The Geology of Pegwell Bay

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Contemporary setting.

Pegwell Bay is situated to the south-west of Ramsgate, on the Isle of Thanet. Until 10,000 years ago the area of the southern North Sea was land (the Dogger Bank, famous for fishing, was an island only about 8,000 years ago). Sea levels rose at the end of the last major glaciation and began to stabilise between 6,000 to 5,000 years ago. When rising waters inundated the land bridge between Britain and Europe, Thanet eventually became separated from the mainland by the *Wantsum Channel*.

Around 55-54 BC the Wantsum Channel was a mile or so wide. However, the build up of the ‘Stonar Bank’ (shingle) at its eastern end and deposition of sediment from the River Stour caused it to silt up and led to its demise. The Stonar Bank advanced northwards and contracted the southern mouth of the channel. By the fifth century it impeded the flow of the Stour and the Wantsum channel started to convert to water meadow. Humans then intervened massively in the development of the landscape, reclaiming 16,000 acres in little over 400 years. In the 15th century a ferry operated across this channel but by the 16th century it had silted up.

Today the River Wantsum flows from Plucks Gutter (TR 270634), by Sarre (TR 252650) and out to sea near Reculver (TR 245695). Between Plucks Gutter and Pegwell Bay (TR 350634), Thanet is separated from the mainland by the (narrow) River Stour.

A short geological history of Britain and east Kent.

Before we look in detail at the geology of Pegwell Bay, it is useful to consider the geological history of the region. Table 1 shows the periods that will be discussed along with a brief description of the conditions prevailing in south-east England and its latitude at those times.

Period	**Age / Ma**	**Conditions**	**Paeleolatitude**
Carboniferous	362.5 - 290.0	Land, then low-lying waterlogged plain	Equatorial
Permian	290.0 - 245.0	Non-marine clastic basin	10 to 20°N
Triassic	245.0 - 208.0	Land	
Jurassic	208.0 - 145.6	Land	
Cretaceous	145.6 - 65.0	Land, then marine	45°N
Tertiary	65.0 - 1.64		
Quaternary	1.64 to present		52°N

Table 1 : Geological periods

Through the processes of Plate Tectonics and Continental Drift, what would become south-east England has moved from a latitude of about 60°S at the start of the Ordovician (510 - 439 Ma) to about 52°N today. At various times the region has been land, a low-lying water-logged plain, part of a marginal marine basin or an emergent beach.

During the Carboniferous Britain was near the equator, there were warm seas and shallow-water tropical carbonates were being laid down. Kent experienced lagoonal conditions followed by a rise in sea level, yielding a sequence of alternating shales and thin crinoidal marine limestones. Folding and erosion took place during Namurian times (325 to 315 Ma) and no deposits of this age are known from the Wealden area. By 315 Ma (the Westphalian) there were coal-swamp conditions, with periodic short-lived marine incursions being registered by thin marine bands. In the later Westphalian the area was dominated by clastic sedimentation arising from erosion of the uplifted *London-Brabant High* to the north.

No rocks from the Triassic or Jurassic periods are present in east Kent (including Thanet), presumably it was above sea-level at this time and exposed to sub-aerial erosion. At the end of the Triassic the Tethys Ocean[1] spread over Britain and marine rocks rich in ammonite fossils were laid down. Jurassic Britain was mostly covered by a shallow sea at the margins of the Tethys Ocean, laying down alternations of clays and limestones.

By the Cretaceous southern England lay around 45°N. Cretaceous deposition begins with the Lower Greensand and Gault (representing marine transgressions). The Lower Greensand is sandy (with some silts and small amounts of material like chert[2] and ironstone[3]) and was laid down in a variety of shallow-water, near-shore environments. The Gault is composed of dark bluish grey to pale grey soft mudstones and silty mudstones. It contains a rich marine fauna in which molluscs predominate and represents an important marine transgression which pushed back the shoreline of the Lower Greensand sea to the borders of Wales and into Northern England. Their marine origin is indicated by their green glauconitic [4] colouration.

The Cretaceous sequence finishes with the Chalk beds (figure 1). These are massive deposits of biogenic calcite, composed of a coarse fraction of shell debris and foraminifera embedded in a fine matrix of cocoliths. The chalk cliffs are folded as part of the Wantsum Syncline which was responsible for separating Thanet from mainland Kent. Examination of the 1:50000 sheet for the area (British Geological Survey, Sheet 274) shows that folding preceded deposition of the Thanet Beds.

Figure 1 : Chalk cliffs at Pegwell Bay (Upper Chalk), December 1999

In the Tertiary period Britain continued to move towards its present location. The climate was often humid and sub-tropical, there may have been palm trees and

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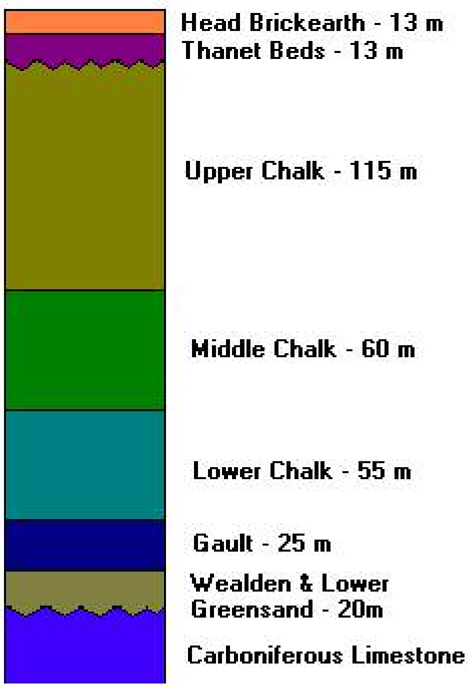
[1] Tethys Ocean - used to separate Laurasia and Gondwana (the Mediterranean Sea is the last remaining relic of this ocean (see Lapidus and Winstanley)
[2] chert - (flint); siliceous microcrystalline sedimentary rock, mainly of interlocking silica (SiO_2) crystals
[3] ironstone - iron-rich sedimentary rock
[4] Glauconite is considered diagnostic of sediments deposited in a continental shelf marine environment. It is suggestive of slow rates of sediment accumulation and may form by biogenetic or diagenetic alteration of minerals such as biotite or volcanic glass (see Internet site http://www.uwrf.edu/~wc01/glauconite.htm)

crocodiles[5] were common in southern England. Whereas other areas were receiving marine sediments at this time, the Thanet area was mostly a near-shore environment accumulating sandy deposits.

In the Quaternary there has been a cycle of glacial periods interspersed by warmer inter-glacials. Ice has spread at least four times to temperate latitudes (most recently between about 18,000 and 10,000 years ago), although it has been confined to high latitudes and mountain glaciers for about the past 10,000 years (we are currently in a warmer interglacial period). During the last glacial maximum ice cover extended as far south as Essex [6].

<u>The geology at Pegwell Bay.</u>

The following vertical section shows the rocks present in the north-east of the bay (these are not all exposed at the surface):



The basement Carboniferous limestones (Dinantian) are about 275m below sea-level. There is an unconformity between them and the overlying beds. There follows a conformable sequence of Cretaceous sediments beginning with the Wealden and Lower Greensand beds (about 20 m in total), the Gault (about 25m), followed by the Chalk (Lower Chalk about 55m, Middle Chalk about 60m and about 115 m of Upper Chalk).

<u>Figure 2 : Pegwell Bay vertical section</u>

The top of the Upper Chalk presents an eroded surface that the Thanet Beds (about 13m, see table 2) were deposited over. The Kentish Sands are not present at Pegwell Bay; they replace the Pegwell Marls and Reculver Silts in outcrops closer to London.

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[5] As an example, although crocodilian fossils are rare in the London Clay (Eocene period), vertebrae and scutes have been recovered from the Isle of Sheppey, plus exceptionally rare whole skulls.

e)	**Reculver Silts**
d)	**Pegwell Marls**[7]
c)	**Kentish Sands**
b)	**Stourmouth Clays**
a)	**Bullhead Flint Conglomerate**

Table 2 : The Thanet Beds sequence

The Thanet Beds are overlain by Quarternary Head deposits in a sequence called the younger Brickearth (about 13m).

Further to the south-west the basement limestones are overlain by coal measures (Westphalian), which were deposited before the Cretaceous sediments noted in this area. However, the coal measures finish around Ebbsfleet (TR 338620) and do not quite reach the bay.

Correlating the exposed geology to the geological history

Figures 3, 5 and 6 illustrate the unconformity between the Cretaceous Chalk and the overlying Thanet Beds. The chalk extends across much of the coast of south-east England. It has been shown to have formed as a white calcareous mud, under normal marine conditions, at a depth of between 100-600 m. Modern chalk sequences found in the warm shallow seas off the Bahamas have a negligible proportion of cocolith material, leading one to question whether this contemporary environment is indicative of the conditions under which the Cretaceous chalk was deposited.

The Upper Chalk exhibits both nodules and extensive tabular sheets of flint (SiO_2) whose origin is controversial. The British Geological Survey suggests it could either have come from the post-depositional solution of siliceous skeletal remains, or by direct inorganic precipitation of silica from seawater. The Open University favour the first idea, suggesting that it accumulated randomly on the seafloor and was then dissolved under acidic conditions in the burrows of marine organisms.

The presence of the Chalk shows that Pegwell Bay was a marine area during Cretaceous times. The environment must have been warm enough to encourage

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[6] See Hart, J., Hindmarsh, R. and Boulton, G. (1990) *Styles of Subglacial Glaciotectonic Deformation Within the Context of the Anglian Ice-Sheet*, Earth Processes and Landforms, Vol 15, pp. 227-241
[7] A marl is a friable mixture of subequal amounts of micrite and clay minerals

prolific production of cocoliths, whilst periodically it shifted in favour of species secreting siliceous skeletons. Today, diatom[8] oozes predominate at high latitudes, whereas radiolarian[9] oozes occur in tropical regions. However, silica oozes can also occur at the sites of coastal upwelling[10], whilst mixed radiolarian and foraminiferal oozes can occur where there has been depression of the carbonate compensation depth[11].

During the Cretaceous the Pegwell Bay area lay at about 45°N; this is hardly the warmest of latitudes. However, a greenhouse climate was prevailing and the Earth was a lot hotter than today. There was little temperature difference between equatorial and polar latitudes, and an absence of ice at sea level. Thus the exposed rock of the Upper Chalk is consistent with Pegwell Bay being located under a warm sea during the Cretaceous. One may continue to question the depth of that sea, and the environmental changes that facilitated switches from calcareous to siliceous sedimentation.

The whole of southern England was gently uplifted during the early Tertiary period (65 Ma to about 1.4 Ma) as a result of ripples from compression in the Alps. This exposed the Upper Chalk to sub-aerial erosion and means that the earliest Tertiary sediments are missing.

A shallow sea then transgressed across the area, extending into the London Basin. Pegwell Bay was a near-shore area, in which the sandy facies of the Thanet Beds were laid down. The sub-Eocene unconformity (figure 3, this is the type section) marks this marine trangression and the start of deposition of the Thanet Beds (from about 65 Ma). The major feature is the Bullhead Bed; a layer of unworn, glauconite coated flints in a matrix of dark clay and glauconitic sand. Maizels suggests that it may "represent the first 'beach' of the rapidly extending Thanet Sea" and dates the unconformity at around 100 Ma, with deposition of the overlying Thanet Beds from about 70 Ma. English Nature describe the 'Bull-head Bed' as "an *in situ* weathering residue of unabraded flint nodules".

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[8] Diatom - unicellular algae which secrete silica shells
[9] Radiolarian - Zooplankton which secrete silica skeletons
[10] Coastal upwelling - a process whereby (in some areas) cool, nutrient rich waters are brought to the surface, replacing nutrient-depleted waters and supporting high rates of primary production
[11] CCD - This is the depth at which less than 20% of the carbonate skeletal material falling from the surface waters is preserved in the bottom sediments; the rest is dissolved during descent.

Above : An exposure of the sub-Eocene unconformity

Right : Close-up of the sub-Eocene unconformity

Figure 3 : The Sub-Eocene Unconformity at Pegwell Bay, December 1999 (Russell, 1999)

Maizels' suggestion is not conclusively supported by the field evidence. However, the angular slabs of flint do not exhibit the signs of mechanical abrasion that would be expected in the littoral zone (arising from the action of tidal currents and waves) or supratidal zone (arising from sub-aerial erosion). There is also some evidence of small-scale cross-stratification in the sands above the unconformity; possibly indicative of wave-formed ripples; and the sandy nature of the deposits is suggestive of a continental shelf environment. It is likely, therefore, that this bed was laid down in a medium energy, off-shore environment, at a depth of up to 200m [12].

Figure 4 shows a sketch of one section at Pegwell Bay and its associated graphic log. The graphic log was constructed by taking samples from a number of positions along the cliff exposure behind the old hoverport apron.

[12] Storm waves can affect sediment as deep as 200m; below that, waves have little affect on bedforms.

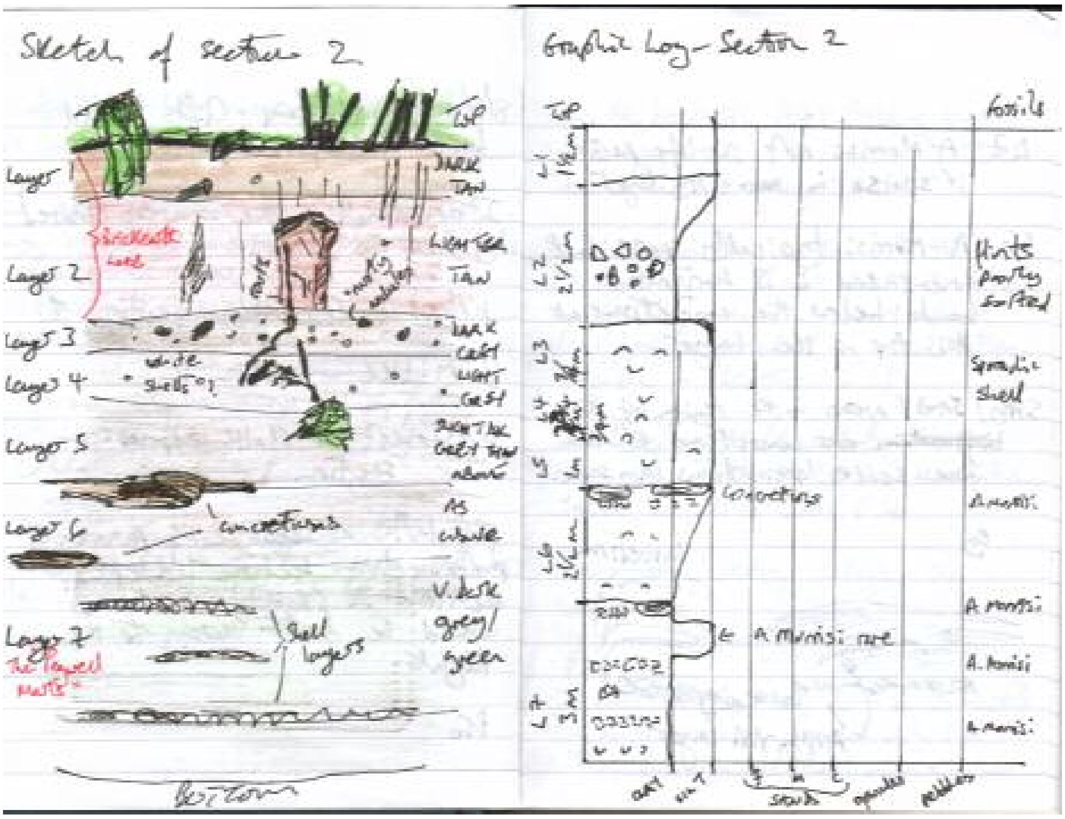

Figure 4 : Graphic log & sketch of exposed geology - Layers 1 & 2 are the Brickearth, Layers 3, 4, 5 & 6 are the Reculver Silts, Layer 7 is the Pegwell Marl

The Thanet Beds themselves are composed of fine, glauconitic sands and fossiliferous sandy clays. There is a 16 inch shell bed at the base of the Reculver Silts [13] which contains an important fish fauna. This is preserved as disarticulated fish debris, including a diversity of identifiable shark teeth. This is the only outcrop which shows the bottom living fish assemblage which was subsequently destroyed by the North Sea volcanicity. Ash falls by these volcanoes brought about an extinction event.

[13] See English Nature, SSSI Notification for Sandwich Bay and Hacklinge Marshes, File reference TR/35-4

Figure 5 : Thanet Beds near the sub-Eocene unconformity, note the wavy beds (Russell, 1999)

Figure 6 : The Thanet Beds

Left - Close-up view of wavy bedding in Thanet Beds near the sub-Eocene unconformity

Above right - Closer to Ebbsfleet the Thanet Beds exhibit linear stratification.

(Russell, 1999)

At the site illustrated in figure 3, the overlying Thanet Beds are about 4m thick and a light grey-tan colour. Just above the sub-Eocene unconformity there is a darker and more clay-rich horizon. At this location the Thanet Beds appear to be a massive deposit with little layering (excepting the cross-stratification noted earlier). However, as one moves along the section towards Ebbsfleet, there is evidence of some wavy-bedforms and large-scale cross-stratification (figure 5), before the sequence settles into parallel bedding (figure 6). Small-scale layering is visible within the Reculver Silts (figure 7).

Layer 6 is bounded to the top and bottom by irregularly spaced sandstone concretions (figure 8). Golding notes that various authors have commented on these “doggers” and suggested that they may have been formed by storm events acting on impersistent beds of clean fine sand.

Figure 7 : Small scale layering in the Reculver Silts (Russell, 2003)

Figure 8 : Sandstone doggers bounding Layer 6 of the Reculver Silts

Top : Lower boundary of Layer 6, note shale-like, fissile nature of the concretion

Top right : Upper boundary of Layer 6, note presence of white *Arctica morrisi* shells at the lower surface

Right : Lower edge of concretion at upper boundary of Layer 6, note presence of ripple-like features & *A. morrisi* shells.

The overall impression of the Reculver Silts is of a low-energy marine environment which was mostly below the storm-wave-base. Sands and silts were deposited with some layering which in some places appears to have suffered little bioturbation. Occasionally storm-waves did disturb the sea-floor and produced the doggers; perhaps the water depth was shallower or the storms particularly vigorous at those times. The *Arctica morrisi* shells found throughout the section (see figures 8 and 9) are typically broken or not in life-position; these may have drifted in from elsewhere.

Figure 9 : *Arctica morrisi* fossils in the Reculver Silts, not in life-position

The capping flinty layer suggests that this area had become a higher energy environment, perhaps representing the emergent Thanet 'beach'(figure 10) . Close examination of this layer, a little closer to Ebbsfleet, shows it to be composed of a mixture of well-rounded to sub-rounded, small calcareous clasts (they react with HCl). These clasts can be scratched with a knife and, whilst being quite hard, are white in colour and probably a hard chalk. Mixed in with these small clasts are larger fragments of flint, ranging in size from small pebbles to very large pebbles. These flint pebbles range in shape from sub-rounded to angular and exhibit varying degrees of wear, although many appear not to have been transported far. The presence of these relatively fresh flint clasts is suggestive of active erosion of the Chalk close to where this sediment was being deposited. Both the flints and calcareous clasts are held in a very fine sand matrix.

Figure 10 : Capping flinty layer at top of Thanet Beds (boundary with Brickearth)

Above the flinty layer the Thanet Beds are covered by about 2.5m of Brickearth. This is a tan-coloured loam, showing little structure, which may have been deposited sub-aerially during the last glaciation. This Head [14] deposit is the "Younger Brickearth" and is described by Gallois as a "buff, structureless loam or silt". Some brickearths resemble the loess [15] deposits of northern Europe and may be wind-borne, others probably accumulated in shallow water during a period of dry climatic conditions. Where the deposits contain angular stones and pockets of flint gravel they may be the result of redistribution of earlier deposits by solifluxion[16] or by widespread 'sheet-flooding'. English Nature assert that there is up to 4m of Devensian (15-18 Ka) loess overlying the Thanet Beds, produced "under periglacial conditions during the [last] Ice Age". Apparently "where the loess rests on the chalk, there is often a highly frost-shattered zone with well developed involutions … Pegwell Bay provides the best exposures of true loess deposits in Britain … they are exceptional in having escaped modification by solifluction".

The Younger Brickearth has been found to contain fossil gastropod ("Siphonalia" subnodosa plus unidentified winkles and limpets) and bivalve (unidentified species similar to the Common Blue Mussel, *Mytilus edulis*) shells (see figures 11 and 12); as well as a fragment of bone from an unidentified (possibly) mammalian animal (Natural History Museum, receipt no. 03-0008).

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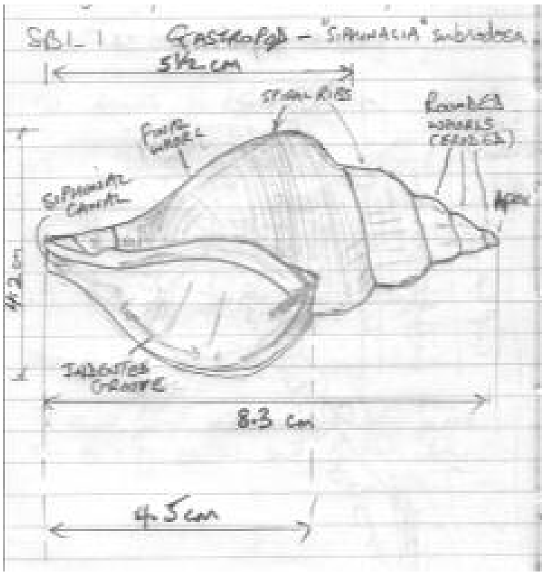
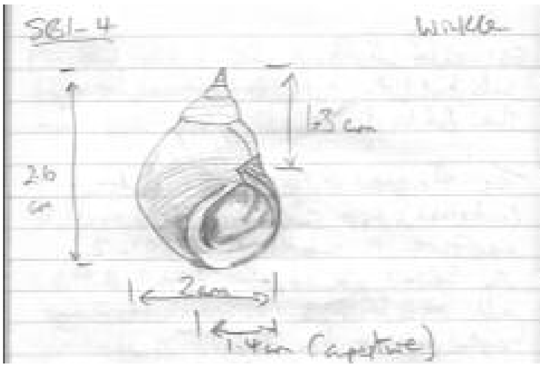
[14] Head deposits are formed by water lubricating the movement of grains, rather than transporting them as bedload or in suspension (Gallois, p. 59 and 62).
[15] Loess : silty deposit; thought to be wind-blown from areas glaciated in the Pleistocene
[16] Solifluxion - a process whereby water lubricates the movement of material rather than being the agent of transport (Lapidus and Winstanley, 1990)

Figure 11 : Shell deposit in the Younger Brickearth, not in life position





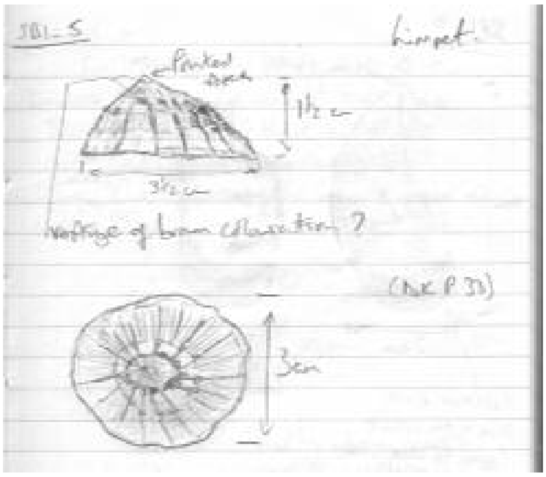


Figure 12 : Fossil s found in the Younger Brickearth

Top left : "Siphonalia" subnodosa
Top right : unidentified winkle
Right : unidentified limpet

Summary

It is clear that for a significant part of its history Pegwell Bay has been submerged beneath sea water. The depth of that water has varied over time from a shelf-sea environment (100 - 600m) to a sandy near-shore environment. Two periods of time when the Bay has been land are revealed firstly by the absence of Triassic and Jurassic rocks, and secondly by the Sub-Eocene unconformity.

Changes in the physical environment and paeleolatitude have resulted in different sedimentary facies being deposited. Over time limestones, sands, clays and biogenic chalk have registered the passing of various marine environments. The presence of the Younger Brickearth records the passing of periglacial conditions and the emergence of the Bay as land.

Study of the Bay to date has only scratched at the surface of its geological history. Further work will reveal a more detailed account of the depositional history of the Chalk, the Reculver Silts and the Younger Brickearth.

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