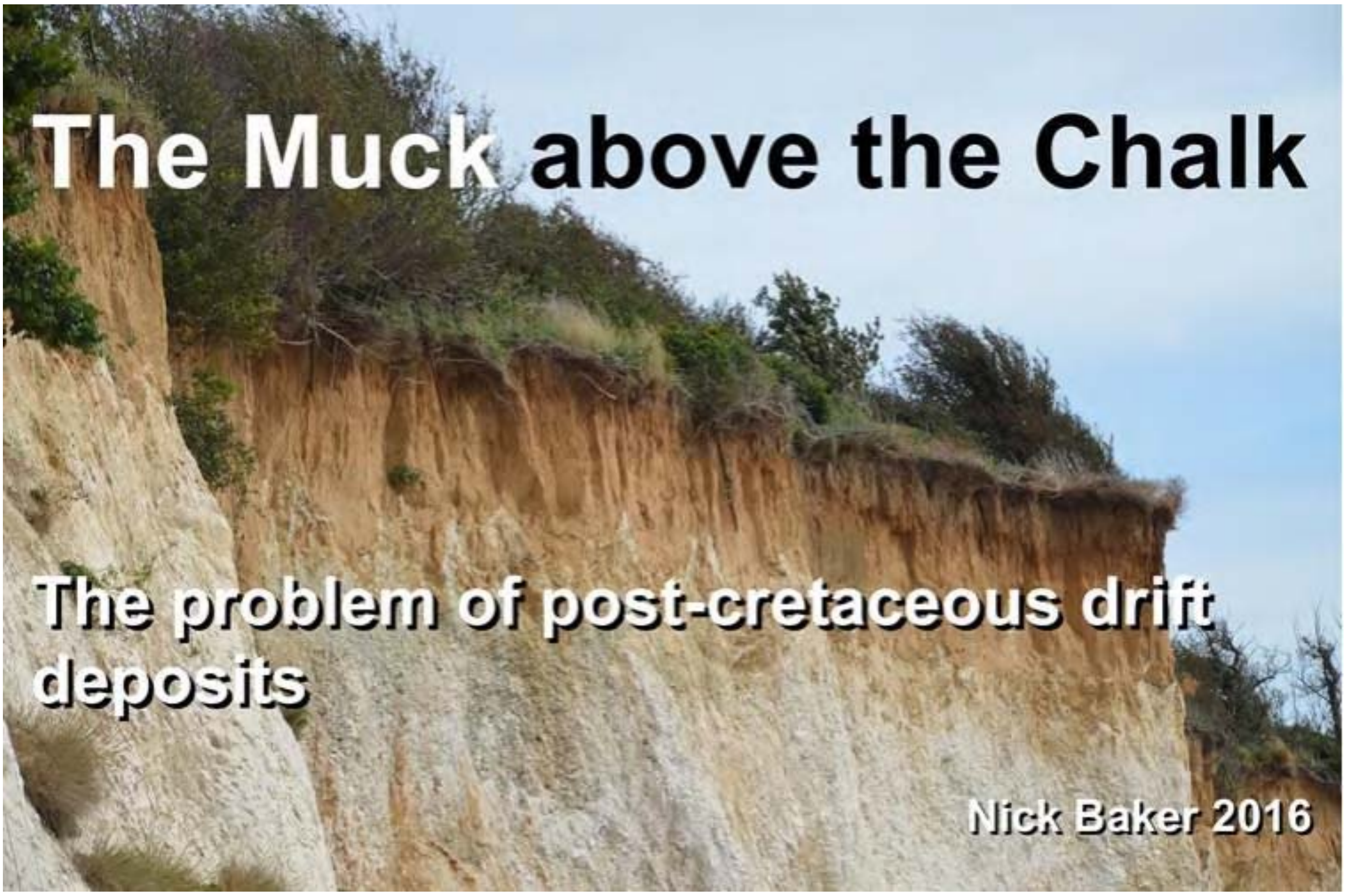


In this account we are dealing largely with the Pleistocene, (except for the sarsens) but not that which is usually taken into account. Not Boulder Clay, or River Gravels, or Marine Pleistocene. In other words, not those whose origin has long been known and well described. What remains are those of, what have been, and in some measure are still, of uncertain origin. In many cases they occupy areas some distance from the definite glacial deposits, and many are assumed to occupy former peri-glacial and tundra-type locations. Hence, the sub title of this talk although some of this investigation goes back as far as the Palaeocene. It is true that the deposits are younger than the Chalk, and are therefore 'above', but in some cases the deposits described are overlying older rocks (e.g. Angular Chert Drift overlying Lower Greensand) and often some distance from the Chalk, but in most cases they are associated with Chalk downland. The rocks are difficult to categorise is terms of content, but can perhaps be more ably grouped by location. Clay-with-Flints and Plateau Gravels are often found on the downland tops, while Hillwash and Brickearths are more a feature of the slopes and lower lands. Loess is often associated with Brickearth, and Sarsens with Clay-with-Flint, but not exclusively so.

Often, in geology, a rock reflects its direct origin. The rocks about to be discussed do not. Their content is often derived, from an original environment, while the whole collection of contents reflect much of the secondary environment during transport, possibly at the ends of a glacial episode, of mud, thawing snow and glacial out-wash.

But a simple explanation of formation is difficult to apply. Often we are working in absence of any contemporary fossil evidence, but, on the other hand, derived fossils often raise further questions. In the first edition of *Occasional Erratics* I tried to propose an origin for the Lenham Beds, using a theory of glacial outwash, just prior to iso-static readjustment. Information supplied to me suggested that the last glaciation produced a down-warp of up to 200 metres in southern England. However, evidence from raised beaches in other parts of the British Isles produces few, if any, examples of a beach more than 45 metres above sea-level. For the Lenham Beds we would need to look for a further 150 metres.

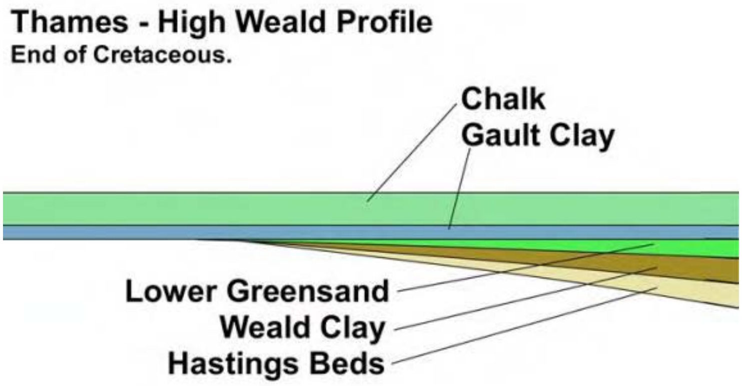
We have casts of Red Crag fossils at 200 metres OD at Netley Heath, in Surrey. There is no evidence for a 200 metre sea-level rise in the early Pleistocene, and the material at Netley Heath is definitely not *in-situ*. Interestingly, examples of Lower Greensand ironstone and sandstone can be seen only a few metres from the Netley Heath 'Crag'. All of this material, both older and younger than the Chalk, is lying on top of Chalk. In the case of the sandstone, it is similar to the sponge-rich material found in the Folkestone Beds near Ightham. While the Wealden Dome was still being eroded, beds older than the Chalk could still be at higher altitude than the Chalk on the eroding slopes.

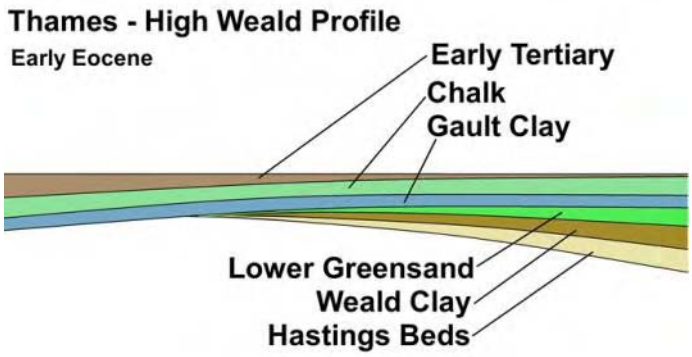
I will give another example, involving a definite fossil. In the third edition of this newsletter, an account was given of the 'eolith' research carried out by Benjamin Harrison, and of the excavation of a gravel patch near Ridley, Kent. These gravels were formerly classified as 'disturbed Blackheath Beds' now 'Chelsfield Gravels'. What is not mentioned in the article is **the finding of a Gault ammonite in the gravels**. It seems the Gault, most likely then at a higher altitude, was being eroded and some material was dumped on the Chalk further down the slope. We have hit a problem in descriptions. In this case a 'Plateau Gravel' becomes a Hillwash in its mode of formation. But all this still does not explain the Netley Heath Crag or the Lenham Crag. The deficit between the isostatic readjustment and the current altitude, might only be explained by a degree of the 'Wealden rise', perhaps still taking place in the Pleistocene—(**Jones 1999**) In fact, iso-static re-adjustments of 100s of metres are more a factor in Scandinavia then in the British Isles, and so, throughout this text, I propose a heresy, that **most of the Wealden uplift in Kent and Sussex (at least) took place in the Pleistocene.**

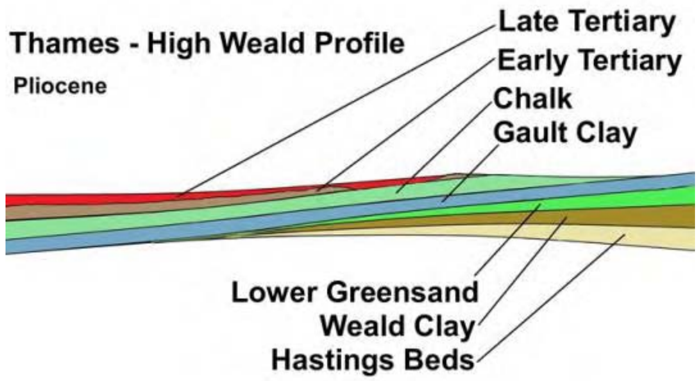
I am going to propose a scheme which would account for much of the material found on the Cretaceous and Tertiary strata. There are four stages.

1. At the **end of the Cretaceous** the newly deposited Chalk and Gault lay unconformable on the Lower Cretaceous strata, which formed a buried syncline in what is now the centre of the Wealden anticline.

2 By the **Eocene,** a large amount of the Upper Chalk had been eroded. Down-warping to the north allowed Palaeocene and Eocene strata to be laid down on the top of the eroded Chalk. The Chalk surface would have been covered by a lot of flint debris, some of which can be seen as the Bull Head Bed at the Chalk-Tertiary junc tion, eg Pegwell Bay.

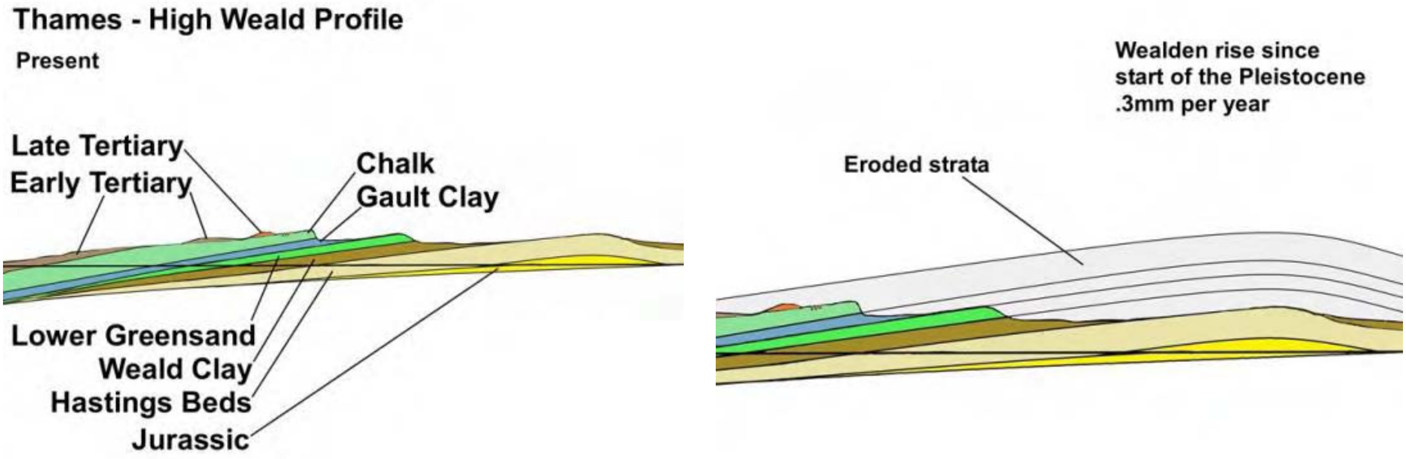






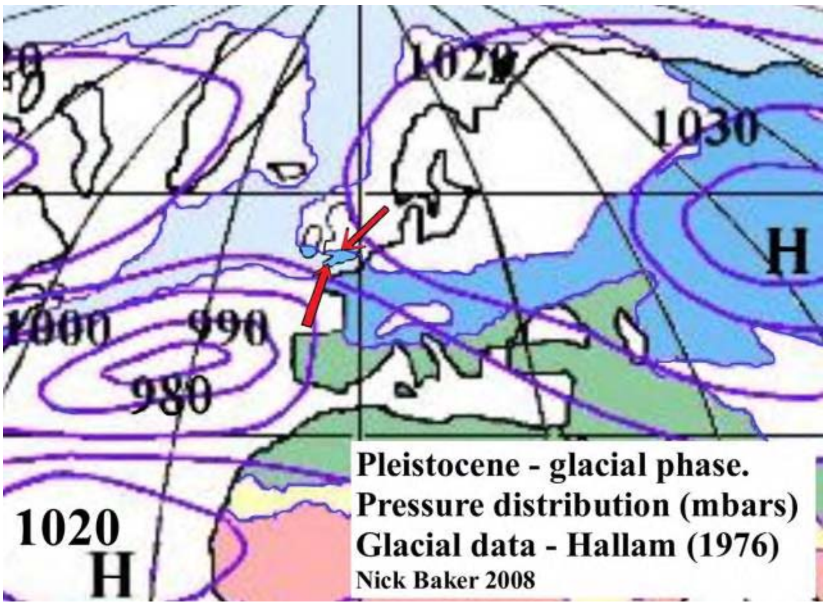
The extent of the Palaeocene invasion is still not known with certainty but it is thought that at least part of the London Clay phase covered the whole of the Wealden area.

3 By the Pliocene, some uplift of the central Weald had taken place but the northern flank would still have been near or below sea-level. A marine invasion took place at the end of the Miocene (c5Ma BP). Another invasion (or a later phase of the first) took place in the Pliocene (c2-3Ma BP) mainly affecting East Anglia, but also the Thames Syncline and the northern fringe of the Weald. In this exercise I am including the Red Crag in the Pliocene



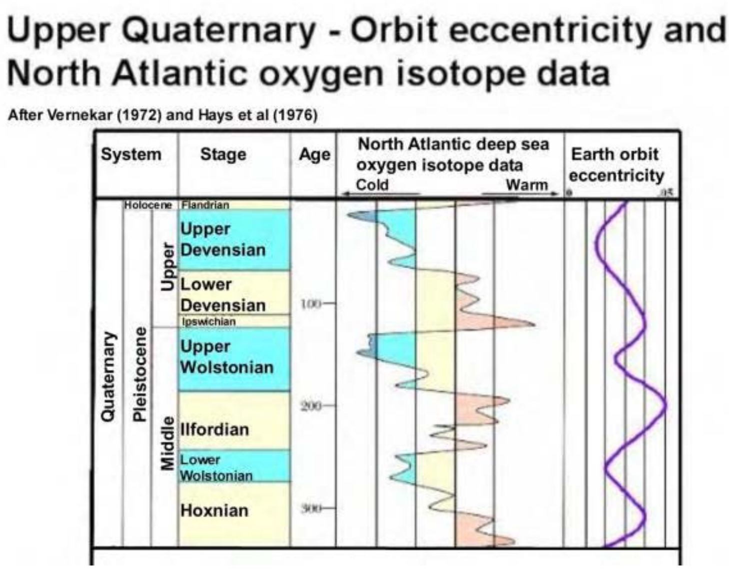
4 Much of the Wealden uplift would have taken place during the Pleistocene, leaving the imported Tertiary strata stranded, much of it then eroded. Without erosion, a ridge of up to c600m would have existed today but much was eroded—mainly during the start of the interglacials, when the area was a sea of mud with little or no vegetation to bind it. The question arises as to what happened to that eroded strata. Much would have retuned to the sea, but what of that which was displaced but remained on land? The estimated rate of **uplift** would have been 300mm per 1000 years, or .3mm per year. Bear in mind that rates of **erosion** would have been intermittent, - very little during permafrost or full-vegetation warm phases, but most rapid at the start of a thawing of the tundra

The Tundra Climate



Pleistocene - glacial phase.
Pressure distribution (mbars)
Glacial data - Hallam (1976)
Nick Baker 2008

How would a weather chart have looked during a glacial phase? First, we can assume that the glacier end would have corresponded with the annual –10C isotherm. But what sort of baratic chart would we see? Essentially, compared with the present day, everything is displaced southward, while the Arctic 'highs' would have expanded. Note the ice-free zone in North Russia, due to the close proximity of the high pressure there (little snowfall). The North Atlantic 'lows' are in the region of the Azores. That is where most snowfall would come from. The prevailing wind in our area would have been east or southeast, with snow coming on a southerly incursion, and mostly in summer. Conversely, a north or north-easterly off the glacier would bring very cold, dry (low-dew-point) air, even drying-out (subliming) the permafrost and causing local dust-storms, deposited as loess.

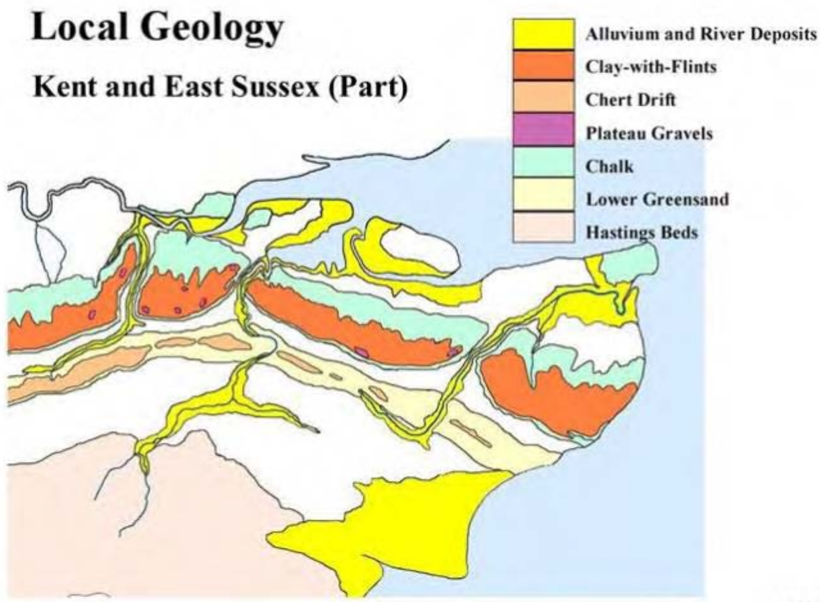


And also to remind us where we are climatically in terms of time. Here we see the latter part of the Quaternary, with warm and cold periods shown. Note the correlation between temperature and Earth orbit eccentricity. The eccentriccity would have gone on through time, but continental position was a serious question by the Pleistocene, as it was in the Permo-Carboniferous, the polar regions either occupying continents or closely surrounded by same.

And so we start with perhaps the most enigmatic of our candidates. In the strict sense, it is as what it says—clay with flints, although the term does and has covered considerable variation.

Below, we see a simplified geological map of Kent and part of East Sussex. It shows areas of Alluvium and the high ridge deposits—Chalk and Lower Greensand. It also shows the Clay-with-Flints and Chert Drift on the Chalk and Lower Greensand, respectively. Both deposits occupy the high areas of both formations and are notably absent from the lower-lying areas.

But what of the origins of the Clay-With-Flints? First of all, Whitaker in 1889 considered that the formation was a residue from solution of the Chalk. In 1906



Clay-with-Flints - Possible origin

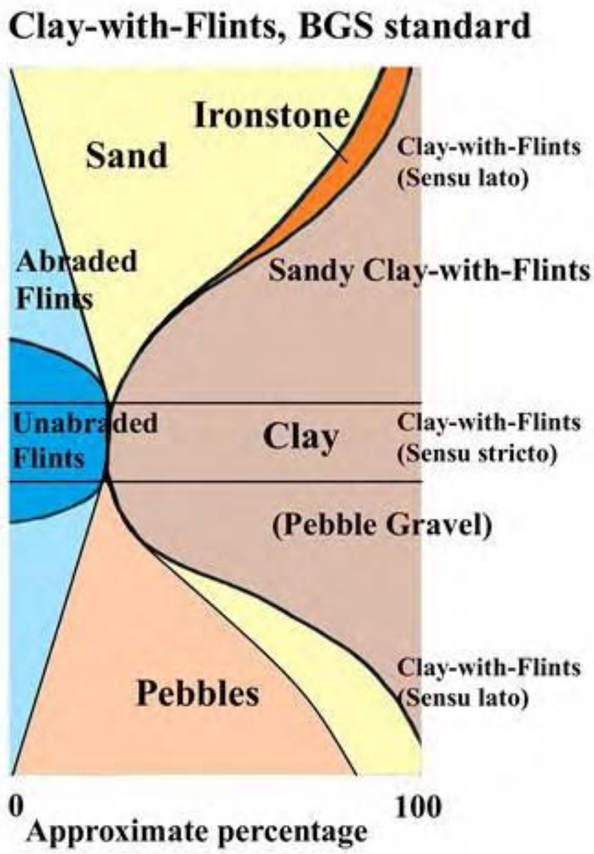
Whitaker 1889
Residue from solution of the Chalk

Jukes-Browne 1906
Too much clay. Possible incorperation of clay from other sources.

Gallois 2006
Back to solution of Chalk

Much of the higher chalk contains <0.5% of SiO_2 and Al_2O_3

Jukes-Browne pointed out that there was too much clay, in relation to the flint, but that there could be incorporation of clay from other sources. As recent as 2006, Gallois, has come back to the ideas of Whitaker. He cites areas, in Devon and Dorset, where Chalk is seen resting on flints, with little chalk or clay. There is little clay content in the Upper Chalk, except for the marl seams. The problem is that the clay minerals in the marl seams is largely montmorillanite, while the minerals in Clay-With-Flints is largely illite and smectite (the same as that in London Clay, Gault and Weald Clay). I will return to these aspects in a moment, and I am sure all of these aspects will be answered.



But the term Clay-With-Flints, covers a multitude of things, and in the past it has been applied to a very varied content. Gallois' strict definition says 'clay with unabraded flints' but the British Geological Survey has applied the name to deposits often containing, sand, ironstone, pebbles, sandstone etc. These deposits are sometimes covered by other names and recently more applicable names are used, such as Chelsfield Gravel, Pebble Gravel, Sandy Clay-With-flints etc. In this article, these names will be dealt with in the next section, namely Plateau Gravels.

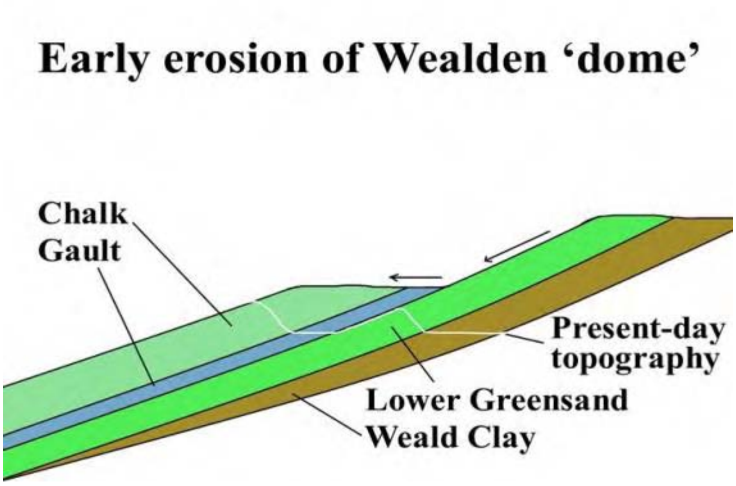
In the mean time, I have not yet dealt with what I believe to be the mode of origin of the Clay-With-Flints.

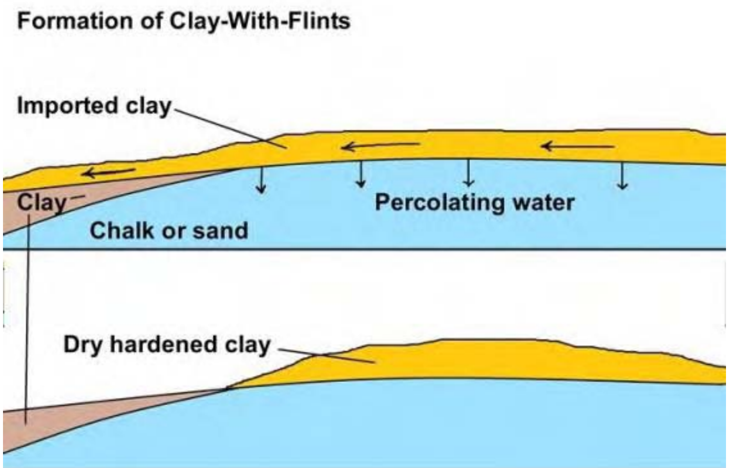

Clay-with-Flints, Burham Common

Photographs of Clay-With-Flints are difficult to come by, with the land-fill and general overgrowth of former geological exposures. This photo on the left is of a ditch on Burham Common. The abraded flints do not meet Gallois' strict definition. I do support the probability that the clay content is derived (in part) from the Lower Chalk, imported from other areas near-by, but I am not so certain of the process of the Chalk being dissolved almost in-situ. That said, the photo below shows a deposit of flints and chert, with little or no chalk or clay, on the summit of Golden Cap, Dorset. Below the deposit is Upper Greensand. Inland, on Hardown Hill, there is a similar capping of flint. chert and quartz pebbles in a greyish loam. This type of deposit in Kent or Sussex has more in common with the Chert Drift on the Lower Greensand, except for the presence of the flint. While I am certain of the possibility of Chalk solution, the Higher Chalk, alone, does not account for the clay content of the Clay-With-Flints. Here is my suggestion.


Golden Cap, Dorset

During the erosion of the Wealden 'dome', earlier strata could have been at a higher elevation than the Chalk. At the end of a glaciation, those strata would have undergone repeated freezing and thawing. Think of a high ridge, now composed of a thick outer covering of mud. Now add periods of rain and snow, possibly little else across a long time period.





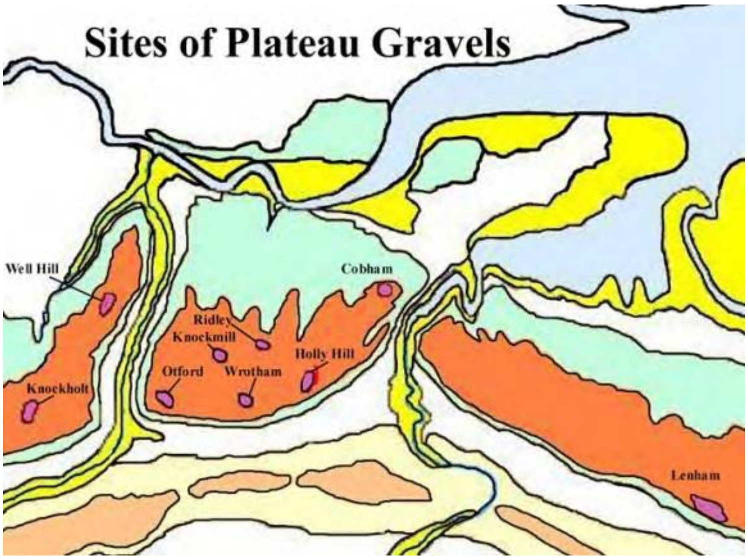
Consider also that the erosion of the slopes would involve the formation of flat bevels where softer clays were exposed. Even if these were temporary valleys, they would become filled with debris from higher up the slope. In this way, material from the Lower Greensand could easily find its way on to the Chalk.

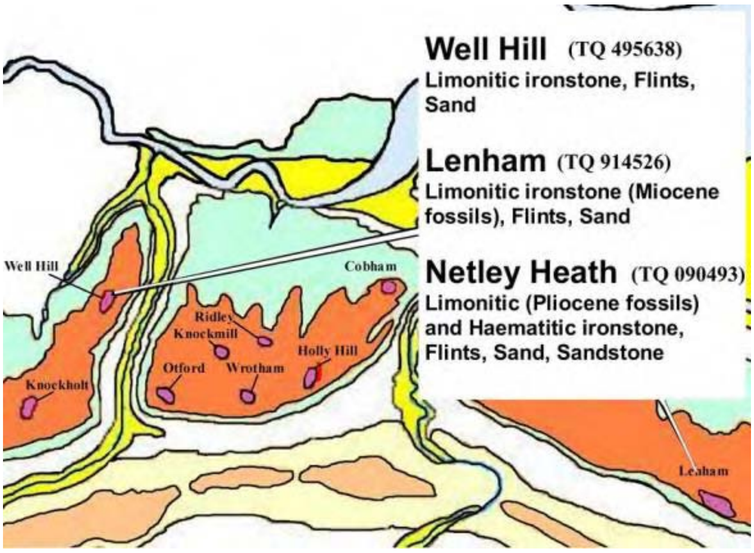
But why does this material end up stuck on the Chalk summit? Well, the first material, when passing across chalk or sand, is passing across a pervious rock and so the water content of the sludge percolates downward through the underlying rock. The invading material would stick to the underlying strata, whereas it would be washed away on clay slopes, and steep hillsides, where it could accumulate as 'valley gravel'.

Given that it is likely that the eroded Lower Chalk and Gault may will have been the first to be eroded, that material will have first chance of being stuck to any bare Chalk surface and survive later erosion. In this respect we can say that the **Clay-With-Flints (sensu stricto) is a Chalk-Gault derivative,** while the **Clay-With-Flints (Sensu lato) is a Chalk, Gault, Lower Greensand derivative**. Moreover the fact that the Lower Greensand would have been eroded from the dome after the Gault and Chalk, it would be sandstone and chert that would be most likely trapped on the Lower Greensand as Chert Drift,

Finally, the brown tint of the Clay-With-Flints indicates oxidization of the clays during transit.

The deposits that deviate in content to a greater degree from Clay-With-Flints are now to be considered. I have chosen the term Plateau Gravels because they largely occupy the highest parts of the downs. The map below shows the main sites that I will consider. Netley Heath is, of course, away to the west, in Surrey.

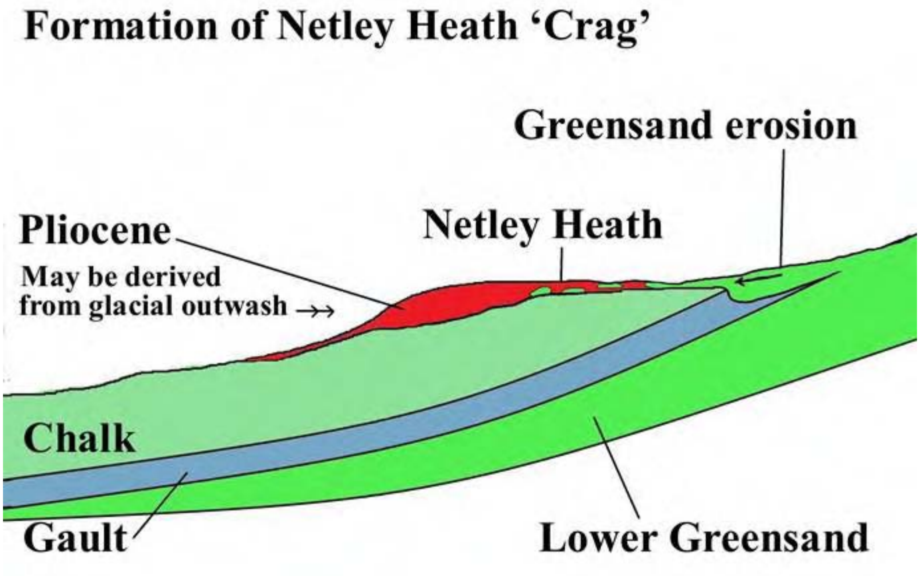


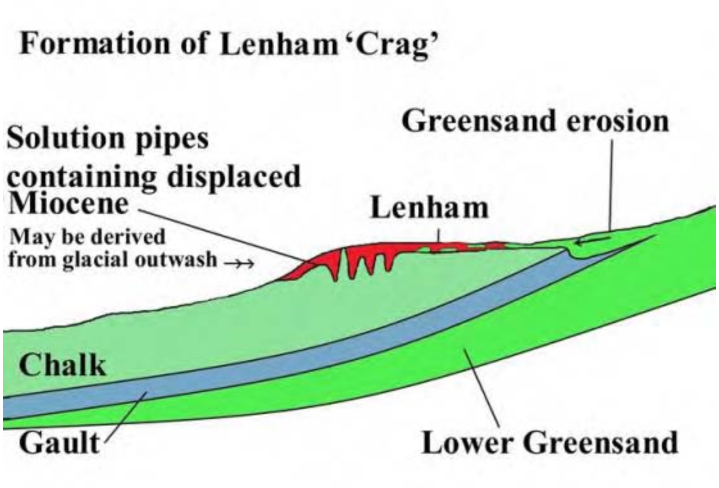


The deposits at Well Hill and Cobham are composed mostly of sand and flints. At both sites there is a small amount of brown, limonitic ironstone, but no fossils. There is, however, a heavy mineral content, similar to that seen at Lenham. At Lenham. The deposits are seen filling solution pipes in the Chalk. Both limonitic and a rarer grey haematitic (Lower Greensand) ironstone can be seen, in a matrix of iron-rich clay and sand (see photo above). The limonitic ironstone contains casts and moulds of Miocene age fossils. Similar material can be seen at Netley Heath. There, the fossils recorded are of Pliocene (Red Crag) age. There is also sandstone derived from the Lower Greensand.

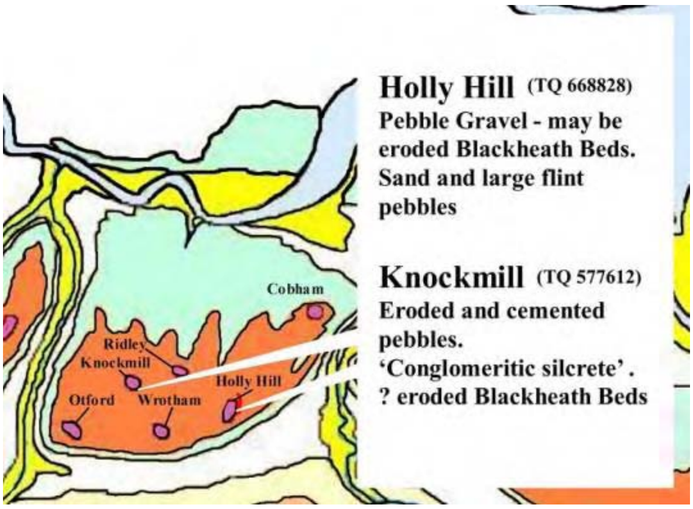
One has to come to the conclusion that the material at both Netley Heath and Lenham has come from two entirely different sources. I mentioned earlier of a marine invasion in the Late Tertiary, which deposited material on the northern edge of the Weald Anticline. By the start of the Pleistocene the area may still have been at low altitude and the material may have been pushed into the Lenham solution pipes from glacial outwash.

Now we must add the contribution of material eroded from the Lower Greensand on the higher slopes to the south. This situation might apply also to Well Hill and Cobham.



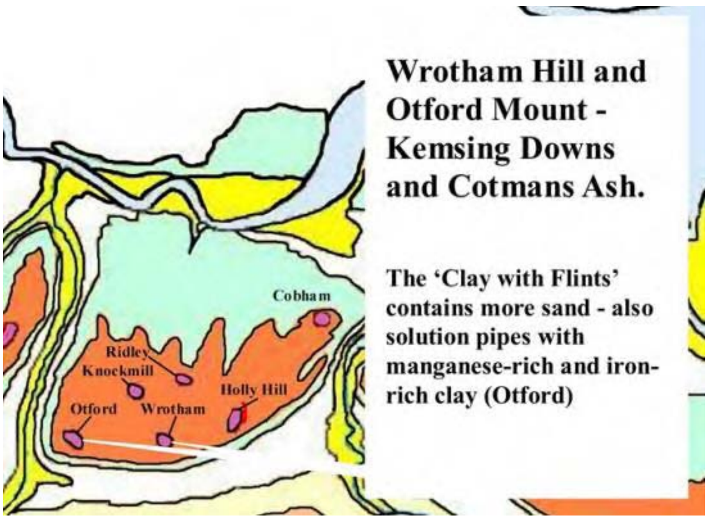


Above we see the emplacement of the Lenham 'Crag' and also two photos of the material filling the solution pipes. Note the heavy iron-rich nature of the material. The iron-stone has yielded an interesting marine, molluscan fauna of about five million years ago

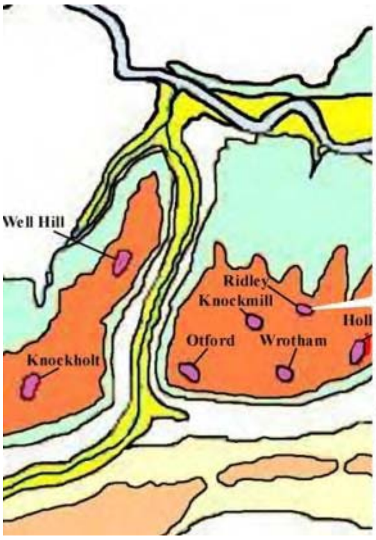


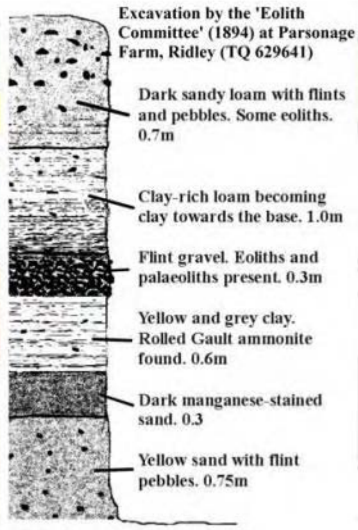
Pebble Gravels

On older geological maps there are areas marked as 'Disturbed Blackheath Beds'. These days many of these are marked as Chelsfield Gravels. Rounded pebbles are a constituent of many drift deposits but I will reference just two sites. Holly Hill and Knockmill. **Holly Hill** is largely of sand and large flint pebbles. The connection with the Blackheath Beds is still made. At the beginning of this text I mentioned the Early Tertiary marine invasions. We can be fairly certain that the London Clay was deposited over a wide area, but we can be less certain regarding the Blackheath Bed. However, the general consensus is that these gravels are eroded Blackheath Beds. The same can be said of **Knockmill**. But this site is strange. Here, the pebbles are cemented into a form of conglomerate, but at the same time the pebbles are corroded (many can be crunched in the hand) while they are re-cemented by the corroded silica, re-crystallised as a micro-quartz. We are dealing with what may be a conglomeritic silcrete. The deposit having been corroded by high-pH water. I will return to this process when we come to Sarsens.



On the high downs around Wrotham and Otford, we are confronted by a different type of mineralogy, infilling solution pipes. On the Kemsing downs there are several solution pipes containing a sandy Clay-with-Flints, together with a black, manganese-rich clay. At the top of the old chalk pit, above Kemsing, a range of clay can be seen, from light yellow, to reddish-brown to black. The last-mentioned being the manganese-rich item. When I first observed these clays in 1961 I mistook the black clay for lignite. The origin of the manganese is not clear, although many of the flints at Lenham are stained with manganese oxide. **Tucker (1981)** mentions manganese as a component in near-shore sediments. A high concentration in the Late Tertiary ironstones is a likelihood, and Tucker also mentions an affinity of manganese to goethite, of which there is an abundance in the said ironstones.





My last port of call in this category is a pit at Ridley, Kent, and involves Benjamin Harrison and his hunt for 'eoliths'. In the 1890s a committee was set up to try and get to the bottom of Harrison's claim that they were very primitive human artefacts. Joseph Prestwich suggested that a patch of gravel at Ridley should be excavated to see if the 'eoliths' occurred in the gravel. Harrisons had collected his specimens only on the ground surface. They did find eoliths in the gravel section. But, in the third bed from the base they found a **rolled Gault ammonite**. Prestwich was dumfounded, but later commented that the Gault must have been eroded from a higher elevation above the Chalk.
(Spencer—1990)

Hillwash

In these photographs the subject is not above the Chalk, but the Lias. None the less, Hillwash is a common 'drift' deposit, often called other names, such as 'Head', 'Slope deposit', 'Solifluxion deposit', formed at the end of a glacial phase, with the melt of the local ice and perma-frost. There is not really a great mystery as to its origin, often containing samples of all the local rocks. In Chalk country, this drift deposit is the only one in which chalk survives, owing to a relatively short distance of travel. In the account thus far, most of the deposits began as 'hillwash'. With 'true' hillwash the origin of the deposit is often without question. However, there are subtle climatic differences in which the deposit can originate.

Lyme Regis, Dorset


Lyme Regis, Dorset

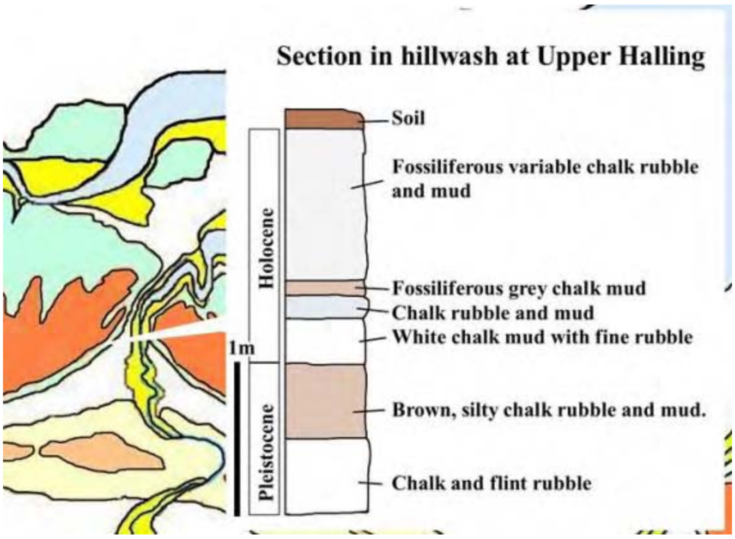
For instance, to the right we are viewing a Chalk pit near Lewes, Sussex. The Chalk is heavily frost-shattered. Wedges of, still-frozen, Chalk had become detached and started to slide down the slope. Their progress was than halted by a further freeze. Note the different composition of the different wedges. Drift deposits on top of the Chalk have become subject to gravitation, as well as the Chalk itself. These solifluxion deposits are a common feature of the terrain to the south of the main glacier, where the process is undisturbed by the disruption of direct glaciation.

In other cases, where there was no hiatus in the thawing process, other structures present themselves.


Lewes, Sussex

Here on the left we see a section at South Stifford. A solifluxion deposit has infilled a gulley in Thanet Sand. The material (flint, chalk and loam) is quite unsorted, so unlikely to be water-laid.

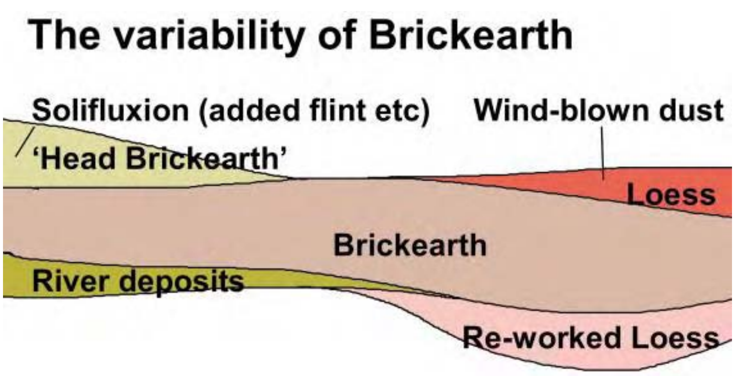
In other instances, the climatic warming has proceeded far enough for the spread of vegetation and the support of a molluscan fauna. The Hillwash is not often fossiliferous, but at Upper Halling (see below) there is a fauna of mollusc and large vertebrates, suggesting a warmer interlude. This was at the very end of the last cold phase, although in places this section is disrupted by frost-heave. So, the warming process was often disrupted. None-the-less, there are ideas that the climatic change could have occurred across a few centuries or even decades!



Here, at Highsted, (see above) near Sittingbourne, a chalk gulley is filled with hillwash. A break in deposition is followed by an accumulation of brickearth and loess. The latter can be seen top-left of the section , and so brickearth and loess is where we must go next.

Brickearth and Loess

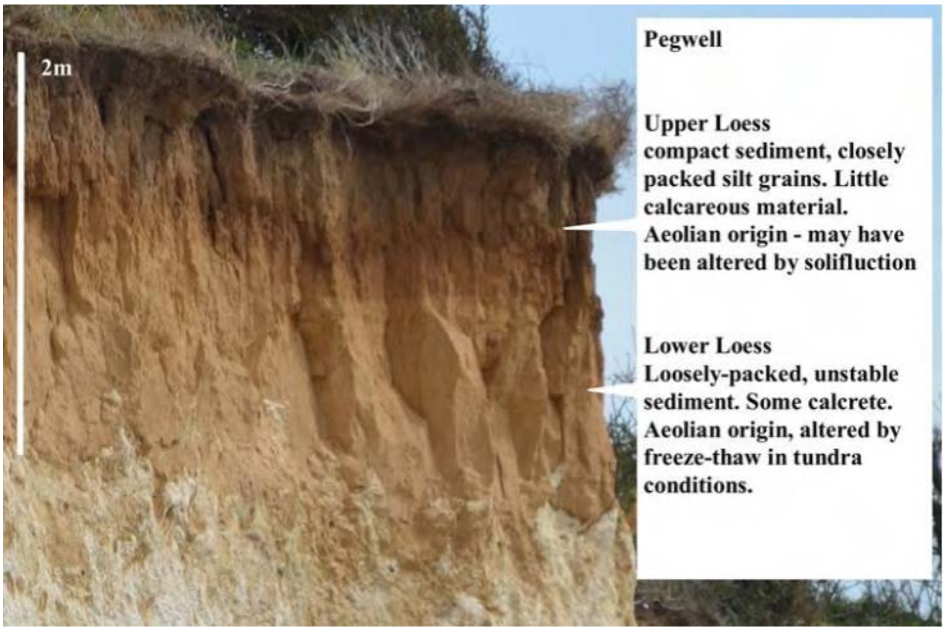
Brickearth has been considered as a semi-'deltaic' deposit forming at lower levels than the Clay-With-Flints or Plateau Gravels. Here at Cliffe (see here to the right) there is a moderate amount of flint, probably introduced by solifluxion or local hillwash. There is a more prominent band of flint in the middle of the section, separating finer loam from the coarser grade below. In the photo below we see a section of typical brickearth near Higham, Kent. The term 'Brickearth' has a wide meaning and the deposit tends to link-in to other categories, for instance, brickearth can trend into loess, as a true



wind-blown deposit, or the brickearth itself can originate as a water-laid loess, or the brickearth can trend into river deposits, while, on the other hand, solifluxion deposits can add ingredients to a matrix of brickearth, giving deposits named as 'Head Brickearth' etc. But there can be problems in these definitions, even industrial, especially when we consider loess.

And if you want to see definite loess here in Kent, then you can do no better than visit this place - Pegwell Bay.

The bay is essentially a syncline between the north fringe of the Wealden anticline and Thanet anticline, so that Thanet Sand overlies the Chalk in the centre of the bay. The loess, in turn, overlies the Thanet Sand. The loess is a fine dust, representing very dry cold conditions. Wind blowing off the ice sheet brought very cold air to the tundra area. Even if the ground was frozen solid, very low dew-points can caused the ice to sublime (direct to vapour). Thus the ground dries out, without going through a wet phase.

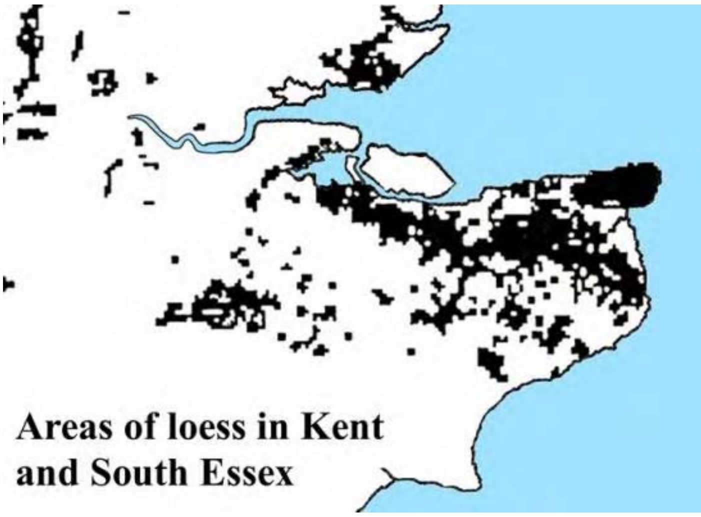


The loess is noted for its polygonal weathering structure, and the cliffs at Pegwell, show two main types of loess.

The first is represented at Pegwell by the upper half of the loess at the very top of the cliff. It is of closely compacted silt grains, little calcareous material and may have been altered by solifluxion.

Below this is the second type—an unstable sediment. Some calcrete. Altered by freeze-thaw in tundra conditions. This second type is very unstable for building or engineering operations.

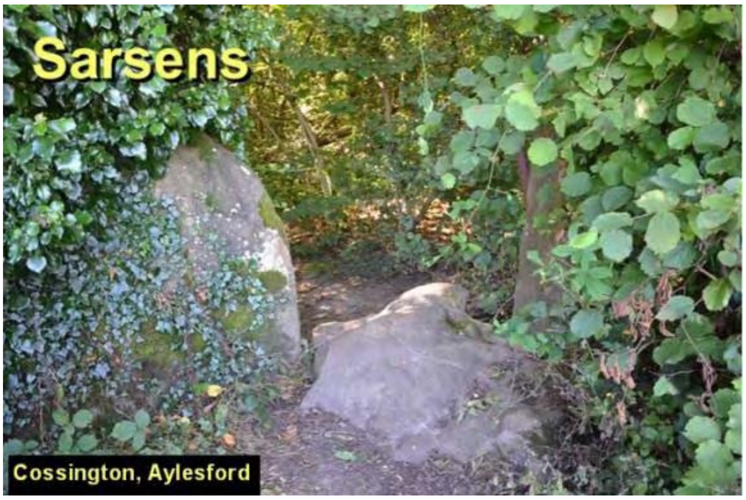
The difference between the two types can only be definitely ascertained by micro examination. This is crucial for area development and large areas of North Kent, formerly surveyed as brickearth, have now been reassessed for their loess content, in many cases the deposits displayed characteristics of typical loess. On the next page is an updated map of the loess outcrop of North Kent.



Note that the loess covers much of the north and east of Kent. Note that this material tends to occupy the lower ground—the valleys of the Medway and Stour can clearly be seen. The relative rarity to the west is curious—may be due to the contemporary position of the ice-sheet.

Sarsens

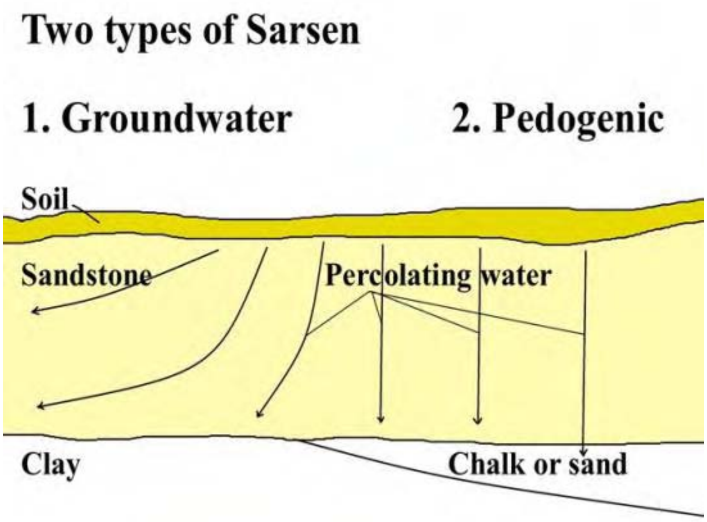
I speak of 'Those Damn Stones' - **Sarsens**. Here in the southeast, Sarsens are often found at the edge of fields, having been dragged off the field by the local farmers! Many of our local megaliths are composed of these boulders of quartzite. I'm thinking of Kits Coty, The Countless Stone, **Coldrum**, etc.

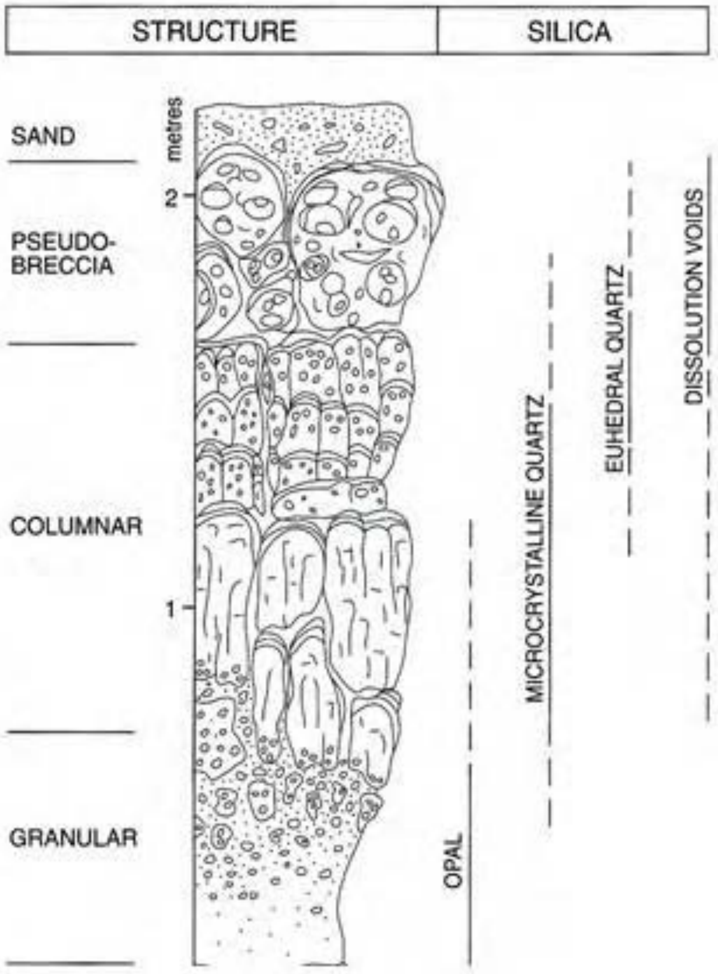


Tony Mitchell has given me some interesting photos of sarsen stones on the Wiltshire Downs. In the above photo we see the sarsens accumulated in a valley bottom, while the photo below shows a sarsen caught in the process of slipping down a slope.

But the photo to the left and those following are the most curious—containing plant rootlets. There is a reference in *The Geology of the country around Dartford* (**Dewey et al 1924**) —referring to 'soft, pale yellow sandstone crowded with fossil leaves and stems' - They were referring to a locality near Eynsford. The surveyors distinguished these from sarsens, but the description seems also a good one for the photos shown here. And then there are two photos showing flints. Whatever the original deposit was, it was laid down on a surface following the erosion of the Chalk. So we are definitely dealing with something that is post-Cretaceous.

With sarsens, we are dealing with silcretes—quartzite type deposits, probably laid down in warm, humid or dry conditions, which have undergone recrystallization. In Kent, sarsens are often associated with Clay-with-Flints, on the downland tops, but also on lower-lying land in the hillwash. In fact, in terms of mode of formation, silcretes are deposits that are resilicified by percolating water. The individual rock grains may be completely dissolved or recemented by silica from the water, and all stages in between. There are two types of silcrete. The **Pedogenic** type, where silica-rich water percolates downwards, through the host rock. There is also the **Groundwater** type, where the water my be flowing horizontally, often due to underlying impervious rock, or where the water table in the underlying rock is raised.



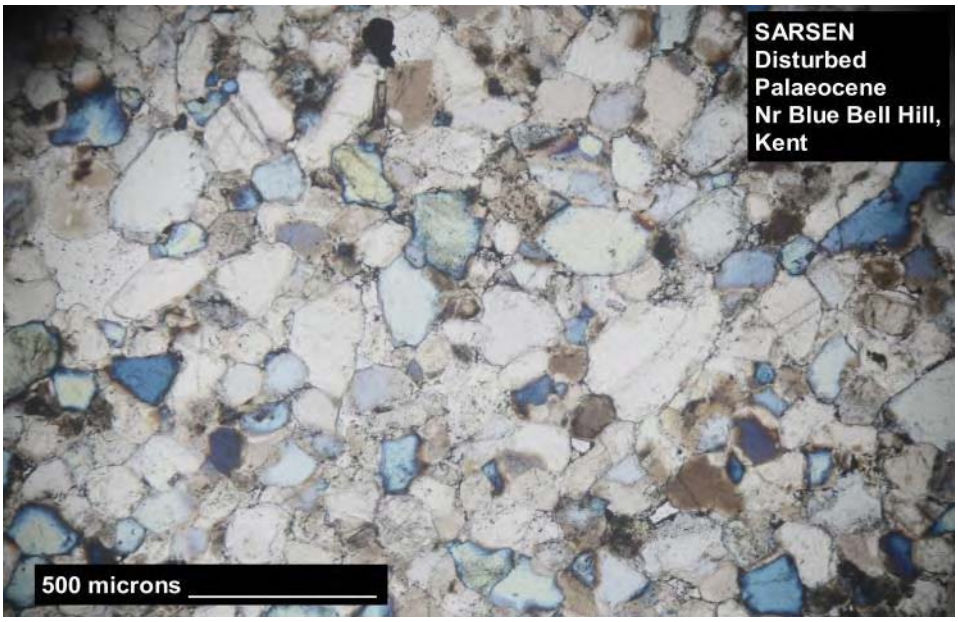


Generalized section showing the consistent facies variations occurring within pedogenic silcrete profiles in the Paris Basin (after Thiry, 1988, 1989).

Where there is a good development of the pedogenic type, a structure can be seen (see diagram to the left). Below the topmost source silicate, there is firstly a layer of pseudo-breccia, followed by a columnar layer, and at base a granular layer. The redeposited silica changes downward from euhedral quartz to microcrystalline quartz and finally opal. There will be overlap in these divisions.

Now, it may well be that the plant rootlets found on the Wiltshire Downs, and near Eynsford, are a sort of fossil seat earth—certainly part of the source rock. What Geological formation is the source rock most likely to have been? Several candidates within the Lower Tertiary have been suggested– Thanet Sand, Bagshot Sand, Barton Sand. In most instances I would favour Thanet Sand, but are not the Wiltshire sarsens too far to the west, unless we have a deltaic deposit of Palaeocene age. This, where lying on Chalk, would help to explain the occurrence of flints within the silcrete. This links us to the first phase of deposition.

The solubility of the silica in the source rock is a result of pH of the percolating water. Silica is not soluble in a pH range of 6-9. In hot, dry climates, water with a pH above 9 will dissolve the silica, while warm and humid climates tend to produce humic acids with pH below 6. Both of these extremes will produce silcretes, but it follows that this can only be detected where there are Pedogenic type formations. Groundwater formations do not supply such information with the same degree of certainty. It remains to be said that the silcrete deposits were broken up, into boulder-form, during the Pleistocene glacial or peri-glacial episodes



I need to make some reference to the micro-structure of this material, but I have only one example from a thin section of a boulder near Blue Bell Hill. (see photo to the left) The first impression is the very uneven nature of the grains in terms of size and angularity—nearly all less than 500 microns diameter. It is not clear how much this was of the original sediment or from the subsequent re-solution. In between the grain, areas of new quartz can be seen, which appears to be mostly microquartz. The rims of some of the grains show new areas of growth. This is typical of silcrete. The blue tone shows quarts grains going into (optical) extinction. Some show undulose (uneven) extinction which would suggest stress in the original eroded strata. Perhaps we are seeing the remnants of a vast deltaic formation, of Palaeocene age, much of which has long since gone.

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