin once more during the late Lutetian–middle Bartonian to deposit the Barton Clay Formation (~42–39.5 Ma). Aided by major eustatic sea level rise associated with the Late Lutetian Thermal Maximum (~41.5 Ma) and especially the Middle Eocene Climatic Optimum (MECO; ~40.5–40 Ma), the sea transgressed far beyond its limits reached during deposition of the Selsey Formation to deposit a monotonous sequence of fossiliferous clays and silts within the Hampshire Basin (Fig. 10). The fossiliferous lower Elmore Member, including the informally named 'Huntingbridge Shell Bed' and 'Coral Bed', was deposited during the Late Lutetian Thermal Maximum and is exposed in the bed and banks of the Latchmoor Brook in Studley Wood (New Forest). It is also exposed on the foreshore around Stokes Bay near Gosport. These horizons yield abundant large, bored and waterworn gastropods such as *Turritella sulcifera* (Fig. 8b) and *Clavilithes* sp., bivalves such as *Venericor planicosta* (Fig. 6), the scaphopod *Fissidentalium grandis* and the coral *Paracyathus caryophyllus*, along with abundant shark and ray teeth. The more famous Highcliffe and Naish members of the middle–upper Barton Clay Formation were deposited during maximum marine transgression associated with MECO and are exposed in the unstable muddy cliffs between Highcliffe and Barton-on-Sea. These units are particularly famous for their prolific gastropods and bivalves, including some species which grew to very large proportions such as *Clavilithes pinus*, *C. longaevus*, *Volutospina luctator* and *Hippochrenes amplus*, along with their abundance of shark and ray teeth. The significantly larger sizes of these gastropods compared with their older ancestors from the Selsey Formation suggest deeper water depths (~40–100 m) within the Hampshire Basin during MECO. The marine basin is likely to have been connected to the North Atlantic through both the North Sea and English Channel during this time, although precise palaeogeographical reconstruction is again hampered by subsequent Miocene erosion.

The Barton Group is capped by regressive fine- to coarse-grained sands of the Becton Formation (~39.5–38 Ma), which document an upward

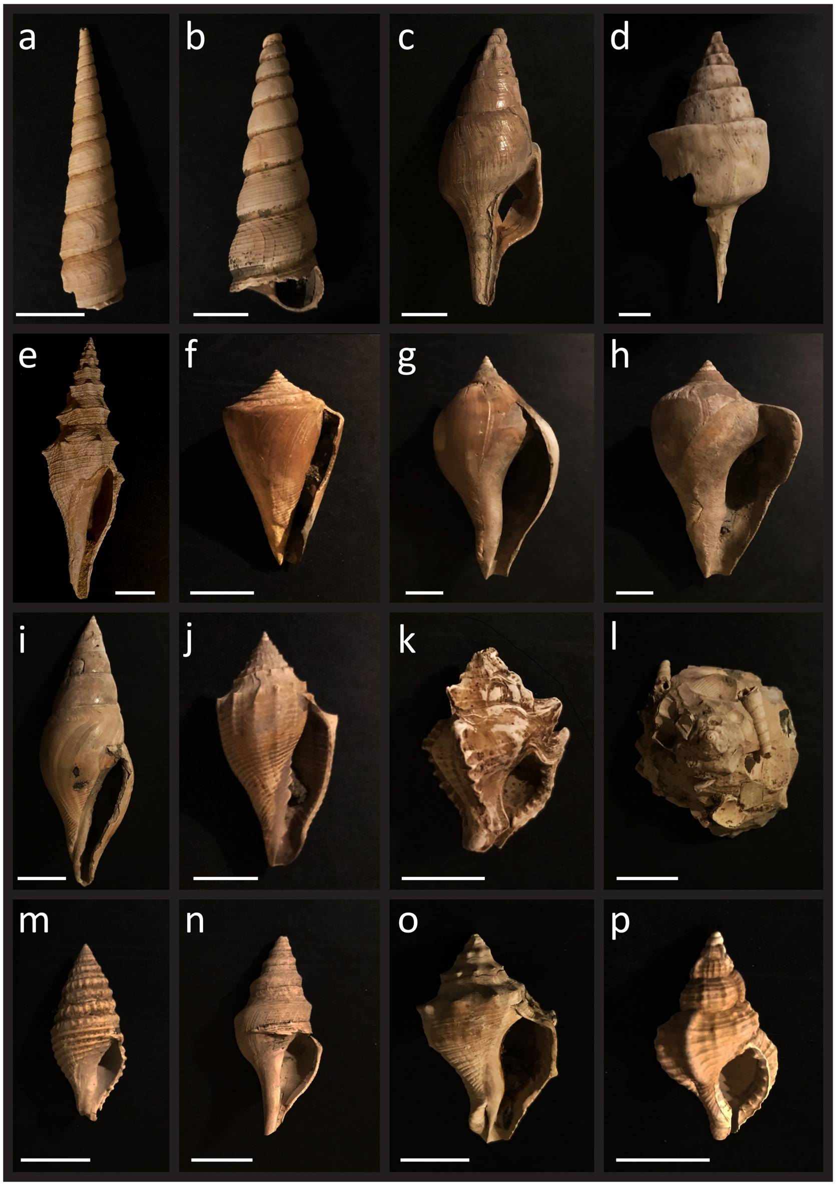


Fig. 8. Characteristic well-preserved gastropods from the upper Selsey Formation ('Brook' and 'Shepherd's Gutter' beds; ~44 Ma) exposed in the beds and banks of streams around Brook and Bramshaw in the northern New Forest. **a**. *Turritella imbricataria* (*Haustator* sp.), **b**. *Turritella sulcifera* (*Ispharina sulcifera*), **c**. *Clavilithes britannicus*, **d**. *Clavilithes contabulatus*, **e**. *Crenaturricula attenuata*, **f**. *Eoconus edwardsi*, **g**. *Sycostoma bulbiforme*, **h**. *Neoathleta selseiensis*, **i**. *Cryptoconus priscus*, **j**. *Volutospina nodosa*, **k**. *Pterynotus denudatus*, **l**. *Xenophora schroeteri*, **m**. *Bathytoma ligata*, **n**. *Orthosurcula planetica*, **o**. *Cornulina minax* and **p**. *Sassia flandrica*. These *Turritella* species also occur within the Earnley Formation ('*Turritella* Bed') at Bracklesham Bay. White scale bars on each image represent 10 mm. These specimens are from the personal collections of James Barnet and Hannah Tippetts.

transition from shallow marine to lagoonal and coastal environments as the sea regressed southeastward from the Hampshire Basin. Very fine-grained glauconitic sands of the lower Barton Common Member were deposited in a shallow marine environment, containing abundant specimens of the conspicuous bivalve *Chama squamosa*. The overlying Becton Bunny and Long Mead End members were deposited in predominantly coastal and lagoonal environments, with the development of a brackish fossil assemblage towards the top. The best exposures of the Becton Formation occur in coastal cliffs around Barton-on-Sea in Hampshire and Alum Bay on the Isle of Wight.

Oxidation of iron-rich minerals such as glauconite, siderite and iron pyrite within fine-grained sediments of the Bracklesham and Barton groups has formed several chalybeate (iron) springs across the Hampshire Basin. A particularly well-known example is the Iron's Well near Fritham in the New Forest, which often runs red or orange during the dry summer months. These waters were believed to have curative properties and used for the treatment of various ailments such as leprosy until the late nineteenth century. Iron cementation of porous coarse-grained sediments has also formed hard ironstones across parts of the Hampshire Basin. These include cementation of sandy Eocene formations to form the 'Heathstone' across the western Hampshire Basin around Fordingbridge, Studland and Hengistbury Head, along with cementation of Pleistocene gravels to form the 'Burley Rock' around Burley in the New Forest. These ironstones have been quarried for construction purposes since Roman and Medieval times.

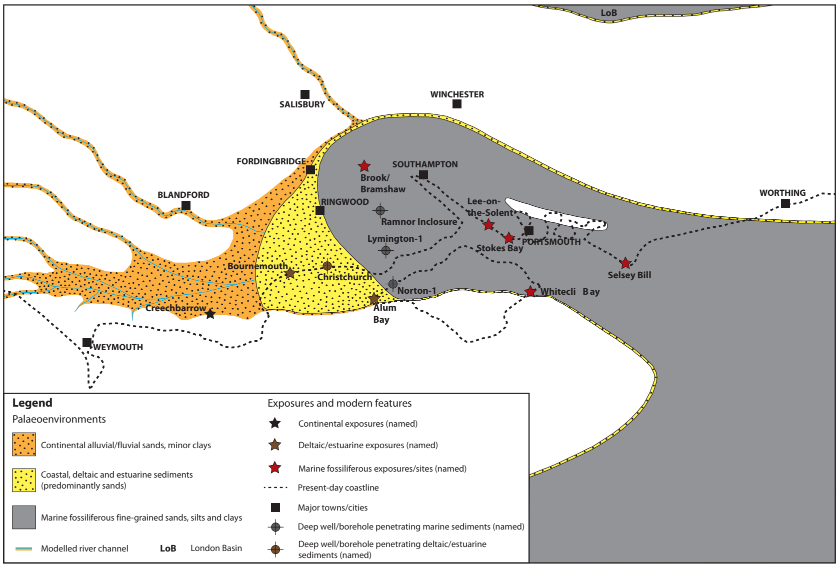


Fig. 9. Depositional environments and palaeogeography across the Hampshire Basin and surrounding area during deposition of the Selsey Formation (middle–late Lutetian, middle Eocene; ~46–43 Ma). Positions of the northern, north-eastern and southern shorelines are entirely speculative and assume the onset of structural inversion across the Weald and Portsdown anticlines, as well as the Isle of Wight–Purbeck Monocline.

Global cooling and marine regression during the late Eocene–early Oligocene

Long-term cooling continued during the late Eocene–early Oligocene, allowing the continued growth of ice caps on Antarctica and eventual continent-scale glaciation during a marked cooling phase at the Eocene/Oligocene boundary (~33.9 Ma). A complex succession of fossiliferous clays, silts, sands, limestones, lignite and palaeosol horizons of the Solent Group were deposited across the central and southern Hampshire Basin, mainly preserved across the northern portion of the Isle of Wight and the New Forest National Park to the south of Lyndhurst. As a result of global sea level fall, the Solent Group was deposited in predominantly coastal margin, lagoonal and lacustrine environments, although a brief marine incursion into the southern Hampshire Basin occurred during deposition of the Colwell Bay Formation (~36–35.5 Ma). The smaller preservational area of the Solent Group is likely to represent the combination of a shrinking depositional area, as the sea generally regressed to the south-east of the basin, along with greater magnitudes of Miocene erosion towards the northern basin margin.

The Solent Group starts with the predominantly non-marine Totland Bay Formation, which is well exposed at Hordle Cliff between Barton-on-Sea and Milford-on-Sea, as well as within Totland Bay on the Isle of Wight. This formation is renowned for its terrestrial mammal, plant and crocodile fossils, deposited when the climate remained subtropical and crocodiles roamed the watercourses of southern England. The overlying Colwell Bay Formation was deposited during the final marine incursion into the southern Hampshire Basin, comprising a diverse marine and brackish bivalve and gastropod assemblage at Colwell Bay and Whitecliff Bay on the Isle of Wight. Across its northern preservational limit within the New Forest, around and to the south-east of Lyndhurst, the formation was deposited in an estuarine environment and is characterized by a restricted brackish fossil assemblage. The late Eocene succession is capped by the Ryde Formation, Bembridge Limestone Formation and lower part of the Bouldnor Formation (Gurnard and basal Hamstead members), comprising some notable lignite, rooted palaeosol and freshwater to brackish limestone beds. These formations were deposited in exclusively coastal plain, lagoonal and lacustrine environments, yielding terrestrial mammals, freshwater to brackish bivalves and gastropods, plants and insects. They are only exposed in cliffs and foreshore exposures around the northern coast of the Isle of Wight between Headon Hill and Whitecliff Bay.

The Eocene/Oligocene boundary has been determined within the lower part of the Bouldnor Formation (near the base of the Hamstead Member), which was accompanied by a major fall in eustatic sea level of ~70 m and an abrupt episode of global cooling. A period of rapid cooling has been identified in the Hampshire Basin at this horizon by a marked shift from subtropical–warm temperate vegetation, including palms such as *Thrinax* sp., to typical temperate vegetation dominated by coniferous and deciduous trees such as spruces and birches. A pronounced cooling is also evidenced by stable oxygen isotope ($\delta^{18}O$) analyses from the lower part of the Hamstead Member. Sediments continued to accumulate for a short time into the early Oligocene, when much of the Hamstead and overlying Cranmore members of the Bouldnor Formation were deposited. These members comprise ~80 m of clays, yielding brackish bivalves, gastropods,

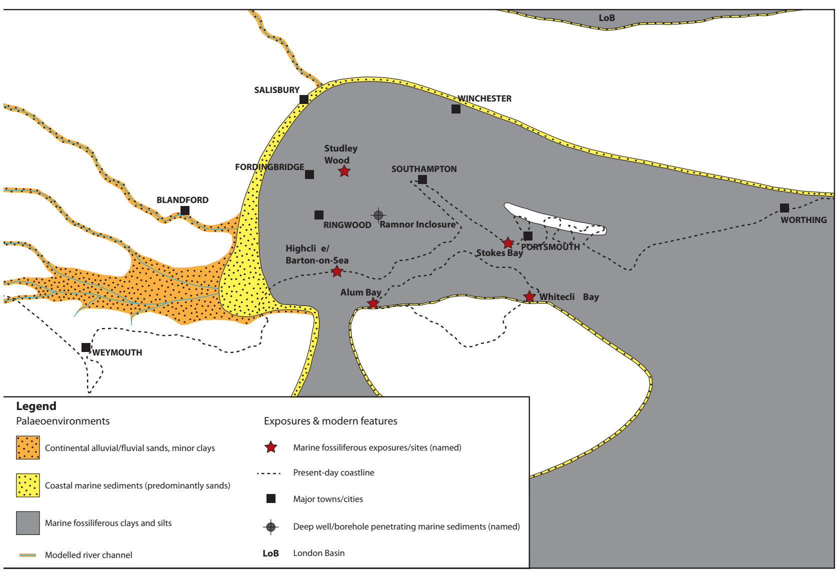


Fig. 10. Depositional environments and palaeogeography across the Hampshire Basin and surrounding area during deposition of the Barton Clay Formation (late Lutetian–middle Bartonian, middle Eocene; ~42–39.5 Ma). Positions of shorelines are entirely speculative.

ostracods and foraminifera. Although sediment deposition may have continued further into the Oligocene within the main depocentre of the Hampshire Basin across the northern Isle of Wight, sediments of younger Oligocene ages have not been preserved.

Miocene structural inversion and erosion

The culmination of the Alpine Orogeny, probably magnified across southern England by compression associated with opening of the North Atlantic, led to the main phase of structural inversion during the Miocene. Basin-bounding normal faults, which had controlled subsidence during development of the Wessex and Weald basins through the Mesozoic, were reactivated as reverse faults with an opposite sense of displacement. Uplift and erosion of the Weald Anticline, Portsdown Anticline and Purbeck–Isle of Wight Monocline occurred, with erosion as deep as the Early Cretaceous Wealden Group or older Jurassic formations beneath. High chalk hills rose across the southern Isle of Wight, southern Purbeck and the Weald of Sussex, Surrey and Kent, while the Palaeogene and older strata adjacent to these fault zones were intensely deformed. The soft Palaeogene sediments along the southern margin of the Hampshire Basin were tilted by almost 90°, producing the spectacular steeply dipping stratigraphy encompassing the entire Hampshire Basin succession in the cliffs of Alum Bay and Whitecliff Bay on the Isle of Wight. As a result, Palaeogene sediments were only preserved from erosion within the intervening synclinal basins, now represented by the Hampshire and London basins.

Following the cessation of Miocene uplift, large river systems draining from melting ice sheets across northern Britain deposited a series of Pleistocene plateau gravel terraces (<2.5 Ma), which unconformably overlie Palaeogene sediments of the Hampshire Basin. These gravels are composed of flint (SiO_2), derived from the erosion of extensive chalk outcrops surrounding the basin. Since flint is very resistant to erosion, these gravels are easily reworked to form the characteristic gravelly stream beds of the New Forest and the shingle beaches along much of the central-eastern Hampshire Basin coastline. Miocene to recent uplift and erosion formed the final phase in the shaping of the geology and geography of southern England that we are familiar with today, yet frustratingly obscure some specific details of the geology and palaeogeography of the distant past.

Suggestions for further reading

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