Read at the Annual Conference of the Ussher Society, January 1997

THE DEVELOPMENT OF LOESS-BEARING SOIL PROFILES ON PERMIAN BRECCIAS IN TORBAY

A.C.CATTELL

Cattell, A.C. 1997 The development of loess-bearing soil profiles on Permian breccias in Torbay. *Proceedings of the Ussher Society,* **9,** 168-172.

A layer of wind-blown silt (loess) up to 1.5 m thick is present over much of the Permian breccia outcrop in Torbay, buried beneath 1.0 to 2.0 m of younger sandy silts. Where undisturbed, the loess layer consists of light yellow coarse silt, contrasting with the red sandy and gravelly breccia-derived soils. Local redeposition and mixing with breccia-derived material has occurred, producing red-orange and yellow-brown soils whose grading curves record their mixed origin.
The loess layer provides a useful marker horizon, separating the transported soils above from predominantly residual soils below. The loess layer and overlying transported soils are poorly consolidated and foundation problems are common wherever the loess is encountered.

A.C.Cattell, Rodney Broom Associates, 15 Courtenay Park, Newton Abbot, Devon, TQ12 2HD

INTRODUCTION

Silty drift deposits are distributed widely over southern England. They are interpreted as the remnants of thin widespread loess deposited towards the end of the last glacial period (Cart, 1985). The wind-blown material is predominantly coarse silt, although the drifts often contain coarser admixed material derived from the local bedrock.

The presence of silty drifts in south and east Devon was noted by Harrod *et al.* (1973), who showed that the deposits were mineralogically uniform and concluded that they represent a single episode of loess deposition. The deposits occur widely on the East Devon Plateau, and also on the small plateaux developed on the Devonian limestones around Torbay, where they are best preserved in dry valley floors and depressions (Harrod *et al.,* 1973). On the limestone plateaux, the silty drifts form part of the Ipplepen and Nordrach Series of the Soil Survey (Clayden, 1971).

The subsoils of the Torbay area are described by Doornkamp *et al.* (1988). A more detailed description of possible loess deposits in the area is given by Griffiths and Lee (1989). High silt contents (>50%) were found in soils developed on Devonian limestones and colluvium on Devonian mudrocks, and taken to indicate a significant loess input into these soils. In contrast, Griffiths and Lee (1989) found low (<35%) silt contents in soils developed on the outcrop of Permian breccias, and concluded that any loess deposited had subsequently been eroded away. This finding was in accord with the earlier observation of Harrod *et al.* (1973) that the Permo-Triassic outcrop in Devon is devoid of silty drift (with the exception of sporadic patches on the Budleigh Salterton Pebble Beds).

The results of site investigations within the Permian breccia outcrop in Torbay are presented here. These show that the loess deposits and soils derived from them are widespread.

TERMINOLOGY

The subject matter of this paper overlaps several disciplines, and some technical terms have slightly different meanings in each. Descriptive terms in this contribution are based on West (1991). Silt refers to particles in the size range 0.002 to 0.06 mm, subdivided into fine- (0.002 to 0.006 mm), medium- (0.006 to 0.02 mm) and coarse- (0.02 to 0.06 mm). Most of the soils described below are predominantly mixtures of silt and sand. Soils with < 35% silt are referred to as silty sands, those with 35 to 65% silt are sandy silts, and those with > 65% silt are referred to as silts.

SOIL PROFILES

Soil profiles at approximately 70 sites on the Permian breccia outcrop around Torbay have been investigated (Figure 1). At most sites a twofold division of the subsoil profile is, with some difficulty, recognisable. The upper unit consists of medium red sandy silts with a variable gravel content, which are usually over 1.0 m thick, and can reach 3.0 m or more. These overlie dark red silty sands and sandy gravels, which can also be several metres thick (profile 1: Figure 2).

The upper unit is usually monotonous and structureless, and shows little or no variation with depth. There is some variation in the material between sites, particularly in the percentage of gravel present, but the unit is always poorly sorted. Despite being the most abundant clast type in the underlying breccias, limestone is not represented in the gravel fraction of the upper unit.

The silty sands and sandy gravels of the lower unit commonly show well-developed layering in the form of grain size variations. These variations appear to reflect original variations in the bedrock, suggesting that the lower unit consists of residual soil developed by dissolution of cement from the parent sandstone or breccia. However, limestone fragments are again absent, indicating dissolution during weathering. The dissolution of limestone clasts is recorded at some sites where fragile pebble rims survive, protected from dissolution by impregnation with silica.

At approximately one quarter of the sites investigated, a third soil unit is present between the upper and lower. Recognition of the intervening unit is difficult at many sites as it is only distinguishable in the field by its slightly less pronounced red colouration. The difficulty in distinguishing the layer should be borne in mind when assessing descriptions of soil profiles in the area, since it is probably often missed. However, at several sites the middle unit is orange or light yellow, and contrasts strongly with the strong red colours of soils above and below. Where grain size distributions have been determined the middle unit is always more silt-rich than the units above and below.

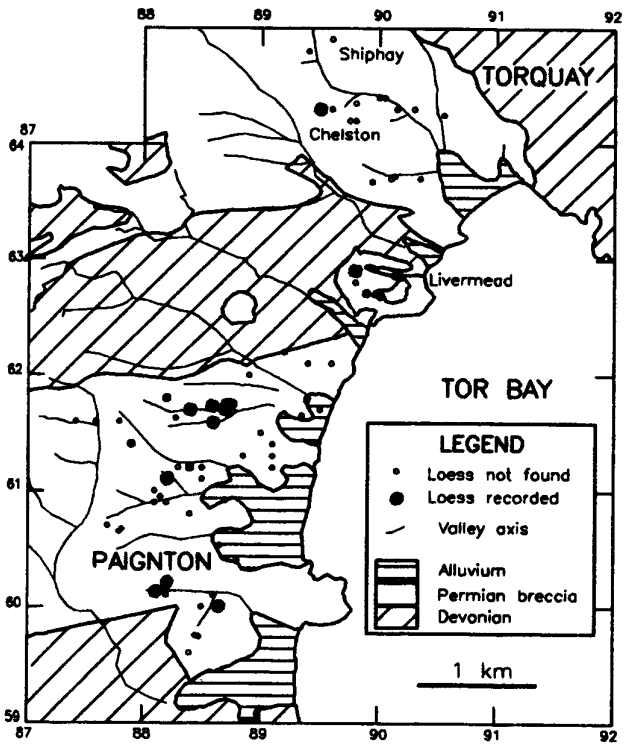

Figure 1. Distribution of loess-derived soils on the outcrop of Permian breccias in Torbay.

The silt-rich unit is always found at the same level, buried beneath at least 1.0 m of the upper sandy silt, and resting on a variable thickness of the lower silty sands and gravels. At its simplest, the middle unit consists of a single layer of silt-rich soil, but at some locations the unit can be subdivided into an upper medium brown or reddish brown moderately silty layer, overlying a light yellow very silty layer. The basal part of the very silty layer is locally gravel-rich. Where simple, the middle unit is 0.7 m thick or less, but the where complex it may reach 1.5 m or more.

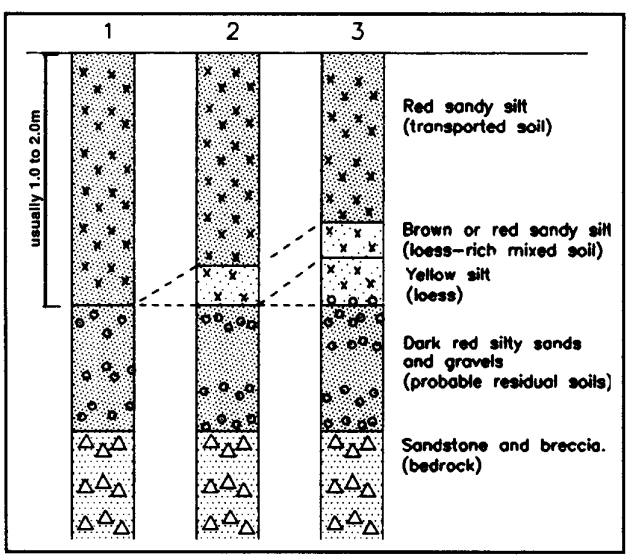

Figure 2. Soil profiles developed on Permian breccias in Torbay. Profile 1 is the most common, whilst profiles 2 and 3 occur at close to 25% of sites investigated. The thicknesses of all layers are variable, and the total thickness may exceed 4 m.

CHARACTERISTICS OF THE YELLOW SILT LAYER

Standard analysis by sieve and hydrometer shows that the light yellow soils contain up to 70% silt-sized particles, and that the coarse silt fraction alone makes up to 35%. These high silt contents distinguish the light yellow soils from the red soils above and below, which contain less than 50% silt and less than 20% coarse silt (Figure 3a). Clay contents in the yellow soils are about 15%, giving a total fines content (clay + silt) of 80 to 85%. A small gravel fraction is present in most samples. Despite their high fines contents, the light yellow soils all have low plasticity with liquid limits in the range 25 to 35% - which are indistinguishable from those of the sandier breccia-derived soils. The calculated activities (= plasticity index / % clay) of the yellow soils are around 1.0, consistent with the main clay mineral present being illite.

The gravel fraction consists primarily of hard well-cemented (Devonian?) sandstones and vein quartz; limestone clasts are not present. The sand consists mostly of quartz with minor feldspar. The fine fraction consists of quartz with subordinate feldspar (both K-feldspar and plagioclase), illite and chlorite.

ORIGIN OF THE YELLOW SILT LAYER

The yellow silt is developed at sites where both the underlying bedrock, and the bedrock upslope from the site, is Permian Breccia. The only local source of material to produce the observed soil profiles is therefore the breccia. Weathering of the breccias produces residual soils: the red silty sands and gravels found beneath the yellow silt. These soils have particle size distributions which are similar to the breccias, with the exception of loss of limestone gravel-sized and coarser material through dissolution. The yellow silt has a significantly greater silt content (particularly coarse silt), than the underlying residual soils, and cannot be derived from them by simple mechanical reworking and chemical reduction.

Silt-rich soils are generated by weathering of Permian breccias, where the breccias contain a significant proportion of clasts of Devonian slates. The silt is generated through breakdown of the slate clasts to their component silt- and clay- sized particles. Examples of such silty soils are common on the various slate-rich breccias in the region, for example on the Watcombe Breccia in Torquay, on parts of the Teignmouth Breccia around Teignmouth, and on the Alphington Breccia (= Alphington Member) in the Exeter area. However, in all these examples, the generation of silt is accompanied by the generation of clay, leading to soils with medium to high plasticity. The plastic soils developed on the slate breccias contrast sharply with the low plasticity red and yellow soils developed on slate-poor Oddicombe Breccia in Torbay (Figure 4). The diagram shows that the high silt contents of the yellow silts do not result from breakdown of any slate debris in the underlying breccia. Since the silt is not derived from the breccia, it follows that the yellow silt contains a significant proportion of "exotic" material.

The grading curves of the yellow silts are very similar to those of the "silty drifts" found on the East Devon Plateau and on the limestone plateaux to the west of Torbay (Figure 3b). Harrod *et al.* (1973) considered that these soils were composed mainly of loess, albeit with a small percentage of coarse material derived from the underlying bedrock. Not only are the grading curves similar, but also the mineralogy of the yellow silt is similar to that of the silty drifts. Preliminary X-ray diffraction data show that the yellow silt contains chlorite (and illite [or muscovite]) with little if any kaolinite, whilst the underlying breccia contains kaolinite and illite with little if any chlorite. Harrod *et al.* (1973) noted chlorite and illite (muscovite) but not kaolinite in the silty drifts.

It is concluded from its grain size distribution, its low plasticity, and its mineralogy that the yellow silt layer in Torbay is also composed primarily of loess, although with a small fraction of locally derived material which contributes the coarser tail to the particle size distribution curve. The similarities suggest that the yellow silt in Torbay is part of the same deposit(s) as the silty drifts recorded over

southern England. The material does not have the carbonate cement typical of most true loess, but as noted above both the overlying and underlying layers also show evidence for loss of carbonate, and the loess-derived silty drift deposits over most of southern England are also decalcified (Catt, 1985). There is no direct evidence for the age of the layer, but by comparison with similar deposits elsewhere it is assumed that the yellow silt was deposited at the end of the last glacial episode (Catt, 1985; Griffiths and Lee, 1989).

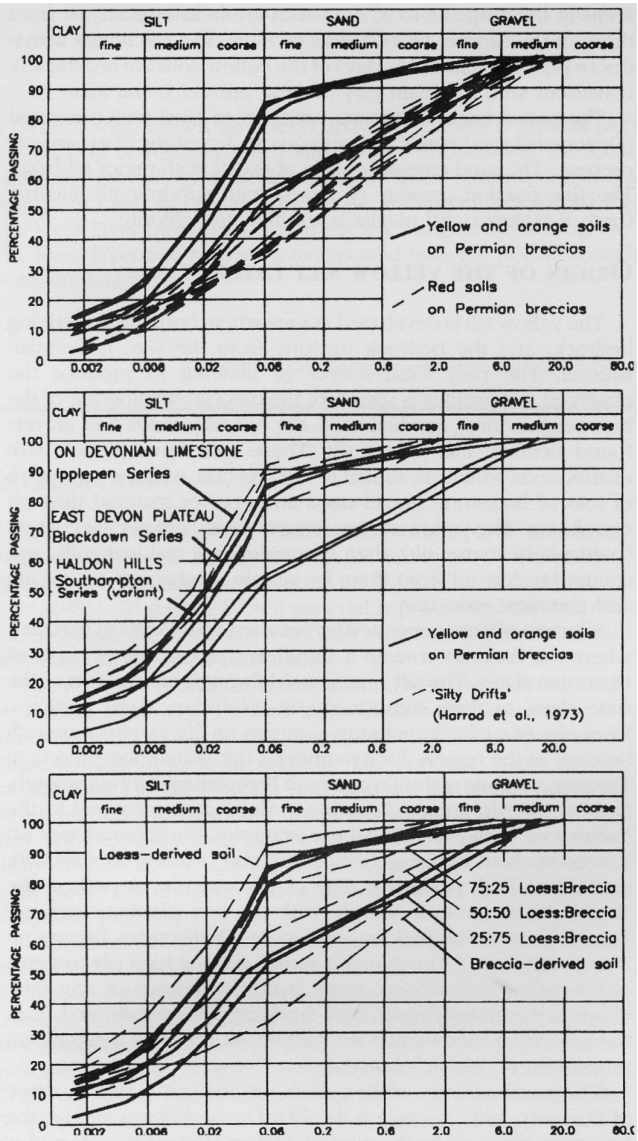

Figure 3 . Particle size distributions: a) Soils developed on Permian breccias in Torbay. b) Yellow and orange silt-rich soils compared with the Silty Drifts described by Harrod et al. (1973). c) Yellow and orange soil silt-rich soils compared with calculated mixtures of loess-derived and breccia-derived material.

DISTRIBUTION

If the interpretation of the yellow silt as a loess is correct, then a roughly equal mass of loess per unit area would have been deposited over the relatively small outcrop area of the Permian breccias around Torbay. This is not the same as saying that a uniform blanket of loess was ever present, since erosion may have been occuring during the period of loess deposition. The present-day distribution reflects the survival of the layer rather than its deposition. The layer would be readily eroded and its survival depends on its being buried beneath coarser breccia-derived soils. The sites where survival of the loess is likely are therefore sites of accumulation of material, where supply of material from upslope outpaces erosion.

The yellow silt occurs widely but sporadically over the Permian outcrop at Paignton, and also in the Livermead and Chelston-Shiphay areas of Torquay. It is most often found along the edges of shallow dry valleys or coombes, which are common in Paignton (e.g. at [SX 888 608], and [SX 881 601]). Less common is preservation in hollows or dry stream valleys on the upper slopes of the coombes (e.g. at [SX 898 627] and [SX 895 643]). These hollows are usually partially infilled so the soil thickness is greater than on the surrounding hillside. Yellow silts have not been found on open hillsides, on ridge crests, or on the relatively flat outcrop of breccia along the coastal strip at Paignton, seaward of the break in slope recognised by Doornkamp *et al*. (1988). The presence of the yellow silt has also not been recorded in boreholes penetrating the alluvial silts and clays behind Paignton seafront.

The most extensive area of yellow silt yet proved is along the shallow dry valley to the north of Oldway Mansion, centred on grid reference [SX 887 617]. Here the layer has been proved in all holes at sites over an area of some 400 m by 150 m, and it may well be more extensive than this. Although it is possible that there has been some reworking of the material, the topography of both the base and top of the layer clearly show it to be a blanket deposit and not alluvial infill of the valley floor. The edges of the deposit wedge out rapidly, and nowhere does the layer extend far up the valley sides. Away from edges of the valley the thickness of the yellow silt is relatively constant at approximately 0.6 to 0.7 m, suggesting that this may approximate to the original thickness of the layer. It is somewhat thicker close to the break in slope at the edges of the valley, where the in-situ deposit is overlain by loess-derived material washed down from the steeper slope above.

REDISTRIBUTION OF LOESS

If the equivalent of a 0.6 to 0.7 m thick layer of loess was deposited over the entire breccia outcrop, and the layer is now only preserved over perhaps one-quarter of the area, then a considerable volume of silt-rich material must have been eroded away since the end of the last glacial episode. Much material will have been transported out to sea, and some will have contributed to the alluvial silts deposited in the lower reaches of the stream valleys and in the coastal embayments around Tor Bay. However, it is also possible that a significant proportion of the loess-derived silt has been incorporated into the sandier soils that overlie the yellow silt and indeed cover almost all the Permian outcrop.

Griffiths and Lee (1989) noted the low silt contents (18 to 37%) of the soils they had tested from the Permian outcrop compared with soils developed on other bedrock types in Torbay (Figure 5). They concluded that the relatively low silt contents indicated extensive erosion over the Permian outcrop through Late Devensian solifluction and later Holocene fluvial and colluvial activity, and by implication that loess-derived silt did not contribute to the soils developed on the breccias, whereas it did contribute to siltier soils on other rock types. The argument used by Griffiths and Lee is however unsound. Weathering of the Permian breccias leads to soils with 25% silt or less, whereas weathering of other rock types in the area, such as Devonian mudrocks, produces soils with silt contents as high as 55%. A soil with 35% silt developed on Permian breccia is likely to contain some loess-derived silt, whilst a soil with 45% silt developed on Devonian mudrock may not. The absolute abundance of silt is not important, it is the silt content of the soil relative to that produced by weathering of the bedrock that is the key, together with the relative abundance of coarse silt relative to other fractions.

The presence of a significant proportion of loess-derived material

ought to be indicated by an anomalously high proportion of silt, and particularly of coarse silt, in the red sandy silts. At first glance the particle size distributions of these soils do not seem to show this effect (Figure 3a). However, assessment of particle size distributions by eye is often misleading as significant variations in grain size do not produce immediately obvious differences on the log-normal cumulative frequency diagrams which are traditionally used to display them. In Figure 3c the effect of mixing increasing proportions of loess-derived material with breccia-derived material is illustrated (the loess curve is the mean of Harrod *et al.'s* (1973) results for Nordrach and Ipplepen Series silts, and the breccia curve is the mean of breccia-derived residual soils from beneath the loess layer). Addition of up to 50% loess-derived material produces only a subdued hump on the breccia-derived grading curve but beyond 50% the effect is more obvious and the grading curve has a pronounced S shape (Figure 3c). The upper red sandy silts all have more coarse silt than the residual soils from beneath the loess (14 to 20% compared with 11%). The grading curves of the upper red soils approximate to breccia-derived material containing 10 to 40% loess-derived component. The only mismatch is at the clay end of the curve; the upper soils not only have less clay than the hypothetical mixed soils, but also less clay than either the breccia-derived residual soil or the yellow silt. Some washing out and removal of the clay fraction must have occurred during the erosion, transport and redeposition of the material which now forms the upper red sandy silts. Note that because the absolute abundance of clay is small, the change in clay content does not have a significant effect on abundance of other size fractions.

SIMILAR PROFILES

Similar silt-rich layers are also developed in soil profiles on other bedrocks to the north of Torbay, particularly along the outcrop of Upper Greensand, Aller Gravel and (Upper) Bovey Formation from Kingskerswell [SX 883 675] through Milber and Decoy to Kingsteignton [SX 878 745]. On these sandy or gravelly bedrocks a layer of pale brown or light yellow sandy silt or silt up to 2 m thick is developed. At most sites the material is sandy (but not as sand-rich as the underlying sediments) and pale brown, and often contains flint pebbles. However, more silt-rich (>60% silt; >35% coarse silt) pale yellow soils are locally preserved, for example in the Milber area of Newton Abbot [SX 874 703]. As on the breccia outcrop in Paignton, the silty soils are most commonly found on lower slopes and are always buried beneath locally derived coarser soils, typically gravelly sand.

Given the origin of the yellow silt as a wind-blown deposit, its sporadic occurrence on many different bedrocks is to be expected. Curiously, in the author's experience the layer does not seem to be present on the Devonian mudrocks which underlie much of the area. Nor is there evidence for its incorporation into the silty clay soils developed on the mudrocks, which always show convex upward grading curves over the silt range (i.e. fine silt > medium silt > coarse silt), the opposite of the loess pattern. The layer may yet be found developed locally on the mudrocks, but present data indicate that it must be much more uncommon than on the sandy bedrocks.

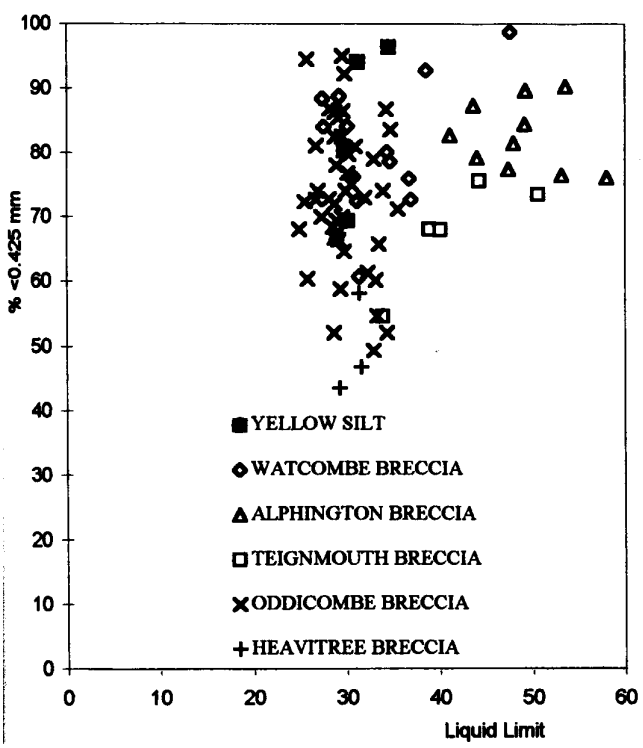

Figure 4. Plasticity and grain-size variation in soils developed on various breccias in the Torbay - Teignmouth - Exeter area. (Plasticity data are determined on samples passed through a 0.425mm sieve, hence data at this point on the particle size distribution curve are abundant and are available on samples for which the plasticity has also been determined, which is why that particular size fraction is illustrated here.)

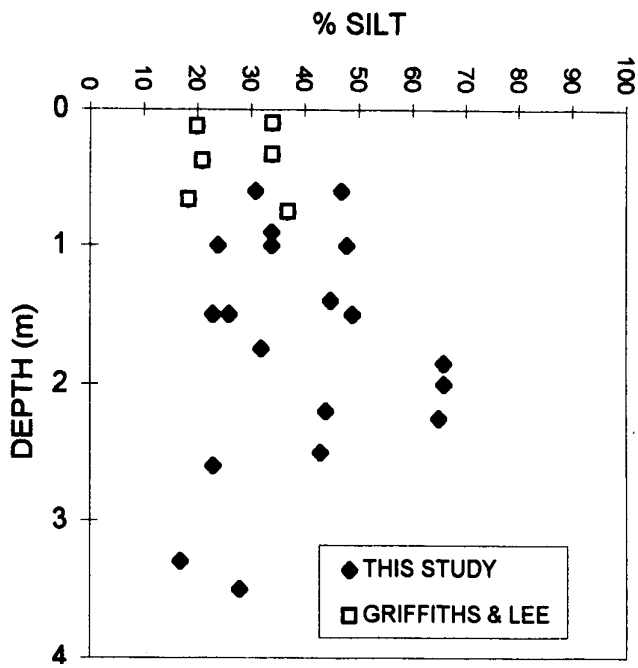

Figure 5. Silt contents of soils developed on Permian breccias in Torbay.

THE YELLOW SILT AS A MARKER HORIZON

Distinguishing between transported and residual soils developed on the Permian breccias is often difficult (Griffiths and Lee, 1989). The loess horizon provides a useful marker, since all soils above the loess must be transported. Using observations made where loess is present, the boundary between transported and residual soils can be identified with some confidence over the whole outcrop. Transported soils are weak poorly consolidated sandy and gravelly silts. They do not occur beneath the loess layer suggesting that the bedrock was bare of soil cover at the time of loess deposition.

ENGINEERING SIGNIFICANCE

Over most of south-west England, soils are derived from the underlying bedrock, and their engineering properties can be predicted

from knowledge of the solid geology. The widespread deposition and sporadic preservation of the loess and its silty derivatives has led to soil profiles which are not predictable from knowledge of the bedrock. The preservation of the loess is erratic and localised, and it would be difficult if not impossible to map its distribution at a useful scale.

The distribution of the loess is of practical interest. The soil and its silt-rich derivatives suffer a large loss in load-bearing capacity on wetting, and foundation problems are common wherever the layer occurs - to the extent that in some cases buildings have had to be demolished. Since the distribution of the deposit is not dependent on bedrock, the risk of encountering foundation problems cannot be predicted from published geological maps. Once the deposition of the layer in an area is recognised, then its likely preservation can be assesed from a combination of geological and topographic maps, and a hazard zonation map could be prepared. Such a map would, however, only be indicative of likely conditions, the distribution of the material is too erratic to allow accurate predictions of conditions at a particular site.

CONCLUSIONS

A layer of wind-blown silt (loess) was deposited over the Torbay area. Both grain size and preliminary mineralogical data indicate that it is part of the same deposit found on the limestone plateaux to the west, on the East Devon Plateau, and probably equivalent to the silty drift and loess found over much of southern England.

The layer is locally preserved as a yellow silt-rich (>60% total silt) layer within soil profiles developed on Permian breccias. More commonly the original presence of the layer can be detected in the high (>30%) silt contents of the upper parts of the soil profiles in the area. Similar soils are developed on other sandy bedrocks in the area, but have not been found on Devonian mudrocks.

The loess and its derivative silt-rich soils give rise to foundation problems; because of its origin, the presence of the silty soils and consequent foundation problems are not predictable from published geological maps.

REFERENCES

CATT, J.A. 1985. Soil particle size distribution and mineralogy as indicators of pedogenic and geomorphic history: examples from the loessial soils of England and Wales. In: *Geomorphology and Soils,* Eds: K.S. RICHARDS, R.R. ARNETT, and S. ELLIS George Allen and Unwin, 202-218

CLAYDEN, B. 1971 Soils of the Exeter District. *Memoir of the Soil Survey of Great Britain.*

DOORNKAMP, J.C., GRIFFITHS, J.S., LEE, E.M. TRAGHEIM, D.G. and CHARMAN, J.H. 1988. *Planning and Development: Applied Earth Science Background, Torbay.* Geomorphological Services (Publications and Reprographics) Ltd., Newport Pagnell. 109pp

GRIFFITHS, J.S. and LEE, E.M. 1989. Loess and head deposits in the Torbay area. *Proceedings of the Ussher Society,* **18**, 188-190

HARROD, T.R., CATT, J.A. and WEIR, A.H. 1973. Loess in Devon. *Proceedings of the Ussher Society,* **2**, 554-564

WEST,G. 1991 *The field description of engineering soils and rocks.* Open University Press. 129pp