Consequences of a modest loess fall over southern and midland England

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Abstract. Loess deposits that are invariably small are scattered over southern and midland England. They can be examined within a simple, speculative geomorphological model. This allows the concentration of loess material to be predicted and explained, and a distribution network relating to the whole system is produced. A complex series of events in the Weald loess trap causes a concentration of loess material by rivers flowing through various gaps in the Downs. The Thames provides loessic estuarine deposits, and the Pegwell Bay loess was a feature of the Stour. South coast accumulations are related to rivers flowing south through Downs gaps, such as the Adur and the Arun. The geomorphological model assumes a modest loess fall (say 200-500 mm, derived from the northeast) over southern and midland Britain, and develops loess accumulations by logical geomorphological processes from this starting point. Palaeoclimatic studies suggest that interest in the British loess is growing; some overall sedimentological studies might be useful. Loess in Britain should be seen as a major landscape material; it is not an obvious landscape component but it is of fundamental importance. The distribution tree within the geomorphological model accommodates all relevant loess deposits, with major deposits falling on the main line of significant events.

There is more loess material in southern and midland England than is immediately apparent. It has a major effect on landscapes and on economic activity. The soils of the midlands are productive soils largely because of a substantial loess admixture. This addition of fresh Quaternary rock material raises the silt content, and thus improves the texture and the nutrient status. But the presence of the loess is not obvious. We lack the large deposits that are a feature of Asian and American loess regions, and as a result the study of loess has been neglected, or at best disjointed. It should be possible to produce a conceptual model that describes the arrival of some aeolian loess into the region, and its subsequent reworking and re-deposition, to explain the deposits and landscapes that we currently observe. This is attempted in an outline and speculative version in this paper. Besides bringing great advantages to farmers and brick-makers, the loess does cause a few problems. The classic engineering problem is hydroconsolidation and subsidence (Rogers et al, 1994), and there are thicknesses of loess in certain places where this can be a problem. Problems were anticipated at the proposed airport in the northern part of the Thames estuary (classic brickearth country) and this initiated a serious study of the engineering geology of loess in Britain.

Northmore et al (1996), in their study of the loessic brickearth in south Essex, found a thickness of around 8 m - quite impressive loess deposits. Loess of this thickness could contain a palaeosol (or two) and perhaps contribute to Quaternary climatic reconstructions, or it might suffer from hydoconsolidation and subsidence and prove to be a hazard to construction. This is real loess, not just a sprinkling of brickearth, and a widespread unified study is required to give a complete overall picture of

Figure 1. Loess exposed in a shallow brick pit at Ospringe, near Faversham. About 2 m of leached brickearth is worked to make distinctive orange bricks, while 2 m of unleached material is left in place.

this hitherto relatively neglected loess region. In truth, loess has not been neglected in terms of the number of investigations and papers published (see Catt 1977, 1985, 1988), but until now there has been no unifying theme and no conceptual framework for the loess deposits of S E England.

A terminological problem needs to be tackled before progress can be made. We can use the term *loessic brickearth* (as recommended by Smalley, 1987) to refer to the material under investigation. When the Geological Survey mapped S E England in the nineteenth century, they used the local term *brickearth* to describe certain silty, loamy, superficial deposits, many of which now turn out to be loess. Unfortunately the term brickearth is not specific, and it does not fit in with international usage. However these deposits cannot simply now be called loess, because virtually all of the literature relating to them uses brickearth. So a compromise is called for, and the term *loessic brickearth* is used. Defined at length by Smalley (1987), this means deposits which we think are loess, which coincide with deposits called *brickearth* or *head brickearth* by the Geological Survey.

The loess fall considered is associated with the Devensian glaciation. We assume, like Fookes & Best (1969), that the ice sheet of this stage was responsible for the provision of the loess material. We will also assume that loess material was delivered to southern Britain by a loess fall that provided a modest overall cover of about 200-500 mm thickness. This is the starting event for our simple developmental model. The consequences of this modest loess fall might be predicted, and could be compared to the loess landscapes that we observe today. Some of the wider consequences are some thin primary loess deposits (like those on the South Downs which, despite much erosion, still provide farming livelihoods), some loess material added to soils (Catt et al, 1971) in Norfolk, the *Chalk Heath* soils of Perrin (1956), and larger deposits resulting from fluvial transportation and second phase aeolian deposition (Fig. 1). This loess also accounts for a modest brick industry, a few subsidence problems, some good-quality agricultural soil, some confusion because it was locally called brickearth, and some opportunities for British scholars to study loess.

Actually, it may be the case that the loess in southern and midland Britain is of much greater consequence than has been realised to date. It is not a spectacular deposit in any of its manifestations, but it has influenced land-use and a whole way of life since pre-Roman times. It has lacked appreciation and full-scale scientific investigation because it falls into a sort of conceptual and intellectual gap. The geologists were, by and large, dismissive of these loamy surficial deposits and it offered no stratigraphic data for the Quaternary investigators; it did not provide major problems for the engineers; and, in the region around London, much of it had been turned into bricks before scientific interest was kindled. Loess needs to be seen as a major influence on life in an interesting English region, it provides the soils on the chalk (that arrive from above, and not from below), it may provide much of the silt for the Fens and Wash region, and it is involved in some interesting fluvial processes in the Weald and the Hampshire Basin.

Loess in Britain

The loess literature is traditionally large, complex, difficult, written in many languages, and touching on many topics and regions - but it is fascinating in total and it repays study. Woldstedt said that it was *ungeheuer*, which is usually translated as monstrous, but we see it as a rich resource. There is literature on the British loess relating to geology, geomorphology, sedimentology, stratigraphy, archaeology, pedology and more.

It appears that the bulk of the scientific papers and journal contributions about the southeastern brickearths were published in the Proceedings of the Geologists' Association. As it happens, the area of interest demarcated by the Association, ie S E England, is the region where many interesting deposits of loessic brickearth are concentrated (Fig. 2). Some classic papers have appeared in the Proceedings, including Kennard (1944), Palmer & Cooke (1923), Bull (1942) and Burchell (1956), together with many others, including Lill & Smalley (1978).

Two local journals also carried important information - the Essex Naturalist and the South-Eastern Naturalist and Antiquary. They flourished in the golden age of the amateur naturalist and geologist, and much useful material was published in their pages - and subsequently was not appreciated as fully as it should have been. A thorough study of the collected volumes of these two publications would reveal some loessic treasures. Wooldridge (1932) published a classic paper in the

W1	Loam of N E Norfolk, in front of Cromer moraine
W2	Loam plateau of the Tendring Hundred in Essex
W3	Southend loam plateau
W4	Taplow terrace with its brickearth covering (in S W Essex, London and S Middlesex)
W5	Sussex levels
W6	The great Medway brickearth modifying heavy clay (in Medway valley from Tonbridge to Maidstone)
W7	High-level brickearth on Chiltern plateau (particularly at the eastern end in Hertfordshire)
W8	E Kent between Chatham and Thanet
W9	On the Thanet Sands
W10	On the Hythe Beds as far west as Sevenoaks
W11	On the Bargate and associated beds in W Surrey
W12	On parts of Hythe & Sandgate Beds (Rother Valley)

Table 1. Loess regions of England (Wooldridge, 1932).

latter on soil and civilization in S E England and produced what might be the definitive list of loess regions; these are be listed and numbered for reference purposes in Table 1. Wooldridge describes these as 'loamy soil regions' and suggested that they are associated with loess: "Much of the true loam and brickearth, both at high and low levels, compares closely, both in origin and character, with the 'loess' and 'limon' of the continent".

The three key papers in engineering geology are Fookes & Best (1969), Derbyshire & Mellors (1988) and Northmore et al (1996). Engineering interest was much stimulated by a proposal to build another London airport in southern Essex, and this provoked widespread investigations by the Geological Survey, many of which were eventually reported in Northmore et al (1996), a comprehensive and useful paper. A major airport in the Thames estuary would generate renewed interest in the loess/brickearth in the region, but this now seems unlikely. An interesting study has just been completed by Fall (2003) at Portsmouth which indicates the growing level of interest in loess/brickearth. He studied the heavy mineral information and found it to suggest a single distant source for the material, a result that should be compared to the investigations by Eden (1980).

The geomorphological model for loess

This model can operate either as a simple thought experiment or as a detailed GIS system, but it is really the former. It starts with a small, even loess fall covering all of southern and midland England, falling on various slopes and in a range of drainage basins. Post-depositional movement of this loess material can be predicted, as it is carried down slopes and into rivers, and into larger rivers, and on to flood plains, and is then blown inland and soliflucted back again.

Using the old PTD system (Smalley, 1966) we can follow two loess particles. One falls into the catchment of the Arun, in the Weald (Table 2). The other falls into the catchment of the Thames, up near the headwaters (Table 3). The so-called PTD system was simply a way of trying to sort out the significant processes and events that determine the dynamics of the loess deposit formation process. P actions were provenance actions, related to particle formation processes (e.g. glacial grinding); T actions were transport actions; and D actions were those related to deposition. The basic idea has been developed and much improved by Wright (2001).

For initial manipulation we assume that the D1 deposit is an even cover of perhaps 200-500 mm - a modest loess fall; farmers on the South Downs appear to operate with a soil cover of about this thickness, while deep erosion gullies expose the underlying chalk. This D1 deposit provides the silt material that was mapped by Perrin et al (1974), mostly falling into zones I and II (Fig. 2). The sequence of events in Table 2 leads to the formation of the loess deposits on the Sussex coast. The initial assumption of the modest loess fall, with a series of apparently reasonable subsequent events, produces a loess deposit where one is currently observed. Actions in the Weald will be further considered in a

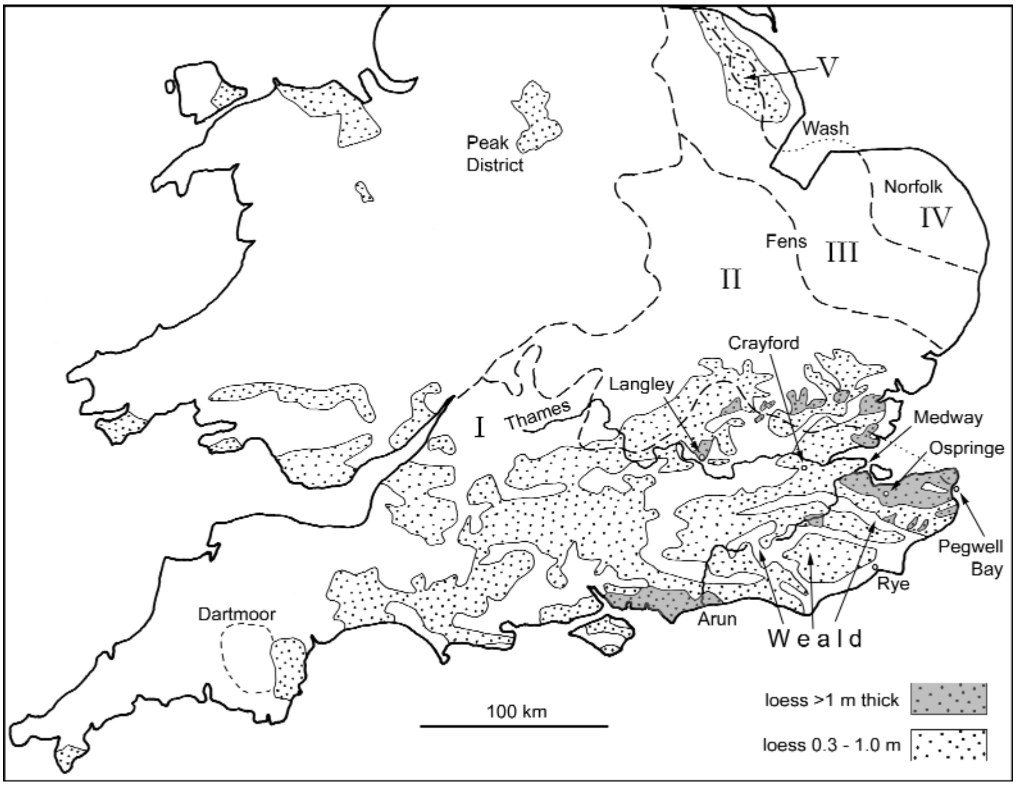

Figure 2. The distribution of loess across midland and southern England. The areas of thin and thick loess are taken from Catt (1988). The provinces of Perrin et al (1974) identify the aeolian deposits that formed away from the Devensian ice sheet; zones I and V have mainly loess, zone III has mainly cover sand, while zones II and IV contain both loess and the cover sand.

later section. The Weald makes a good region to study hypothetical loess activities because it represents an almost closed system, and is surrounded by what appear to be original D1 deposits.

The situation for the loess in the Thames catchment is more complex, and more speculative (Table 3). Its first three stages are the general case, and the same as in Table 2. The Thames might be seen as a classic loess providing river, but the associated deposits are too diffuse and ill-defined for this vision to be really convincing. If the modest loess fall occurred, the Thames has access to loess material in the same style as that of the great loess rivers like the Danube and the Mississippi, and can therefore produce similar downstream deposits. This idea is explored in a later section.

The geomorphological model distributes loess material over the map of southern and midland Britain, and the genetic processes can be outlined by a distribution tree diagram (Fig. 3). This is a simple speculative tree diagram that focuses on the main line of loess deposit development after the original modest fall. Various speculations grow from this distribution network. Loess material deposited in midland England, which avoids the Thames catchment, can be carried to the north and east by streams draining into the Wash, and can provide much of the silt material for that part of England. Loess falling into the Rother catchment can provide silt for the silting up of the port of Rye. Silt has to come from somewhere, and much of it is covered by this geomorhological model.

P1	particles are formed by cold phase glacial action; the actual formation mechanism is not important, all the model needs is a supply of loess material
T1	loess material is blown in a generally southwards (or south-west or even west) direction Hobbsean anti-cyclonic winds (Lill & Smalley, 1978)
D1	deposits over midland and southern England
D1a	material for the southern deposits; silt deposits in the Arun catchment, in the W Weald
T2a	carried into the River Arun by slope wash; small channel fluvial transport
T3a	carried by the River Arun in suspension, out through South Downs gap and into coastal region
D2a	deposited on coastal plain, near to the Arun mouth
T4a	blown into final position
D3a	loess deposit formed; it relates to the W5 deposit of Wooldridge (Table 1), and to part of the Sussex and Dorset coast deposits on the Catt map (Fig. 2)

Table 2. Progress of a loess particle that falls in the Arun catchment in the Weald.

The Thames, Mississippi and Danube

There is a huge difference in scale between the Mississippi-Missouri river system and the Thames, but there are some interesting similarities. The headwaters of both gather in a region associated with glacial cover, and, in each case, glacial sediments can be carried into the mainstream. The Missouri gathers loess material near the Canadian border and transports it south. It flows between Nebraska and Iowa and has provided loess for both states. It carries material further south, joins the Mississippi and delivers large quantities of material for the delta construction and the loess deposits of the lower valley (those described so provocatively by Russell, 1944). The main American loess system depends on the delivery of loess material into the Mississippi drainage basin, and its secondary redistribution by fluvial, and then aeolian means.

The Thames picks up loess material, provided by glacial action, and delivers it to the estuary, where it contributes to loess deposits in south Essex and north Kent. On the Kent side, the Thames material might be seen as augmenting Wealden material that has been collected by the Medway system and delivered into the Swale region (south of Sheppey). Essex and Kent act as small-scale versions of Nebraska and Iowa - the loess-carrying river flows between them, and it contributes loess to both regions, via the ‘all directions’ loess distribution mechanism of variable winds (Handy, 1976). With loess deposits 8 m thick in S Essex (Northmore et al, 1996), we need to allow for more than a tiny amount of material to be delivered into this loess zone.

The Mississippi-Missouri system provides the classic example of the interaction of a great river and a loess region (Smalley, 1972), but another notable example is the Danube (Smalley & Leach, 1978). The Danube is the great loess-transporter of eastern Europe. It picks up material from the Alps, the Carpathians and other mountainous regions in its basin, and supplies it to regions to the east. As it flows into the Black Sea it has delivered material to

P1	particles are formed by cold phase glacial action
T1	loess material is blown generally southwards
D1	deposits over midland and southern England
D1t	deposits in Thames catchment, headwaters region
T2t	carried into River Thames by slope wash and streams. Short transport may deliver it to the Langley silts
T3t	carried by River Thames into estuary region
D2t	deposited on northern bank as a floodplain deposit
T4t	blown inland to form loess
D3t	loess deposit formed, perhaps in S Essex

Table 3. Progress of a loess particle that falls in the headwater part of the Thames catchment.

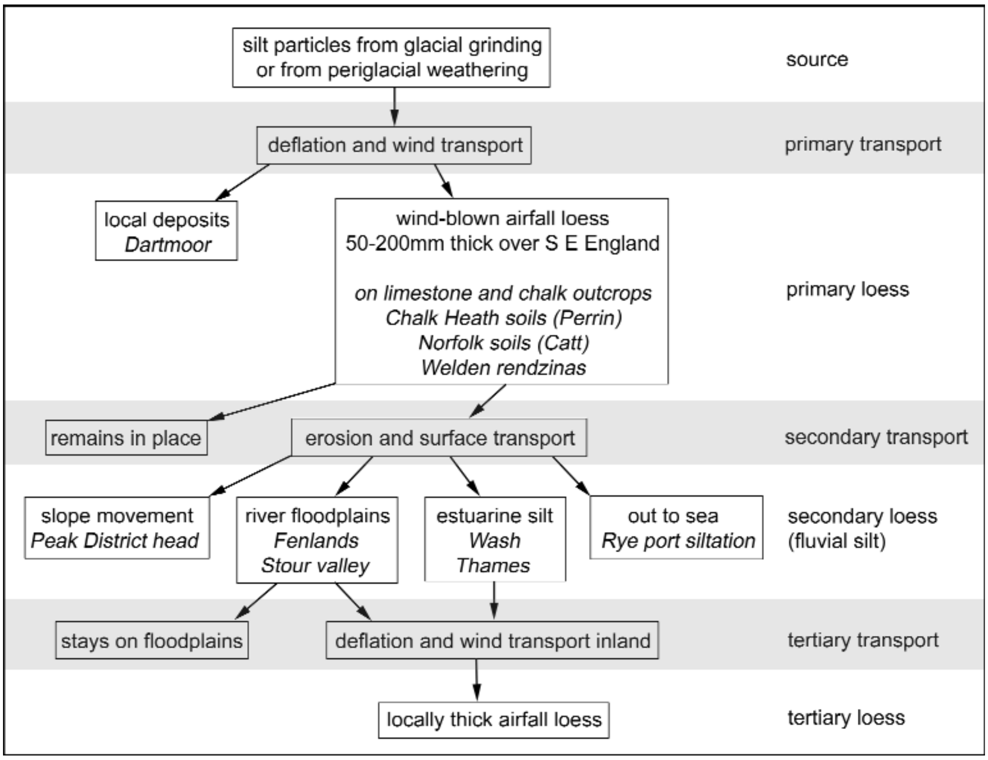

Figure 3. The geomorphological model for the loess of England, presented as a tree diagram that links processes and materials. Selected examples are in italic script.

Bulgaria and Romania, to loess zones north and south of its course. Bulgaria and Romania can serve as larger analogues for Kent and Essex.

It is clear that the Thames fits well into the classification of the world's great loess-carrying rivers; it is on a small scale, but this does not make it any less interesting or significant. If loess material is delivered into a particular catchment, the associated river serves to concentrate the material, to provide major intermediate transportation, and subsequently to lead to a downstream loess deposit. This is true for the Mississippi, the Danube and the Thames, and also for the River Dart, which carries silt from Dartmoor to provide a loess deposit in Torquay.

The Weald as a loess trap

The main line of the distribution network in our genetic model delivers material into the Thames basin. In the same initial modest loess fall, material accumulates in the Weald and on the chalk lands around the Weald. Burrin (1981) offered a study of loess in the Weald, but it had a fairly narrow focus and concentrated on the petrology of some of the southern sediments. The Weald offers a fascinating region for the study of loess deposition, transport and re-deposition. The loess, in its Wealden setting, provides the most interesting and challenging aspect of the study of loess in S E England, and is a good test for the geomorphological model.

The consequences of the initial modest loess fall into the Weald depend on the timing of the event. A fairly recent loess fall would yield widespread deposits of primary loess. A loess fall that occurred more than 10,000 years ago could leave a Weald virtually devoid of loess today but with concentrated deposits placed where fluvial movement had positioned the material for a final short aeolian re-deposition. In this longer-term vision, there should be deposits associated with rivers that flow out from the Wealden region. This is the genesis of the south coast deposits, associated with rivers such as the Adur and the Arun, and the north Kent deposits associated with the Darent and the Medway. The Medway provides a classic case of loess transportation; it dominates the drainage of the Weald and it is no surprise that near the mouth there are major accumulations of loessic material. The Medway augments deposits that might have been formed by the Thames, and provides one of the best known and most commercially viable brickearth regions. Loess falling into the Darent and Cray catchments may also have provided material for the famous Crayford Brickearths (Kennard, 1944; Smalley, 1984).

The Pegwell Bay deposit is the most famous loess deposit in Britain (Fig. 4). Some classic papers refer to it (Pitcher et al, 1954; Weir et al, 1971; Dalrymple, 1969; Fookes & Best, 1969). We perceive it as a Stour deposit, fitting neatly into the geomorphological model. The concentration of material at the coast occurs because the Stour delivers material out of the Weald trap, into Pegwell Bay. Material is blown into position from the seaward side; Shearman (pers.comm.) reported that

Figure 4. Exposure of brickearth at Pegwell Bay, with the darker decalcified horizon overlying the paler unleached material that has the calcite needles bridging between the silt particles.

marine organisms have been observed in the Pegwell Bay deposit. A distinctive feature of the Pegwell Bay loess is the diagenetic variation within its structure (Fig. 5).

The soils of the Weald were described by McRae & Burnham (1975), but, from the loess point of view, the most interesting soils are perhaps just outside the Weald proper. Rendzina soils are indicated on the McRae & Burnham soil map all around the fringe of the Weald. These are classically formed by aeolian deposition of silty material. They are A-C soils where the A horizon sits directly on the chalk C horizon. Perrin (1956) observed the same situation with the Chalk Heath soils of East and West Sussex. These are remnants of the original modest loess fall, and they sit high in the geomorphological model (Fig. 3). In the Weald trap the loess has been extensively moved and redeposited. Burrin (1981) quoted Catt (1978) to the effect that reconnaissance of large areas of the Weald, especially the Weald Clay outcrop, revealed insignificant amounts of loessic material. Within the geomorphological model, most of the initial Weald deposit that arrived at the same time as the rendzinas on the rim would be moved into rivers and carried away, while some was re-deposited, but some was carried into the estuaries and some out to sea.

The rendzina soils on the Weald rim, and the Chalk Heath soils of Perrin play an important role in the study of loess in S E England. Their presence establishes the occurrence of a widespread and significant loess fall, their silty nature is explained by the operation of this modest loess fall. “The commonest rendzinas have a brownish colour and a considerable silt content, attributed to loessial contamination” (McRae & Burnham, 1975). The deposition of the loess on calcareous materials allows a stabilising effect to develop. In the soil classification of Avery (1973), used by McRae and Burnham, the rendzinas are in the lithomorphic soil section, with a topsoil resting directly on bedrock or on a C horizon. In the USDA Soil Taxonomy system, they fit uncomfortably into the mollisol order. The rendzinas are difficult to classify because of their carbonate content (Fig. 5) - which caused problems in early attempts to define loess. Most are the result of airfall material arriving on a rocky substrate. The lack of mineral soil material derived by weathering of pure carbonate rocks leaves airfall loess as the major soil material - accounting for the obvious correlation of loess distribution (Fig. 2) with the outcrops of the Carboniferous limestone and the Chalk. The loess is not a contamination, but is the key ingredient in the formation of these soils.

Crayford and the fossil collectors

In his definitive study of the Crayford brickearths, Kennard (1944) concentrated on the vertebrate and mollusca fossils, and rather neglected the interesting material in which they were embedded. The collectors worked over the Crayford region at the end of the 19th century. Two factors worked together here - a golden age for fossil collectors and amateur geologists, and the widespread exploitation of the N W Kent brickearths to build the London suburbs. When this region was mapped by the Geological Survey in the 1890s some of the pits were already worked out. The underlying strata are shown as visible on some maps because all of the superficial Pleistocene material has been removed.

Upper Brickearth, including the ‘trail’ up to 6m thick
Lower Brickearth (up to 9 m thick)
including the Corbicula Bed (up to 1.5 m thick)
Basal sands and gravels: the ‘Crayford Gravel’ up to 4m

Table 4. The brickearth sequence at Crayford (after Kennard, 1944).

Kennard collected at Crayford between 1892 and 1900, until his attention was diverted by the re-opening of the brickpit at Grays in Essex, the opening of the sections in London Wall and Dierden's Pit at Swanscombe, Kent, as well as excavations for the new reservoirs at Tottenham. Leach (1905) reported a GA excursion to Crayford and Erith and described five new sections; the deposits at Crayford were well described by Whitaker (1889). Chandler and Leach (1912) described another GA excursion, and later Chandler (1914) described the whole Crayford brickearth environment.

Kennard described the Crayford series, with three well-marked divisions (Table 4). The mollusca from the Lower Brickearth were very largely freshwater species with *Sphaerium corneum* and *Psidium ammicum* predominating. The Upper Brickearth has yielded few fossils, but has been the subject of much speculation. It was proposed that the Upper Brickearth was "probably a weathered and decalcified loess" (Bull, 1942) and this is essentially the position that we adopt. But there are questions that need to be asked. Was the Crayford brickearth part of a large spread of brickearth that covered much of the land adjacent to the Thames estuary? Is the deposit essentially a Thames deposit, or is there a significant contribution in the Crayford region from material deposited in the Cray and Darent catchments? Given the modest loess fall, where did the thick Crayford material originate? Comparison with the lower reaches of the Danube suggests that this is a true loess. Arguing by analogy, the Kent loess relates well to the Bulgarian loess. The Thames, like the Danube, is a river with terraces; we might reasonably expect loess on several terraces.

The Langley Silts

West of London's Heathrow Airport, the Langley Silt Complex overlies the Taplow Gravels (as do the Crayford Brickearths). This silt is probably largely primary loess (Fig. 3). It was studied by Rose et al (2000) who suggested that, as it overlies a Last Interglacial (Ipswichian) soil, it could provide evidence for sedimentation and soil formation during parts of the Last Glacial. The material provides new evidence for depositional and periglacial processes that occurred over this period of time in low-relief, valley-floor locations in southern England. The airport site also provides evidence of soil formation during the Devensian Late-glacial, reinforcing existing proposals for the development of an argillic soil horizon during the Late-glacial and Windermere Interstadial. Rose et al (2000) propose that there is indirect evidence for loess formation in the region during the Late-glacial Younger Dryas.

The silts are part of the sedimentary unit defined by Gibbard (1985, p57) as the Langley Silt Complex, which is interpreted as being formed by a

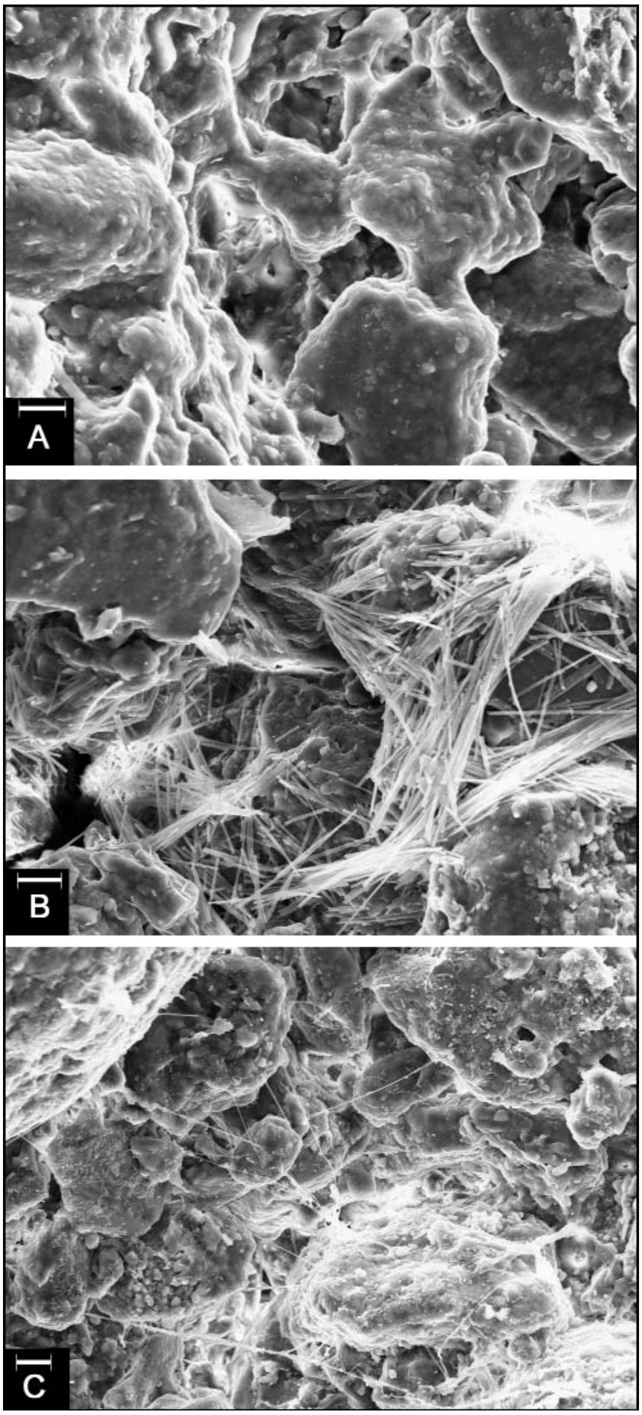

Figure 5. Scanning electron micrsocope (SEM) images of brickearth from Pegwell Bay. On each image the white scale bar is 10 microns long.

A: 6 Brickearth with well-developed clay bridges linking adjacent quartz silt grains. The grains are heavily coated with a gelatinous film of clay similar to, and contiguous with, the clay forming the grain-bridging fabric.

B: 2 Brickearth with needles and fibres of calcite cement forming a coating on clay-coated silt grain surfaces, and bridging pore throats.

C: 4 Brickearth with very fine and delicate fibres of secondary authigenic calcite. These rest on the surface of, and bridge between, clay-coated silt grains on the face of a large void (possibly a root cavity).

variety of processes including direct wind action, slope wash and fluvial reworking. The material has been regarded variously as loess, colluvium and overbank sediment, or mixtures of each (Gibbard et al, 1987). These silts comprise classic brickearth, and are around 2-3 m thick. The location of the Langley silts is north of the Thames, 5-6 km from the river (Fig. 2). The Wey and the Mole, after traversing the North Downs in their respective gaps, join the Thames on either side of the Heathrow site.

How do the Langley silts fit into our model? Here is a relatively substantial brickearth deposit, subjected to wide-ranging and careful investigations. Yet in some ways the Crayford question remains - is it largely aeolian or fluvial? How loessic is it? In terms of particle size distribution it compares well to western European loesses. It looks like primary loess material, within zone 1 of Perrin et al (1974). Its presence and nature will doubtless attract further investigations but it looks as though, in a simple overall sense, it fits our geomorphological model. The silt in the Thames valley, like the silt in the Chalk Heath soils, should be loessic.

Figure 6. Blocky joints distinguish the weakly cohesive brickearth in a sample 600 mm high from the face of the Ospringe brick pit.

Discussion and conclusions

From all the writings on loess in southern Britain, it is possible to assemble a rough overview of a possible deposition scenario. There are enough indications of the observation of loess for it to be fairly obvious that there was a substantial, but fairly thin, cover of loess material delivered in the later phases of the Pleistocene period. The geomorphological model assumes that the development of the deposition environments after the last significant loess fall can account for most of the deposits in S E England. Some material is still in its original position as primary loess (Figure 3); evidence for this is found in the rendzina soils on the Weald rim, and in Perrin's Chalk Heath soils. The thick, substantial deposits on the Catt map (1988) are the result of subsequent sedimentological events.

Interesting events focus on the Weald. It is possible that the Wealden loess operations are unique, that nothing similar is observed elsewhere in the world of loess. The modest British loess deposits may have something unexpected and significant to offer the world of loess scholarship. The idea of the loess trap in which material is initially deposited, to be later moved and re-deposited to form thicker deposits, is a development of most loess deposition scenarios. It has a certain similarity to the proposals for the North China deposits by Smalley and Krinsley (1978). They proposed that the northern deserts acted as loess material reservoirs that supplied material for downwind deposits. The particles did not form in the deserts, they were simply stored there (a conjecture whose validity was subsequently proved by Sun Jimin, 2002). Here we have the Weald as a loess store, but only a short-term loess store, as the material from the modest fall is quickly concentrated by the Wealden rivers and delivered through Weald river gaps to form coastal deposits. The Chinese deserts are part of a dynamic system in which silt material is delivered from mountains to deserts fairly continuously; in the Weald the system is more or less closed and the one-off modest fall has not been repeated. Thus much of the loess has disappeared from the Weald interior (Burrin, 1981) and now forms the Dorset coast deposits and the Pegwell Bay deposits, and perhaps contributes to the North Kent deposits.

There is a benevolent excess of silt in southern and midland Britain, which contributes to the agricultural excellence of the soils. It also provides good bricks and may have affected the concentration of ancient brick buildings in the south-east part of England (Smalley, 1987). In recent geomorphological terms it may have contributed to the nature of the ground in the lowlands near the Wash, and the silting up of Rye Harbour may have happened because of the abundance of silt in the Rother catchment of the Weald: silt must come from somewhere.

Bull (1942) made some interesting observations over sixty years ago - "During the early and middle parts of this last glaciation, brickearths were spread over the country to the south of the ice-sheets. These brickearths have received much attention at Crayford, where they overlie the Taplow gravels. At Crayford the lower brickearth is about 20 feet thick and contains *Elephas primigenius*, *Rhinoceros antiqitatis*, and *Ovibos moschaties* indicative of a cold steppe climate." Bull describes the setting for the primary loess deposition, and he points to Crayford as a significant site. Two years earlier, Bull was involved in what was probably an even more significant observation on the primary loess. Kircaldy and Bull (1940) stated that "A further complication, whose widespread occurrence does not appear to have been previously recognized, is that the whole country is mantled with a sheet of fine grained unstratified brown loam of a loess-like character, which is commonly one to three feet in thickness and occurs at all levels over the area to the north of the Downs." Here is a clear statement about the existence of widespread loess; strange that it did not provoke systematic and widespread study of loess in southern Britain, but it did not. The sixty years since Kirkaldy and Bull have yielded all sorts of isolated studies, some of great scholastic and scientific virtue, but providing no overall sedimentological and geomorphological picture of the formation and reformation of the main parts of the British loess. The geomorphological model is an initial step towards providing a framework for study; all loesses should have a position on the tree diagram (Fig. 3), and the mainline of the tree leads to the major deposits, those marked solidly on the Catt map of 1977.

Using the Langley silts, Rose et al (2000) contrived a reconstruction of climate and environmental change in southern Britain from the Last Interglacial (Ipswichian or Eemian, Oxygen Isotope Stage OIS 5e, 132-123 ka BP) through to Holocene (OIS 1, 11.5 ka BP to present). By using the brickearths rather than successions in river sediments a considerable step forward in Quaternary palaeoclimatology and sedimentology has been achieved, and the Rose et al paper represents significant progress in loess research in southern Britain. It is a matter of regret that the Crayford Brickearths, which could have yielded similar data, are lost under a collection of playing fields and housing estates. Those with a responsibility to the geology in southern and midland England need to encourage the location and preservation of major sites with brickearth and loess - now that their potential has been realised, sixty years after Kirkaldy and Bull (1940). As the palaeoclimatic significance begins to be appreciated, there is now a need for an overall sedimentological model to provide a framework for further studies.

References

Avery, B.W., 1973. Soil classification in the Soil Survey of England. *Journ. Soil Sci.* **24**, 324-338.

Bull, A.J., 1942. Pleistocene chronology. *Proc. Geol. Assoc.* **53**, 1-45.

Burchell, J.P.T., 1954. Loessic deposits in the fifty-foot terrace post-dating the Main Combe Rock of Bakers Hole, Northfleet, Kent. *Proc. Geol. Assoc* **65**, 256-261.

Burrin, P.J., 1981. Loess in the Weald. *Proc. Geol. Assoc.* **92**, 87-92.

Catt, J.A., 1977. Loess and coversands. In Shotton, F.W. (ed) *British Quaternary Studies, Recent Advances*. Clarendon Press: Oxford, 221-229.

Catt, J.A., 1988. Soils and Quaternary stratigraphy in the United Kingdom. In Boardman, J.W.(ed), *Quaternary Geology for Scientists and Engineers*. Ellis Horwood: Chichester, 161-178.

Catt, J.A., Corbett, W.M., Hodge, C.A., Madgett, P.A., Tatler, W. and Weir, A.H., 1971. Loess in the soils of north Norfolk. *Journ. Soil Sci.* **22**, 444-452.

Chandler, R.H., 1914. The Pleistocene deposits of Crayford. *Proc. Geol. Assoc.* **25**, 61-71.

Chandler, R.H. & Leach, A.L., 1912. Report of an excursion to the Pleistocene river drifts near Erith. *Proc. Geol. Assoc.* **23**, 183-190.

Dalrymple, J.B. 1969. Une region typique d'Angleterre: l'Ile de Thanet. In *La Stratigraphie des loess d'Europe. Bull. Assoc. France Etude Quat.* Suppl. 13-16.

Derbyshire, E. & Mellors, T.W., 1988. Geological and geotechnical characteristics of some loess and loessic soils from China and Britain: a comparison. *Eng. Geol.* **25**, 135-175.

Eden, D.E., 1980. The loess of N E Essex. *Boreas* **9**, 165-177.

Fall, D.A., 2003. *The geotechnical and geochemical characterization of the brickearth of southern England*. Ph.D. thesis, Portsmouth University.

Fookes, P.G. & Best, R., 1969. Consolidation characteristics of some late Pleistocene periglacial metastable soils of east Kent. *Quart. Journ. Eng. Geol.* **2**, 103-128.

Gibbard, P.L., 1985. *The Pleistocene History of the Middle Thames Valley*. Cambridge University Press, 155p.

Gibbard, P.L. , Wintle, A.G. & Catt, J.A., 1987. Age and origin of clayey silt 'brickearth' in west London, England. *Journ. Quat. Sci.* **2**, 2-9.

Handy, R.L., 1976. Loess distribution by variable winds. *Geol. Soc. Amer. Bull.* **87**, 915-927.

Kennard, A.S., 1944. The Crayford brickearths. *Proc. Geol. Assoc.* **55**, 121-167.

Kirkaldy, J.F. & Bull, A.J., 1940. The geomorphology of the rivers of the southern Weald. *Proc. Geol. Assoc.* **51**, 115-150.

Leach, A.L., 1905. Excursion to Erith and Crayford. *Proc. Geol. Assoc.* **19**, 137-141.

Lill, G.O. & Smalley, I.J., 1978. Distribution of loess in Britain. *Proc. Geol. Assoc.* **89**, 57-65.

McRae, S.G. & Burnham, C.P., 1975. The soils of the Weald. *Proc. Geol. Assoc.* **86**, 593-610.

Northmore, K.J., Bell, F.G. & Culshaw, M.G., 1996. The engineering properties and behaviour of the brickearth of south Essex. *Quart. Journ. Eng. Geol.* 29, 147-161.

Palmer, L.S. & Cooke, J.H., 1923. The Pleistocene deposits of the Portsmouth district and their relation to man. *Proc. Geol. Assoc.* **34**, 253-282.

Perrin, R.M.S., 1956. Nature of 'Chalk Heath' soils. *Nature* **178**, 31-32.

Perrin, R.M.S., Davies, H. & Fysh, M.D., 1974. Distribution of late Pleistocene aeolian deposits in eastern and southern England. *Nature* **248**, 320-324.

Pitcher, W.S., Shearman, D.J. & Pugh, D.C., 1954. The loess of Pegwell Bay, Kent, and its associated frost soils. *Geol. Mag.* **91**. 308-314.

Rose, J., Lee, J.A., Kemp, R.A. & Harding, P.A., 2000. Palaeoclimate, sedimentation and soil development during the Last Glacial Stage (Devensian), Heathrow Airport, London, UK. *Quat. Sci. Rev.* **19**, 827-847.

Russell, R.J., 1944. Lower Mississippi Valley loess. *Geol. Soc. Amer. Bull.* **55**, 1-40.

Smalley, I.J., 1966. The properties of glacial loess and the formation of loess deposits. *Journ. Sed. Petrol.* **36**, 669-676.

Smalley, I.J., 1972. The interaction of great rivers and large deposits of primary loess. *Trans. N.Y. Acad. Sci.* **34**, 534-542.

Smalley, I.J., 1984. The Crayford brickearths and other loess materials in the Thames valley. *Loess Letter* 12, 34-39.
Smalley, I.J., 1987. The nature of 'brickearth' and the location of early brick buildings in Britain. *Brit. Brick Soc. Info*. 41, 4-11.
Smalley, I.J. & Krinsley, D.H., 1978. Loess deposits associated with deserts. *Catena* **5**, 53-66.
Smalley, I.J. & Leach, J.A., 1978. The origin and distribution of loess in the Danube basin and associated regions of East-Central Europe - a review. *Sed. Geol*. **21**, 1-26.
Sun Jimin, 2002. Provenance of loess materials and formation of loess deposits on the Chinese loess plateau. *Earth Planet Sci. Letters* **203**, 845-849.
Weir, A.H., Catt, J.A. & Madgett, P.A., 1971. Postglacial soil formation in the loess of Pegwell Bay, Kent (England). *Geoderma* **5**, 131-149.
Whitaker, W., 1889. The geology of London. *Mem. Geol. Surv*. **1**, 328-478.
Wooldridge, S.W., 1932. Soil and civilization in south east England. *South East Nat. & Antiq*. **37**, 56-58.
Wright, J. S., 2001. 'Desert' loess versus 'glacial' loess: quartz silt formation, source areas and sediment pathways in the formation of loess deposits. *Geomorphology* **36**, 231-256.

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