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THE GEOLOGY OF THE PORTSMOUTH REGION: A PERSPECTIVE OF THE WESSEX AND HAMPSHIRE BASINS

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ABSTRACT

This paper results from the scene-setting presentation given at the opening of the 16th Extractive Industry Geology Conference at Portsmouth University in September 2010.

The geology and structure of the Hampshire region is, at first glance, simple and laid open for inspection in rolling countryside with a subdued topography of scarps and long shallow dip-slopes of the Chalk downlands and broad synclines preserving Palaeogene strata, all of which are cross-cut with languid streams in wide gravel-filled valleys. However, the structure of the underlying and co-extensive Wessex Basin, with its Permian to Cretaceous infill, up to 3.5 km thick in places, provides the grain of the country we see today. This Wessex Basin-infilling tells a story of massive tectonic extension and normal faulting, related to the opening of the proto-Atlantic, and an equally massive phase of tectonic compression and reactivation of some of the faults in a reverse sense, as the result of the later collision (principally of Miocene age) of the African and European tectonic plates (the Alpine Orogeny). This extensive geological history relates to an imprint, preserved in a Palaeozoic basement, of deep-seated thrusting created at the initiation of the supercontinent Pangea (when the continental masses of Gondwana and Laurentia collided during the Variscan Orogeny). It is the break-up of Pangea that provides the depositional accommodation space for the Mesozoic sediments and through time has given the continental plates we are familiar with today.

The outline geology of the region demonstrating the infilling of the Wessex Basin and the later more restricted Hampshire Basin is presented. This thick succession, brought to crop by simple folding that belies its complex structural origins, contains significant bulk mineral resources and a flavour of the long history of exploitation of those resources is presented.

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INTRODUCTION

This paper describes the geology of a significant part of Hampshire, Wiltshire, Dorset, a part of West Sussex and the Isle of Wight being centred around the city of Portsmouth that provided the venue for the EIG conference 2010. The region is founded on Cretaceous and Palaeogene bedrock, the older representing the final phase of the infilling of the underlying Wessex Basin and the younger forming the infill of the more restricted Hampshire Basin. The bedrock is covered by a patchwork of thin and, in places, extensive succession of Quaternary superficial deposits subdivided into a number of units (deposited principally by fluviatile and periglacial processes) that represent a long Quaternary history as the landscape was denuded through numerous glacial/temperate climatic cycles.

The district is the focus for a long term, National Capability, mapping project by the British Geological Survey (BGS) that provides up-to-date published maps (BGS, 1975, 1976, 1987, 1991, 1994, 1996, 1998, 1999, 2002, 2004, 2005, 2006a, b, c, 2008, in prep x3) and supporting texts (Aldiss, 2002a, b; Aldiss et al., 2006; Barton et al., 2003; Booth, 2002; Booth et al., 2008, 2010; Brayson, in prep; Bristow et al., 1991; Edwards and Freshney, 1987; Farrant 2002, in press; Hopson 2001a, b; Hopson et al., 2007, 2008; Lake et al. 1987; Young and Lake,1988) to add to the wealth of other historic descriptive documents both published by the BGS and in a huge number of articles in learned journals.

Figure 1. An overview of the work of the Survey 1991 – present. The geological sheet boundaries in red are the individual map tiles completed in the Chalk Downlands Project and those shown in green represent those tiles completed pre 1991. They are shown here over a backdrop of the digital bedrock geology data at the 1:250 000 scale that gives a broad overview of the structure of the southern England. The Weald Anticline separates the North and South Downs and its closure to the west is marked by the extensive Chalk plain stretching from Hampshire into Wiltshire. The Hampshire and London synclinal Basins carry an infill of Palaeogene sands and clays.

Whilst concentrating on the distribution of the Chalk Group (Hopson, 2005) (a group that constitutes the UK's largest and most heavily used aquifer) and the application of the new Chalk stratigraphy, this survey has also determined in more detail the outcrop of Lower Cretaceous and Palaeogene rocks and Quaternary deposits and their lateral variability. An example of the increased level of information between the previous survey and that completed in 2002 is shown in Figure 2a and b for the area around Michelmersh Brickworks (a pre-conference field excursion venue, see herein) east of Salisbury.

However, these modern maps and texts carry a great deal more information than just the two dimensional (2D) surface geology distribution. They provide three dimensional (3D) insights into a history that stretches back some 250 million years, and beyond, within a succession of Mesozoic sedimentary rocks that reaches up to 3.5 km or more in thickness. Much of this detail is derived from extensive seismic and deep borehole data resulting principally from the search for oil and gas in onshore Britain. Whilst the oil and gas industry is not part of the EIG remit, nonetheless the results from hydrocarbon exploration in the Wessex Basin have provided this wealth of data that can help illustrate the geological history of the area and help understand the deep geology and the structural complexity across the region that strongly influence surface rock distributions up to the present day.

Figure 2 a and b. The geology of the area around Michelmersh Brickworks contrasting the level of information available from the original survey (a. 1896, reprinted without revision in 1975) compared to that of the recent survey (b. 2002).

GEOLOGY AND TOPOGRAPHY

Structure and basin development

Structurally, the district falls within the Wessex Basin that extends over most of southern England, south of the London Platform and Mendip Hills. This sedimentary basin preserves a thick succession of Permian/Triassic to Cretaceous rocks and is underlain at great depth by Palaeozoic strata.

This Palaeozoic (or Variscan) basement preserves an imprint of deep-seated structures initiated when the continental masses of Gondwana and Laurentia collided to create the supercontinent of Pangea (i.e. the Variscan Orogeny). This period of deformation culminated at about 299 Ma at the end of the Carboniferous period. As a consequence of this collision the Palaeozoic basement was affected by the Variscan orogenesis and are cut by several major, shallow southward-dipping thrust zones and north-west-oriented wrench faults that have been identified principally from seismic reflection data.

Throughout the following Mesozoic the supercontinent of Pangea began to break up – a process that in this region is effectively related to the opening (extension) of the early Atlantic Ocean and initiated by reactivation of the deep-seated Variscan structures. Crustal extension was accommodated on faults developed above these basement thrusts as a series of generally southward-throwing normal faults creating half-graben-like structures. The largest of these faults divide the basin into a series of sub-basins and beneath this district the Weald and Channel sub-basins are separated by the Hampshire–Dieppe High (also known as the Cranborne–Fordingbridge High) (Figure 3). The boundary between these two sub-basins lies along the Portsdown–Middleton faults, which underlie the northern margin of the Portsdown and Littlehampton anticlines.

Initially within the Wessex Basin deposition comprised continental red beds lithologies with progressively deeper half-grabens (basins) and thicker and more complete Permian and Triassic successions preserved toward the SW outside of the area described herein (e.g. The Dorset Basin). Jurassic (201-145 Ma) marine successions were developed more widely within these sub-basins as extension and relative sea-level rise provided greater accommodation space. This extension continued into the Early Cretaceous (145-99 Ma). However, as time went by, the intervening structural highs became more influential and suffered thickness attenuation or even severe erosion depending on the relative sea-level, the degree of movement on individual faults and accommodation space availability. At this time separate Early Cretaceous successions were developed within the Weald and Channel sub-basins (see for example Chadwick, 1986; Hopson et al., 2008; Penn et al., 1987) and onlap, particularly onto the London Platform and the Hampshire – Dieppe high, can be demonstrated within the Wealden Group, Lower Greensand Group, and Gault and Upper Greensand formations of the Lower Cretaceous (Figure 4).

Figure 3. The structures of the Wessex Basin and younger coextensive Hampshire basins

Figure 4. The cross section a-b shown in Figure 3. This simple section illustrates:-

1. the extensional normal faulting and some of the reverse movement during Alpine compression
2. the Cimmerian unconformity that separates the Lower Cretaceous from the underlying Jurassic at the sub-basin margins
3. and the overstep of the Upper Cretaceous over the Hampshire – Dieppe High.

A further period of regional subsidence, but with considerably less fault movement, and relative sea-level rise within the Late Cretaceous [99-65 Ma] (this period saw the highest relative sea level in Earth's history), resulted in a relatively uniform and thick Chalk Group deposited widely in this region and across the continental shelf areas adjacent to the ever-widening North Atlantic. Global sea-level fall at the end of the Cretaceous resulted in erosion of parts of the uppermost Chalk and the development of a pre-Cenozoic unconformity. This was effectively the end of the Wessex Basin as a major structural/depositional unit. However structural disharmonies preserved in the sediment-pile within the Wessex Basin continued to influence sedimentation and tectonics through to the present day.

Marine and fluviatile deposition in Paleocene to Oligocene times, within a geographically more limited shallow subsiding Palaeogene (59-23 Ma) or 'Tertiary' North Sea Basin, was followed by the onset of compressive tectonic regime during the mid-Miocene (Alpine Orogeny, c. 25 Ma) earth movements. This compression, as the direct result of the collision of the African and Eurasia plates, was for this region essentially from the southeast, a direction at a slight angle to the preserved structures of the Wessex Basin. This huge compressive event effectively reversed the sense of movement on the major bounding faults of the older Wessex Basin (Weald and Channel sub-basins) resulting in the inversion of these earlier basins and highs. The slight obliquity of the maximum stress direction to the existing fault structures during the Alpine Orogeny, led to differential movement along each of these major fault traces. These pressures also perhaps emphasise the north-west – orientated wrench faulting inherent in the underlying strata and there is evidence of block and 'scissor' faulting particularly associated with the most significant structures (e.g. the Isle of Wight structure).

This compression effectively separated the London and Hampshire Palaeogene basins onshore in southern England and created the reverse-faulted monoclinal structures best exemplified by the Hog's Back in Surrey (and its westward extension south of the London Platform) and the Isle of Wight Monocline (that extends westward into the Ballard Down and Isle of Purbeck structure). A series of roughly east – west-trending strongly asymmetric anticlines and synclines, formed at the same time, are the often less striking result of this transpressive event and can be found evenly spaced between the Isle of Wight and the northern margin of the Wessex Basin. This northern margin is the London Platform, a long-term feature, founded on the stable block of the East Midlands microcraton. Maximum uplift during the Alpine Orogeny, exemplified by the Weald Anticline, is estimated at about 1500m (Simpson et al., 1989).

Geomorphology of the region

This long-term structural and depositional history, and the subsequent denudation and 'un-roofing' of the resultant Miocene structures, provide the 'grain' of the landscape that has subsequently guided the depositional events in this part of southern England (Figure 5).

Figure 5. The principal structural elements of the Hampshire Basin. Insert of the underlying Wessex Basin extensional fault pattern.

Five principal topographical entities, namely: the South Downs and Hampshire Plain; the south-western part of the Weald; the Hampshire Basin; the Solent and Sussex Coastal Plain; and the Isle of Wight are recognised in this area.

In the northwest of the district the ‘primary’ northward-facing Chalk escarpment of the South Downs, whose maximum slope break occurs in the relatively hard Lewes Nodular Chalk Formation, represents the southern flank of the denuded Wealden Anticline. The view northward from the escarpment over the Weald shows a series of arcuate ridges and vales representing the outcrop of Lower Cretaceous strata, a pattern that is modified by extensional normal faulting principally of mid-Cretaceous age.

Figure 6. The relief and geomorphological units of the region.

Within the South Downs a further ‘secondary’ escarpment founded on the Newhaven Chalk Formation is represented by a laterally extensive series of ‘flat-iron-like’ upstanding bluffs. The maximum break of slope at the top of this secondary scarp effectively controls the distribution of the clay-with-flints deposits as it approximates crudely to the base-Palaeogene unconformity. The ‘primary’ and ‘secondary’ escarpments diverge south of Petersfield and around the Meons, with the primary scarp turning northward to form the closure of the western Weald, whilst the secondary escarpment carries westward towards Winchester and onwards towards the River Test, north of Romsey. This dissected secondary scarp reappears further west, south of Salisbury.

The area west of Petersfield, to the south of the Andover region and on towards Salisbury is often referred to as the Hampshire Plain in a structural sense. Salisbury Plain, which lies further northward and westward within Wiltshire, is its natural extension. This Hampshire Plain is dissected by the major southward flowing chalk streams of the Itchen, Test and Avon.

To the east, shorter-course rivers such as the Meon, Ems, and Lavant drain the South Downs of southeast Hampshire and the far west of West Sussex. Further east the major rivers of the Arun and Adur, whose headwaters are in the Weald, cut deeply through the South Downs of West Sussex. Whether these deep gaps are the result of an inherited drainage from a former Palaeogene cover or as the result of short-course dip-slope chalk rivers (left bank tributaries of a Solent River) backcutting through the scarp and eventually capturing headwaters of a ‘Wealden River’, or a mixture of both these and neotectonics, is a matter of debate

A further, topographically less imposing and more dissected, escarpment to the south of the chalk plain (the ‘Tertiary’ scarp) marks the edge of the Palaeogene strata and the Hampshire Basin proper. This escarpment is clear between Salisbury and towards the asymmetric anticline represented by Ports Down, but fades eastward on the northern flank of the Bere Forest and Chichester synclines where the Palaeogene strata are overlain by the Quaternary deposits of the Sussex Coastal Plain.

The ‘Tertiary’ scarp defines the eroded extent of the Palaeogene on the northern margin of Hampshire Basin. The southern boundary of which is the northern margin of the steeply-dipping chalk ridge formed by the Isle of Wight monocline (and its’, now breached, extension westward from the Needles to Ballard Down north of Swanage in Dorset). In general, the bedrock dips gently southward towards the synclinal axis that runs close to the monoclinal fold thereby creating a shallow topographical basin with a steep southern lip. Within the bedrock, to the west of this basin, minor synclines and anticlines and the change to a predominantly sandy Palaeogene succession, compounded by an extensive Quaternary cover, tend to produce a muted topography of shallow scarps and valleys. This muted topography is further disguised by the urban areas of Southampton, Portsmouth and their satellite towns. In the east, the topographically impressive Chalk inlier of the Ports

Down asymmetric fold separates the main Palaeogene basin, with its thick succession, from the Bere Forest and Chichester synclines that preserve the youngest Lambeth and Thames groups part of that succession.

The Sussex Coastal Plain with its extensive, but generally thin, Quaternary cover is defined to the north, by the Ports Down inlier and further east by a degraded cliff-line that runs north of Chichester towards Arundel and on eastward, as a separate element, towards Portslade west of Brighton. This broad, generally flat and low-lying plain, carries representatives of at least four distinct raised beach deposits and contains the famous Boxgrove Man site (of 'Cromerian Complex' age) within the highest raised beach successions. West of Ports Down this coastal plain loses its identity as it merges into the Solent coastal fringe with its cover of Solent River terrace deposits. Beneath the Solent, representatives of Pleistocene deposits are preserved within channels that were eroded to lower base-levels at times of glacial maxima. Bathymetry and isopachs show a distinct palaeovalley with up to 30 metres of infill trending along the eastern Solent. Offshore of Bembridge this valley turns sharply south and south-southwest (see Bellamy herein) to join the so called 'Northern Palaeovalley' that follows a medial NNE – WSW route along the floor of the English Channel.

The Isle of Wight owes it distinctive diamond shape to the spinal east – west-trending steeply-dipping Chalk ridge (see excursion report herein). This is not a simple topographical structure but is interpreted as two *en-echelon* monoclinal folds (probably with a reverse faulting component on each of their northern limbs). These two Miocene-age compressional structures (including the Brighstone and Sandown monoclines) are offset from each other by a broad structural ramp area, central to the island, comprising shallow-dipping chalk. The prominence of this ridge owes much to the intense tectonic hardening of the Chalk. The westward continuation of this feature connected the island to the mainland between the Neddles and Ballard Down in Dorset, effectively formed the southern margin of the developing Solent River, until it was breached during the Late Pleistocene. North of this major structure, Palaeogene strata form a gently sloping topography to the present-day low cliffs on the margin of the Solent. This slope carries patchy fluviatile and marine deposits on the southern flank of the Solent River. To the south, a dissected topography founded on the Lower Cretaceous carries a thin Pleistocene 'terrace' cover with significant Holocene deposits associated with the present-day eastern and western Yar and the Medina River. All three rivers flow in gaps through the Chalk ridge, probably following north – south orientated faults within the bedrock.

Bedrock Geology

A simplified bedrock geology is presented in Figure 7 and the principal units and lithologies present within the Cretaceous and Palaeogene succession are given in Table 1.

Representatives of the Lower Cretaceous strata are found south of the Isle of Wight Monocline (Brighstone and Sandown anticlines) on the Isle of Wight and within the Weald, to the northeast of the South Downs. They comprise the Purbeck Group, Wealden Group, Lower Greensand Group and Selborne Group.

The Purbeck Group, that spans the very youngest Jurassic and oldest Cretaceous, includes shallow water fresh, brackish and hyper-saline limestones and evaporites together with, quasi-terrestrial soils beds (including tree stumps) that represent a variable hyper-saline shallow lagoonal, mangrove or lake depositional environment.

These deposits are the precursor to fully terrestrial deposition of the Wealden Group that includes thick successions of lacustrine and overbank fluviatile multicoloured mudstones and channel sandstones.

Figure 7. The distribution of the principal bedrock units within the district. See Table 1 for an expanded listing.

Age Ma	Series	Group	Formation		Principal rock types
			Hampshire Basin		
			Western Basin	Eastern Basin	
30.0[4]	Oligocene	Solent	Bouldnor		Marl, Multicoloured mud
33.9	Late Eocene		Bembridge Limestone		Limestone and marl
			Headon Hill		Mud, sand, marl and limestone
36.9	Mid Eocene	Barton	Becton Sand		Fine sand
			Barton Clay		Muds and laminated muds
			Boscombe Sands	Selsey Sand	Fine sand[1], glauconitic sand
		Bracklesham	Branscombe		Sand & mud[1], glauconitic sand
			Poole	Marsh Farm	Sand, mud & lignite
				Earnley	Sand & clay[1], glauconitic sand
45.0	Early Eocene			Wittering	Sand[1], glauconitic sand & mud
		Thames	London Clay		Cyclic silty clay to fine sand with rounded flint pebble beds
55.8 56.0[4]	Late Paleocene	Lambeth	Reading	Reading (inc. Woolwich and Upnor)	Stiff multicoloured clay, sand
			Unconformity		
			Channel Basin	Weald Basin	
71.0[4]	Late Cretaceous	Chalk (White Chalk Subgroup)	Portsdown Chalk		Soft chalk[2], large flints, marl
			Culver Chalk		Soft chalk[2], large flints
83.5			Newhaven Chalk		Soft chalk[2], few flints, marl
85.8			Seaford Chalk		Firm chalk[2], large flints
89.3			Lewes Nodular Chalk		Very hard nodular chalk[2], flints
			New Pit Chalk		Firm blocky chalk[2], marl
93.5			Holywell Nodular Chalk		Intensely hard and shelly chalk[2]
		Chalk (Grey Chalk Subgroup)	Zig Zag Chalk		Marly chalk, gritty chalk and limestones[2]
			West Melbury Marly Chalk		Marly chalk and limestones[2]
99.6	Early Cretaceous	Selborne	Upper Greensand		Sandstone, siltstone, glauconitic and chert
			Gault	Gault	Ironstone and gritty sandstone[3], mudstone calcareous concretions
		Lower Greensand	Monk's Bay Sandstone		
112.0			Sandrock	Folkestone	Sand and sandstone
			Ferruginous Sand	Sandgate	Mudstone
				Hythe	Sand and mudstone[3], calcareous sandstone
			Atherfield Clay		Mudstone, calcareous concretions
125.0		Wealden	Vectis	Weald Clay	Shale with sandstone[3], mudstone with thin limestone and sandstone beds
			Wessex	Tunbridge Wells Sand	Sandstone, siltstone with thin quartz pebble beds
				Wadhurst Clay	Mudstone

145.5				Ashdown	Shale and sandstone[3], mudstone, sandstone
		Purbeck	5	As an inlier in the central Weald	Limestone, mudstone and evaporites

Table 1. The Principal units within the bedrock encountered in the district

Notes for Table 1
1. Description of units within the western part of the Hampshire Basin.
2. All of the Chalk formations are tectonically hardened within the Isle of Wight Monocline and can form significant durable clasts locally within the Quaternary deposits.
3. Description of units within the Channel Sub-basin.
4. The youngest Chalk Group at outcrop is latest Campanian Stage and dated at approximately 71 Ma; the oldest Paleocene at outcrop is Thanetian Stage (possibly late Thanetian) at approximately 56 Ma: and the youngest Bouldnor Formation at outcrop is Early Oligocene in age at approximately 30 Ma.
5. The Purbeck Group on the Isle of Wight is only substantially proven in deep hydrocarbon wells to the south of the structural spine of the island. Different lithostratigraphical schemes were formerly defined for the Purbeck and Weald successions but these have recently been amalgamated at formation level (Hopson et al. 2008).

The succeeding Lower Greensand Group sees a return to fully marine deposition in both the Channel and Wealden basins where different lithostratigraphical successions, but all essentially representing shallow-water deposits, have been recognised. Both successions commencing, however, with the mudstones of the Atherfield Clay that passes up into a variable sand-dominated succession with significant thin mudstone beds and members.

Lower Cretaceous marine deposition continued into the Selborne Group. Deposition commences with the deeper-water clays of the Gault Formation and these form the complete succession in Kent and much of Surrey to the east. Progressively to the west the co-eval shallower-water Upper Greensand Formation forms the younger and thickening part of the group and the Gault has a limited chronological range in the extreme west.

The Chalk Group, represented by up to nine formations, forms the generally southward-dipping northern margin of the area (the Hampshire Plain or Downs and the western extension of the South Downs). The Dean Hill – Winchester Anticline and Portsdown Anticline (and to a lesser extent the more heavily denuded Littlehampton Anticline) on the mainland, together with the Sandown and Brighstone structures on the Isle of Wight form very prominent ridges that for the most part confine the course of the proto-Solent and the extent of the Sussex/Hampshire Coastal Plain.

The central and western part of the district is founded on Palaeogene strata that comprise five groups divided into numerous formations and members (Table 1). The strata are present within the major asymmetric Hampshire Basin Syncline that trends WNW – ESE across this district. In the west the outcrop is delimited, to the south, by the steeply-dipping Purbeck/Isle of Wight structure, and to the north, by the dipslope of the Chalk. To the east the outcrop bifurcates around the Ports Down and Littlehampton anticlines with only the older part of the Palaeogene succession preserved in the asymmetric Chichester and Bere Forest synclines to the north (Figure 5).

The Palaeogene strata of this district show an upward transition from an early terrestrial record, through a marine transgression, into nearshore, paludal environments and finally back to terrestrial deposition. For a significant part of the middle Eocene the sediments also pass laterally from more marine lithofacies in the east (around Selsey) to nearshore lithofacies in the west (Lymington and beyond).

These Palaeogene strata represent a significant part of the record of the Paleocene/Eocene Thermal Maxima and the decline into temperate (the Terminal Eocene Cooling Event), and eventually (although the Neogene record is substantially missing from southern Britain) glacial/interglacial cycles that characterise the Quaternary.

Quaternary Geology

The regional distribution of superficial deposits can be summarised as follows: early Quaternary residual deposits cap many of the hills and upper valley flanks on the Chalk Downs. An extensive spread of fluvial granular deposits of the proto-Solent River and its tributaries are developed through a large part of the Pleistocene and these pass laterally and vertically into co-eval marine and near-shore deposits. Their distribution and relative degree of downcutting into the bedrock is in response to huge sea-level fluctuations during glacial/interglacial cycles. Finally, as the result of the most recent sea-level rise, Holocene deposits, both fluviatile and marine, form the infill within lower reaches of drowned valleys, as present day floodplains and as beach and nearshore deposits on the margins of the Solent and on the sea-bed of the English Channel.

Figure 8. The simplified lithostratigraphy and distribution of the Quaternary deposits.

The bedrock, it's structural evolution and the resulting topography profoundly affect the distribution of the Quaternary superficial cover and provide much of the material from which those deposits are formed.

Because of the regional geomorphology setting south of the Quaternary glacial ice-sheet maxima, the majority of the Quaternary successions in the region comprise materials derived from within the confines of the Wessex Basin and principally, within that basin, from the Cretaceous and Palaeogene strata. There is little extra-basinal material introduced into the system other than within the marine or oldest fluviatile deposits. The simplified lithostratigraphy and distribution of the Quaternary deposits is shown in Figure 8.

About 25 million years is estimated to have elapsed between the deposition of the youngest preserved Palaeogene and the oldest Quaternary deposits in this district. During the Quaternary, a further break in deposition occurred after the accumulation of the clay-with-flints and before the deposition of the younger Pleistocene superficial deposits. During the Pleistocene, sea level rose and fell in response to astronomical cycles, which influenced climate and the amount of water locked up in land-based ice caps. A number of glacial maxima affected southern England and at these times a periglacial environment was established in this area with much subaerial erosion by solifluction and by the action of an extensive river system eroding to much lower base levels.

During the intervening warm stages, marine transgressions resulting in the drowning of the lower courses of the incised river systems, principally the Solent River and its tributaries, and the breaching of the Straits of Dover and the Needles – Ballard Down chalk ridge (in so doing effectively 'capturing' the western-headwaters of the Solent

River system). Beach and nearshore sediments were deposited along the margin of the English Channel. Two degraded cliff lines related to those marine transgressions are preserved on the Sussex coastal plain. The southern flank of Ports Down forms the westward extension of those cliffs.

On the maps of the British Geological Survey superficial deposits are depicted in relation to a perceived process of deposition, relative age and lithostratigraphy where this can be determined. Thus, mapped divisions are related to five principal categories; namely Residual, Periglacial, Fluviatile, Marine and Aeolian. A sixth, related to man-made deposits (and voids), can with some justification be regarded as being confined within the Anthropocene. Inevitably this approach can lead to conflict particularly in depositional systems as dynamic and long-lived as the Solent River and its associated lateral marine equivalents, where process, climate and sea-level have such powerful influences on the type and distribution of deposits. The detailed pictures derived from intensive Quaternary studies can nonetheless be encompassed in the more regional appraisal capable of being depicted on maps.

The clay-with-flints is the principal residual deposit of the district. It is primarily a remanié deposit created by the modification of the original Palaeogene cover and dissolution of the underlying chalk. The clay-with-flints caps the high ground underlain principally by the higher formations of the Upper Chalk. The thickness of the clay-with-flints is estimated at about 5 to 6 m at its general maximum, but locally at sites where dissolution of the underlying chalk is most pronounced, this may reach to over 10 m thick. The basal surface of the deposit is generally represented by to the sub-Palaeogene unconformity, but the deposit may be carried some distance below that, generally planar surface, in solution pipes. Some areas of clay-with-flints, apparently in situ, are mapped well below this projected sub-Palaeogene surface. Their preservation at this lower topographical level is open to debate but may be the result of neotectonics or perhaps wholesale mass movement. There is preliminary evidence of at least three phases of development in this enigmatic deposit and it may well record events from the post-Miocene uplift of the area and degradation of the Palaeogene cover through to later solifluction events associated with periglacial cycles.

There is a wide variety of head deposits depicted on British Geological Survey maps. Their mode of formation is also variable although it is presumed that a major part in their deposition is as the result of solifluction, gravitational creep and colluvial reworking, but they may contain fluviatile and aeolian derived units. There is a continuum of process preserved in these deposits despite their often patchy occurrence. Older units, generally on steeper valley slopes, are probably directly derived from the clay-with-flints with lower slope and valley deposits progressively showing indications of periodic gravitational and fluviatile reworking. Indeed, it is presumed that the continuum of process culminates in truly fluviatile deposition where the materials become differentiated and have distinct geomorphological terrace associations. Thus the landscape can be divided into ‘immature’ areas where the process has not proceeded far down this course, through to ‘mature’ landscapes where periglacial and fluviatile materials are completely differentiated. For the most part this continuum of process is best seen in areas underlain by the Chalk Group as here the lack of surface water, during temperate phases at least, has aided the preservation of much of each deposit. It could be that any differentiation seen within these deposits may well record catastrophic single climatic events such as, by analogy, the Boscastle flood event in our recent history. The broad sheet-like deposits are composed of locally derived materials. In some exposures the matrix contains chalk, particularly in accumulations formerly call ‘dry valley’ or ‘coombe’ deposits on older BGS maps, but elsewhere chalk is not present and may have been lost by decalcification.

Extensive tracts of fluviatile sandy gravels, generally about 6 m thick, are present in the area which borders the Solent. Smaller areas inland are associated with the major southward-draining rivers in the district. In general, the deposits comprise gravels and sandy gravels, but the higher terraces are clayey. In the Weald area the deposits are more sandy and many are graded as pebbly sands reflecting the general lack of granular material in the source bedrocks. In places, clayey and sandy silt and silty clay mask the underlying aggregate, perhaps indicating preservation of overbank or aeolian deposits at the top of each fluvial cycle.

For the most part the terrace aggradations and subsequent incisions are related to the 'Solent River' which developed in response to variable sea levels throughout the Pleistocene. Up to fourteen terrace aggradations are depicted on BGS maps. Although there is still considerable debate on the precise number and age of these terrace deposits. There is an added complication of how these onshore deposits relate to the complex of offshore channel fills (see Bellamy herein). Many of the high-level gravel aggradations in this district were formerly called the Plateau Gravel. For the most part these have been reclassified as terraces on recent maps of the Solent River, but the currently available Lymington (1963 reprint) and Isle of Wight (1975 reprint) maps still show the old designation. In the case of the IoW these deposits are probable remnants of the right bank Solent River terraces, or may also be deposits of right-bank northward-flowing tributaries of that river.

Over the Sussex Coastal Plain a deposit formerly described as 'brickearth' has an extensive outcrop. Its overall grain size and sorting suggest that these deposits are similar to continental wind-blown loess. However, the presence of flint and other pebbles throughout the material, some lithological differentiation and weakly defined bedding structures suggest that wholesale remobilisation occurred probably by solifluction or fluviatile reworking and they are re-designated as undifferentiated river terrace deposits.

Narrow ribbons of alluvium are mapped along the floor of the valleys with flowing streams. It represents the fine-grained late-stage (mature) phase of river development with cut-off channels, overbank flood deposition and localised peat and calcareous tufa formation. In general, the deposit is thin, usually between 1 and 3 m in the upper reaches of rivers, but at major confluences and in the lower reaches of the larger rivers about 8 m have been proved. Such thicknesses of alluvium are known in the lower reaches of the major valleys, and some of these sequences are known to contain a stack of inter-fingering organic, calcareous tufa, fluviatile, estuarine and shallow marine elements indicating the 'rise and fall' of sea level change even in our most recent past.

Marine and estuarine deposits are represented by a wide range of lithologies, depositional environments, ages and height relative to former sea levels (at least four such beach levels are interpreted in this region). They comprise organic mud, channel sand, gravel and sand shoals, storm beach and shell banks and commonly interdigitate with fully fluviatile deposits in the lower reaches of major valleys. This group includes the older raised beach deposit described from the Boxgrove site.

Landslides are a ubiquitous feature of the Upper Greensand/Gault boundary along much of the outcrop both within the Weald and on the Isle of Wight. Such features are also significant within the younger Palaeogene deposits on the Isle of Wight. The landforms, for the most part composites of sequential rotational slips and translational slides, are quite striking, with fault-like back-scarps up to 30 m high, ponds trapped by slip slices, and hummocky ground usually with a prominent toe separating the slips from the undisturbed bedrock. The age of the slips is uncertain, almost certainly they were initiated under periglacial conditions, but the landforms are still remarkably fresh suggesting that some movement is more recent. They form a significant geomorphological feature in the landscape of the district but are frequently overlooked for their value in determining a denudation chronology.

Extractive Resources

Historically all of the units delimited at the surface have been used locally to provide, variously, brick and tile clays, building stone, sand (building, foundry and glass), cement and other rock resources. This industrial activity on the part of our forebears is demonstrated by the significant number of abandoned and overgrown quarries, some now little more than shallow depressions, throughout the district. The form of the materials extracted (for example was it sand, sandstone, chert or freestone blocks extracted, in the case of the many Upper Greensand quarries) from these many sites is often lost in antiquity and the only readily available guides are the old Ordnance survey maps that tend to give a location (and sometimes a brief description e.g. 'Sand Pit') or the geological maps. In the case of the latter of course the more detailed the demonstrated stratigraphy, the better the estimation of the material extracted will be.

A great majority of this widespread local industry has ceased within the region with essentially production only from particularly valuable units and specialist suppliers surviving. Of course much of the local character within the built environment has resulted from the local sourcing of building material. With the increasing planning regulation and the designation of considerable tracts of this region as AONBs and National Parks will there be a return to local heritage sourcing of materials and/or will the industry seek to increasingly differentiate its products to satisfy these planning constraints? The discussion following by no means represents a comprehensive review but gives a flavour of the long history of exploitation in the region.

The **Purbeck Group** is worked for anhydrite and gypsum in the central Weald (see Brightling Mine excursion report herein). The group in this area formerly provided some building stone from the limestone beds (locally termed Blues and Greys) within it, and these units were also a source of ground limestone, burnt lime and agricultural lime (the Blues Limestone bed was preferred to the lower grade Greys Limestone). To the west in Dorset the Purbeck Group is a significant provider of heritage building stone (including the far-travelled 'Purbeck Marble'). Block, paving and roofing stone are still produced in a number of surface quarries, shallow adits and underground mines and there are a variety of local names applied to the different individual beds within the succession.

The **Wealden Group** provides a wide variety of resources. There is an extant brick and tile industry utilising mudstones from the Grinstead Clay Member, Wadhurst Clay Formation and Weald Clay Formation. The generally thin *paludina* Limestones (including the ornamental Sussex Marble) have been quarried in the past from the Weald Clay Formation and the calcareous sandstone of the Horsham Stone is still won from this formation. The Cuckfield Stone Bed (also known as the Tilgate Stone) is a similar lithological unit within the Grinstead Clay Member. The fine- to medium-grained, quartzose, Ardingly Sandstone within the Tunbridge Wells Sand Formation forms the extensive natural crags in the central Weald and is used as blocks and freestone on a local basis. Clay ironstones from the basal unit of the Wadhurst Clay Formation and other such beds throughout the group was the basis for England's seminal iron smelting industry since Roman (and probably earlier) times that reached its acme during the Tudor and Stuart periods. The iron-ore was generally extracted from a series of closely spaced bell-pits and degraded examples of these are common over the ironstone-bed outcrops throughout the Weald. The Wealden of the Isle of Wight has been used on a much smaller scale for brick and tile manufacture and the shelly limestones from within the Vectis Formation on the Isle of Wight have been used historically on a local basis for building. To the west in Dorset and Wiltshire the Group is thin and is generally not exploited.

The **Lower Greensand Group** is principally sand in both the Weald and Channel basins with notable ironstone facies of the Monk's Bay Sandstone Formation (Isle of Wight) and the Seend Ironstone (in the west), this latter only, providing a limited iron-ore resource in the past. The 'clean' sands within the Folkestone Formation in the Weald and the Sandrock Formation on the Isle of Wight are the principal resources still extracted today. There has been some investigations into the presence of commercially valuable fuller's earth deposits within the group, but their occurrence as lense-shaped bodies has limited their exploitation. Within the Weald building stone resources are limited with only the calcareous sandstone concretions (Bargate Stone) of the Sandgate Formation in the northwest Weald, and the hard sandy limestones ('Ragstones') of the Hythe Formation in Kent and East Sussex providing material in the past. Only limited use is made locally of the hard iron-bound sandstones within the group on the Isle of Wight. However this use has led to a characteristic look to older buildings in these areas

The **Selborne Group** comprises the Gault and the Upper Greensand formations throughout the district. The Gault has been used extensively in the past wherever it outcrops and bricks are still made of the formation at Selborne Brickworks and by using traditional 'artisan' methods at Pitsham in the southwest Weald. The Selborne Brickworks famously produced a range of moulded bricks in a myriad of shapes and styles in the past. The formation was exploited on the Isle of Wight well into the 20th century but the last site at Rookley Brickworks closed in the 1970s. The Upper Greensand generally displays three overlapping lithologies of glauconitic sandstone, a finer-grained 'malmstone' and cherts/cherty sandstones. All have been exploited in the past with the 'malmstone' providing the best freestone in both the southwest Weald and the Isle of Wight. In the northwest Weald firestones and hearthstone have been mined (Mersham) from the intensely hard colloidal silica-rich beds within the Upper Greensand.

The **Chalk** was formerly used widely for the production of cement and agricultural lime but with the concentration of the cement industry into mega-production units only a few quarries remain and provide agricultural lime products and some by-product flint nodules. The modern stratigraphy embodied within all of the newer maps of the district provides a greater definition to the varied lithological characteristics of the Chalk throughout its thickness and provides further insight into potential exploitation of the group. On the Isle of Wight the tectonically hardened chalk within the monoclinal structures has provided freestone and dressed blocks for use on a local basis.

The **Palaeogene strata** are lithologically heterogeneous, providing potential sand, clay, and limestone resources. Most of the clay units have been used for brick and tile manufacture in the past with the Reading and London Clay Formations being the most popular and extensive both on the mainland and the Isle of Wight. The Michelmersh Brickworks (see excursion report herein) exploits the highly coloured clays of the Reading Formation but locally in that area the formation is divided into three lithologies and along with the clays, thick units of sand and unusually thick well-rounded flint pebble beds are found. These demonstrate the course of a major distributary channel draining the low lying fluvial plain extant at that time. Sand units within the Palaeogene succession are widespread and exploited on a local basis but some are far too glauconitic to provide a useful resource. Clays suitable for the manufacture of ceramics are common in the Poole Formation in west Hampshire and Dorset and their extraction supported the Poole Pottery factory until recently. Ball clays, used for bricks, tiles and pottery (including high specification ceramics), are extracted from the same horizons further west around Wareham from Poole Formation Bracklesham Group. On the Isle of Wight limestone has been quarried from the freshwater Bembridge Limestone (see excursion report herein) and to a lesser extent the underlying thin limestones of the Headon Hill Formation. The famous Quarr Stone (or 'Feather Bed' a term derived from its feather like appearance created by closely packed cross-bedded detrital shell laths) from the Bembridge Limestone outcrop on the north coast formed the basis for a significant medieval industry controlled by the monks from Quarr Abbey. The stone has been used commonly on the mainland (notably in Winchester Cathedral) but only in a limited way on the island itself.

The most valuable, currently, of the region's natural resources (other than water and hydrocarbons) is to be found within the aggregate-rich units that form much of the **Quaternary succession** along the coastal plain and within the larger tributary streams of the long-lived Solent River. These form wide terrace spreads through the New Forest and Lymington area and within the Avon valley to the west; and are also worked within the Test, Itchen and Meon valleys around Southampton and Romsey, and eastward into the Sussex Coastal Plain. There are significant offshore resources preserved in drowned portions of this Solent River system to the east of the Isle of Wight (see Bellamy herein). There has been some historic exploitation of the variously named 'brickearth' deposits for local brick and tile manufacture.

Conclusion

The geological history of the Wessex Basin provides the foundation to the surface geology of central southern England and provides the geomorphological grain of the region within which the near-surface geological resources can be assessed. The long term mapping (1991 to present) of the region provides a comprehensive framework for the development of strategic planning for many aspects of life in the region. The results underpin decision making about strategic resource management, and the safeguarding and exploitation of mineral resources that is central to a well-informed extractive industry remit.

Acknowledgements

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Figure and Table Captions

Figure 1. An overview of the work of the Survey 1991 – present. The geological sheet boundaries in red are the individual map tiles completed in the Chalk Downlands Project and those shown in green represent those tiles completed pre 1991. They are shown here over a backdrop of the digital bedrock geology data at the 1:250 000 scale that gives a broad overview of the structure of the southern England. The Weald Anticline separates the North and South Downs and its closure to the west is marked by the extensive Chalk plain stretching from Hampshire into Wiltshire. The Hampshire and London synclinal Basins carry an infill of Palaeogene sands and clays.

Figure 2 a and b. The geology of the area around Michelmersh Brickworks contrasting the level of information available from the original survey (a. 1896, reprinted without revision in 1975) compared to that of the recent survey (b. 2002).

Figure 3. The structures of the Wessex Basin and younger coextensive Hampshire basins

Figure 4. The cross section a-b shown in Figure 3. This simple section illustrates:-

1. the extensional normal faulting and some of the reverse movement during Alpine compression
2. the Cimmerian unconformity that separates the Lower Cretaceous from the underlying Jurassic at the sub-basin margins
3. and the overstep of the Upper Cretaceous over the Hampshire – Dieppe High.

Figure 5. The principal structural elements of the Hampshire Basin. Insert of the underlying Wessex Basin extensional fault pattern.

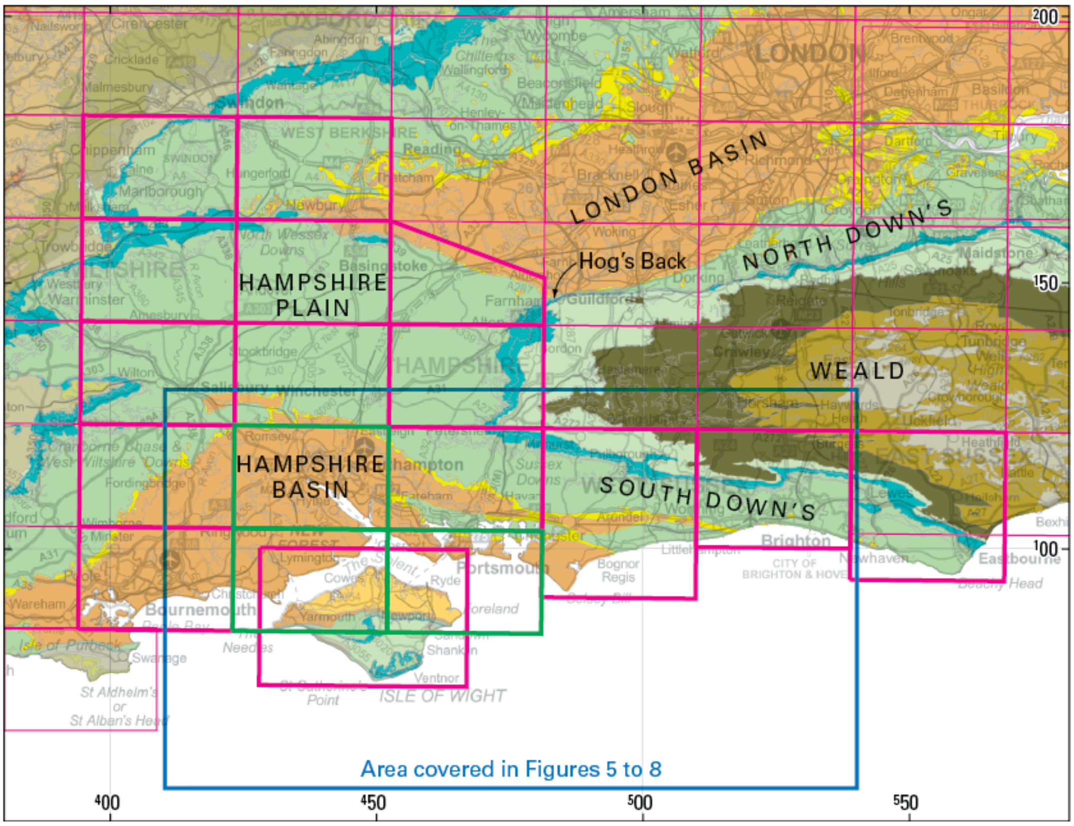
Figure 6. The relief and geomorphological units of the region.

Figure 7. The distribution of the principal bedrock units within the district. See Table 1 for an expanded listing.

Figure 8. The simplified lithostratigraphy and distribution of the Quaternary deposits.

Table 1. The Principal units within the bedrock encountered in the district

Notes for Table 1
1. Description of units within the western part of the Hampshire Basin.
2. All of the Chalk formations are tectonically hardened within the Isle of Wight Monocline and can form significant durable clasts locally within the Quaternary deposits.
3. Description of units within the Channel Sub-basin.
4. The youngest Chalk Group at outcrop is latest Campanian Stage and dated at approximately 71 Ma; the oldest Paleocene at outcrop is Thanetian Stage (possibly late Thanetian) at approximately 56 Ma: and the youngest Bouldnor Formation at outcrop is Early Oligocene in age at approximately 30 Ma.
5. The Purbeck Group on the Isle of Wight is only substantially proven in deep hydrocarbon wells to the south of the structural spine of the island. Different lithostratigraphical schemes were formerly defined for the Purbeck and Weald successions but these have recently been amalgamated at formation level (Hopson et al. 2008).



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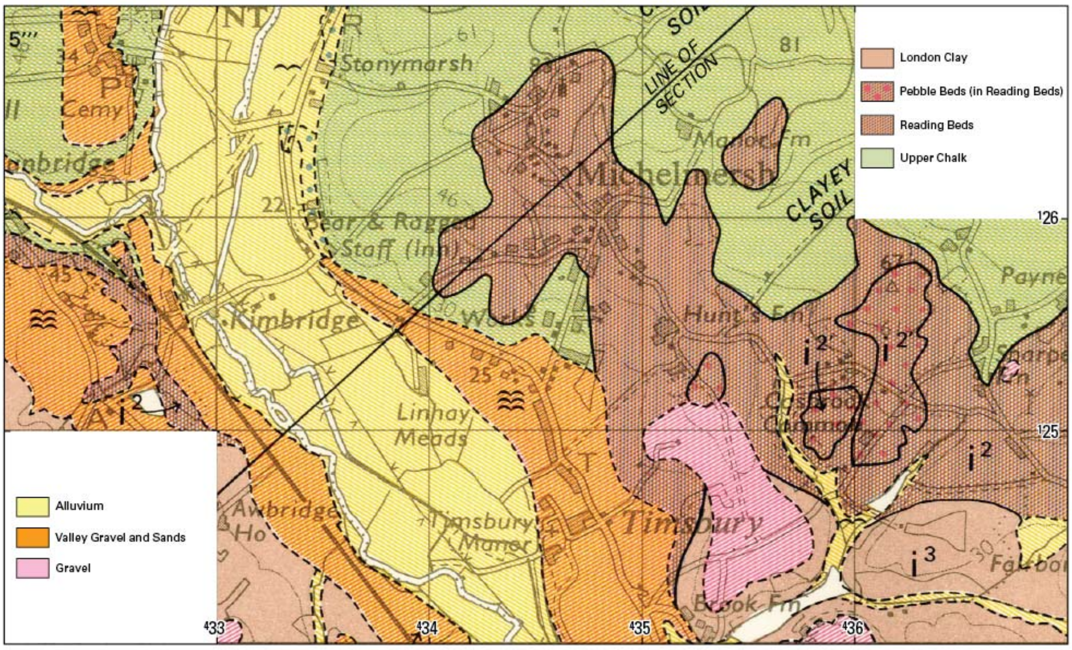
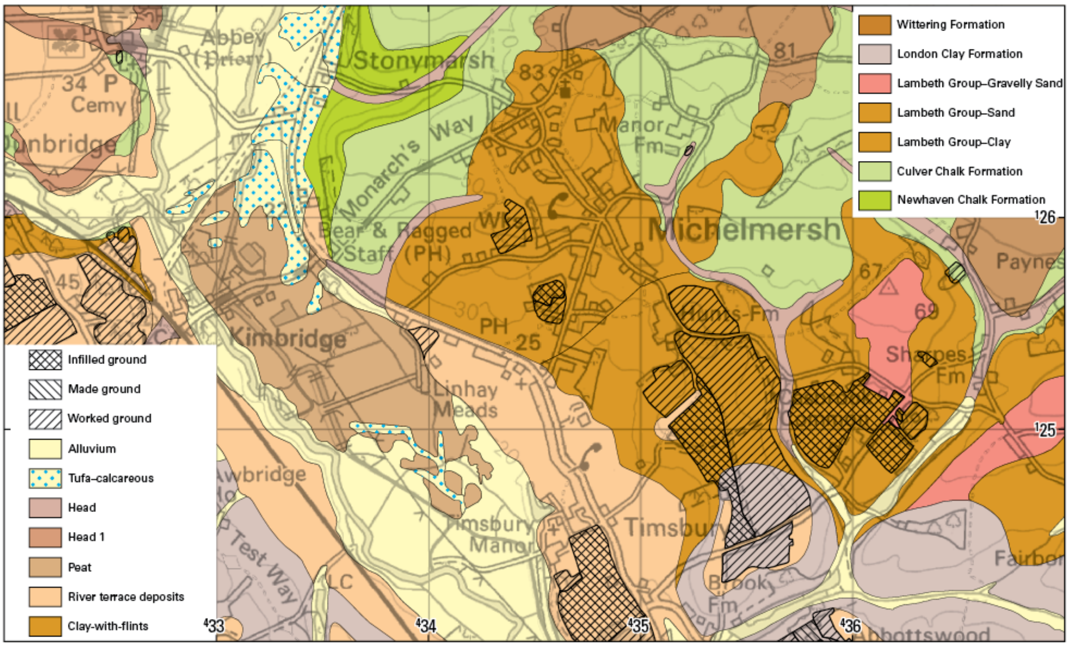


a.



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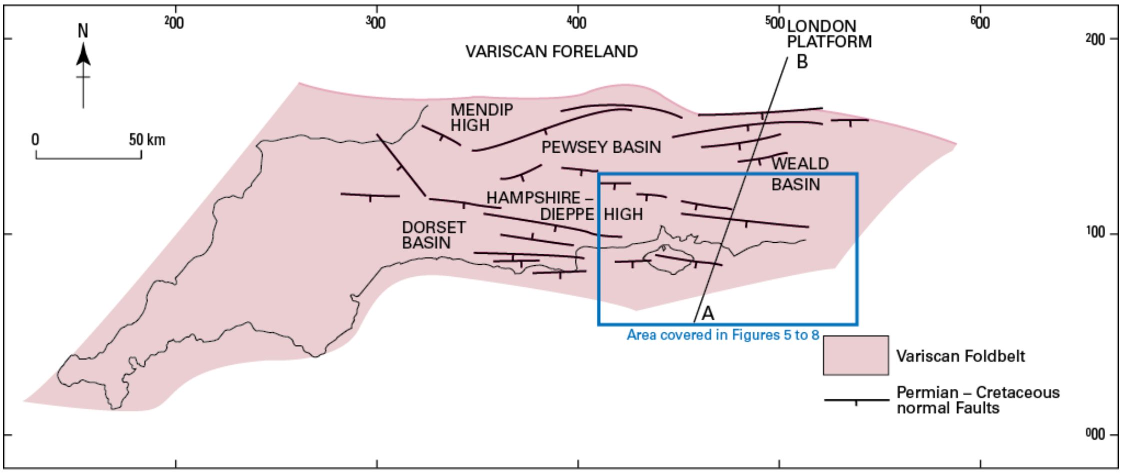

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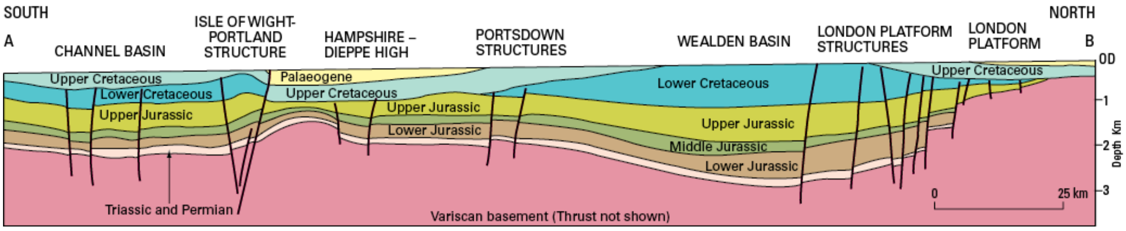

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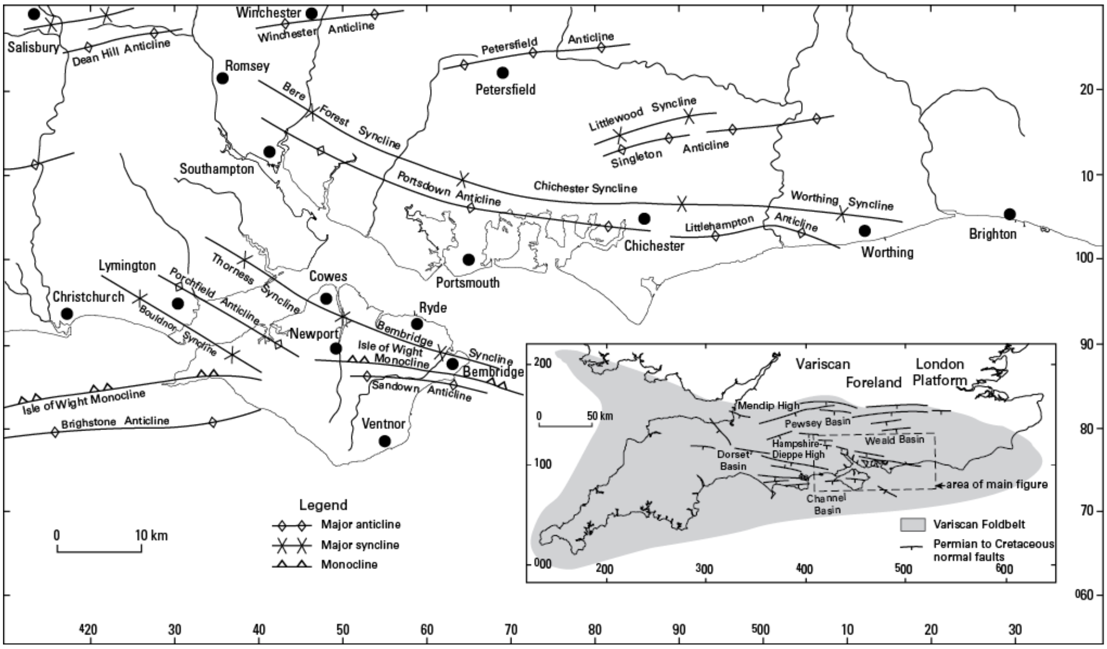

Figure 5. The principal structural elements of the Hampshire Basin. Insert of the underlying Wessex Basin extensional fault pattern.

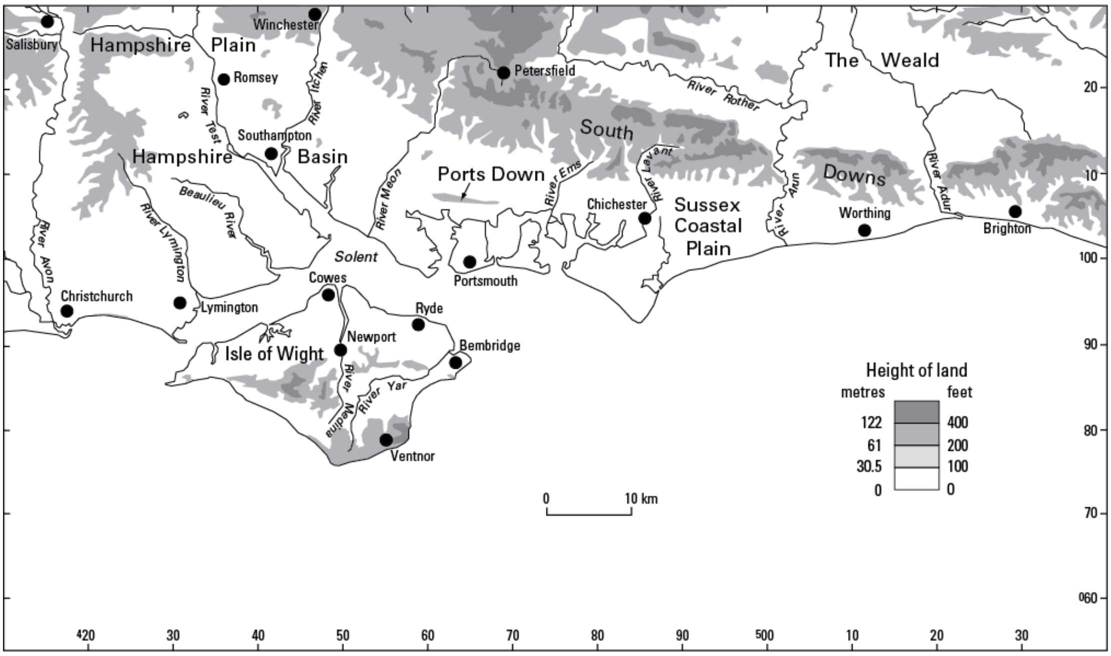

Figure 6. The relief and geomorphological units of the region.

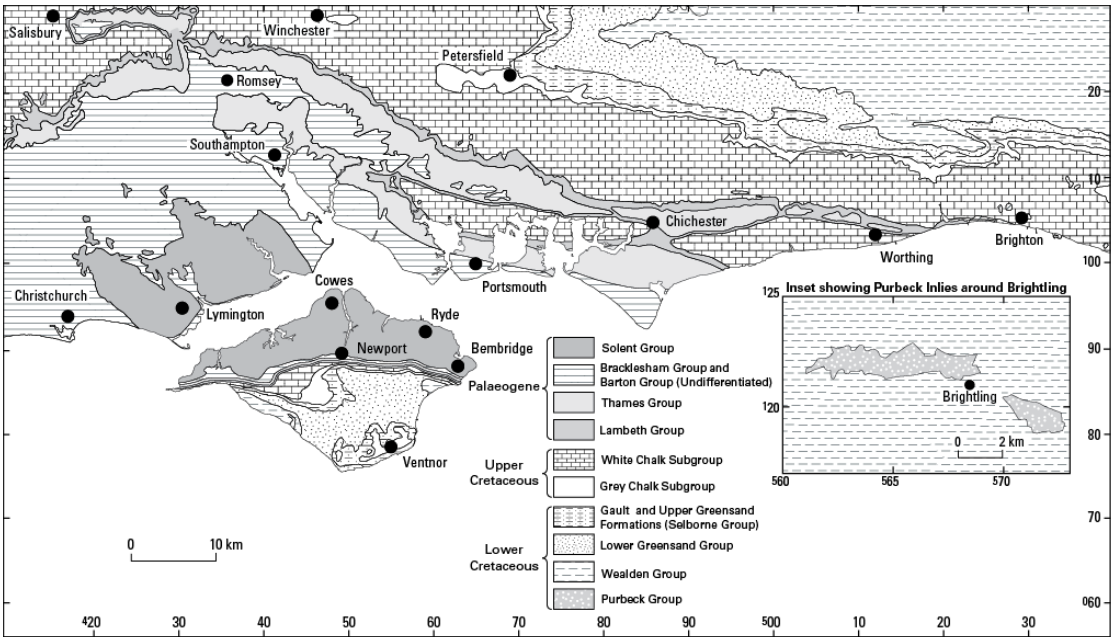

Figure 7. The distribution of the principal bedrock units within the district. See Table 1 for an expanded listing.

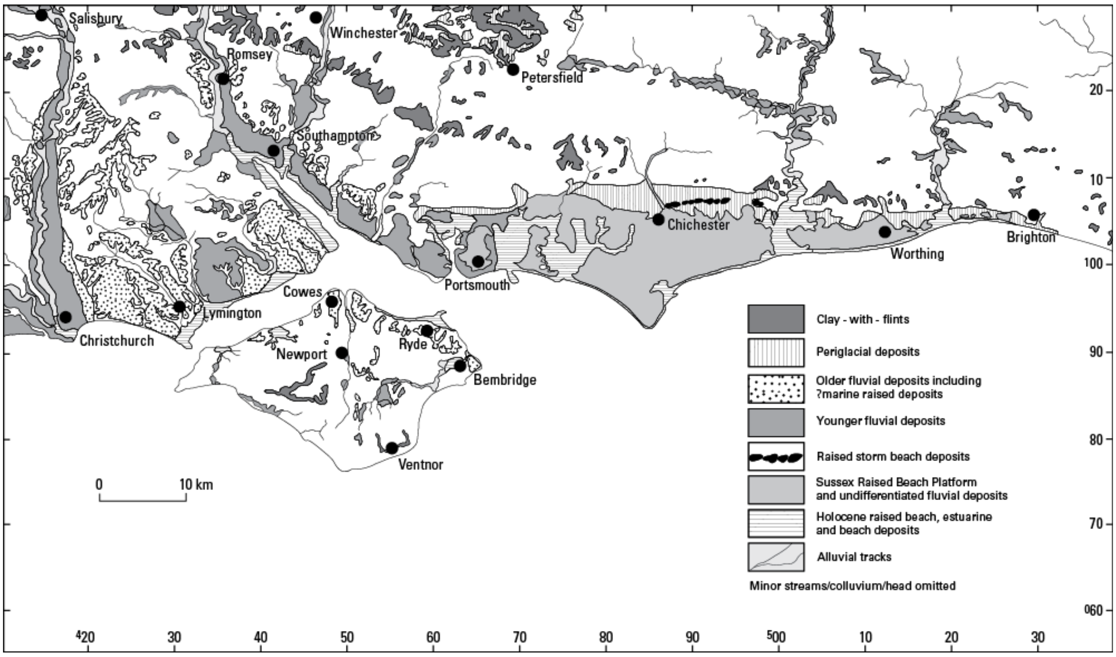

Figure 8. The simplified lithostratigraphy and distribution of the Quaternary deposits.