Read at the Annual Conference of the Ussher Society, January 1989

Loess and head deposits in the Torbay area

J.S. GRIFFITHS and E.M. LEE

Geomorphological Services Ltd, 1 Bassett Court, Newport Pagnell, Bucks, MK16 0JN.

The results of the recently completed environmental geology study of the Torbay area, carried out by Geomorphological Services Ltd and Engineering Geology Ltd for the Department of the Environment, have been presented in Doornkamp *et al.* (1988). This paper describes the extent of periglacial deposits in the area and the widespread nature of silty material within soil profiles, and demonstrates their geomorphological significance.

Head deposits resulting from periglacial processes are widespread in the Torbay area. Two main types of head deposits can be recognised:
(i) shaley head; these clay-rich deposits have been derived from the Devonian mudrocks. Periglacial weathering of these shales and slates caused extensive softening of the bedrock which, together with high water contents during thaw periods resulted in a combination of viscous flow (solifluction) and shallow translational sliding. At Brixham Heights Estate an exposure of these deposits showed creep deformation, with beds bending over in a downslope direction. Planar slip surfaces roughly parallel to the ground surface may be anticipated within these deposits and could give rise to problems of slope instability during engineering works;
(ii) non-argillaceous head; these are heterogeneous deposits derived from the Devonian gritstones, sandstones, tuffs, igneous rocks and limestones. The best exposure of these deposits is along the low coastal cliffs at Shoalstone Point, Brixham where the materials are crudely bedded with dense irregular layers of angular cobbles of varying sizes and occasional small soft patches of silty material. There appears to be no preferred orientation of the cobbles within this deposit. These head deposits probably accumulated as a result of viscous flow under periglacial conditions and consequently may not contain relict shear surfaces.

The presence of head deposits should also be anticipated throughout the Permian breccia outcrop. However, it has not been possible to delineate the extent of these deposits because of the difficulties experienced in distinguishing between head and *in situ,* weathered breccia. It is likely that both clay-rich and non-argillaceous head deposits occur within the Permian outcrop, reflecting the variable nature and composition of the source materials.

It has been suggested by Catt (1985) that most of the land area south of the Devensian ice margin in Britain was covered by a thin layer of Late Devensian wind-blown silt. These loess deposits are considered to have been blown westwards across southern England from a source area of glacial outwash deposits in the North Sea Basin (Catt *et al.* 1971). Previous soil mapping in Devon has indicated, that thin silty drift deposits occur in several upland sites, including the Devonian Limestone Plateau of south Devon (Clayden 1971; Harrod *et al.* 1973).

Field assessments of particle size distribution carried out by the authors indicated that many of the soils of the Torbay area contained significant proportions of silty material. To confirm this 23 soil samples from 10 representative sites were taken for mechanical analysis by the pipette method. The results of these analyses are presented in Table 1, which reveals that with the exception of site 2 all of the samples have a silt content of over 34%. Indeed, sites 3, 4, 5 and 9 have a silt content of over 50%, with a maximum value of 66% recorded at site 9. These results suggest that traces of loess are present in most of the soils within the area, although the greatest concentrations tend to be in head and colluvial deposits. Bearing in mind the limited number of samples, three broad groups of soils (Fig. 1) can be recognised on the basis of their silt content:
(i) soils with low silt contents (less than 35%), which tend to occur within the Permian breccia outcrop (Fig. 2);
(ii) soils developed on the Devonian mudrocks with 35-50% silt (Fig. 2). Although weathering of these bedrocks produces residual soils dominated by clays and, to a lesser extent, silts, it is likely that a significant proportion of the silt content is a remnant of the loess deposit;
(iii) soils with over 50% silt content, which tend to occur both on the limestone plateau where there has been only limited erosion, and also on the lower slopes and valley bottoms where eroded material has accumulated as head, colluvium, alluvium and mixed estuarine/marine deposits (Fig. 2).

As it is particularly susceptible to mechanical erosion, a thin loess cover is a sensitive indicator of land surface stability over the period since it was deposited (Catt 1985). Assuming a uniform, thin former cover, the soils with low silt contents shown in Fig. 1 indicate those areas where there must have been extensive erosion by Late Devensian solifluction and later Holocene fluvial and colluvial activity.

High silt contents will also have an important bearing on the geotechnical properties of these soils, suggesting that frost susceptibility and liquefaction warrant examination in site investigations, along with the standard range of tests.

Table 1. Grading analysis results (key to soil unit parent materials: B1, B2 = Permian breccia, L = Devonian limestone; S1= Devonian mudrocks; S2 = colluvium over Devonian mudrocks; H2 = silty head; H3 = shaley head; see Doornkamp *et al (1988)* for further details).

Site	Location	Soil unit	Depth (cm)	Soil Grading % in size (µm) fraction: 2000-600	600-212	212-63	63-2	< 2
	896 688		0-20	13.72	11.22	17.2	34.42	23.44
1	Ridgeway Lane	B1	20-45	14.54	9.61	15.81	34.18	25.86
			45-100	12.29	8.26	13.98	37.23	28.24
	904 676		0-25	15.73	13.75	27.04	20.26	23.22
2	Barton Cross	B2	25-49	20.55	14.57	27.85	20.77	16.26
			49-83	23.93	17.98	25.95	18.51	13.63
	909 564							
3	Churston Ferrers	L	0-21	3.57	5.29	7.53	53.33	30.28
	908 560		0-20	5.34	6.55	9.29	50.9	27.92
4	Churston Ferrers	H2	20-40	4.33	403	6.38	54.37	30.89
			40-80	4.2	3.69	6.08	51.36	34.67
	901 570		0-15	5.68	8.56	14.94	46.78	24.04
5	Elberry Cove	H2	15-35	4.23	5.67	13.59	50.6	25.91
			35-75	1.76	3.51	13.03	55.08	26.62
	892 553							
6	Higher Alston	S1	0-10	19.58	11.71	8.42	36.06	24.23
	889 558		0-18	12.22	8.31	6.75	42.21	30.51
7	Galmpton	H2	18-49	14.48	9.94	7.89	40.88	26.81
			49-90	13.1	9.96	8.65	41.96	26.33
	877 578							
8	Waddeton Lane	S1	0-10	16.15	9.05	6.92	41.95	25.93
	877 579		0-20	8.76	5.13	5.24	55.99	24.88
9	Waddeton Lane	S2	20-45	7.9	4.24	4.47	59.96	23.43
			45-70	5.04	260	4.63	66.16	21.57
	938 568		100-160	10.27	10.75	17.12	40.39	21.47
10	Shoalstone Point	H3	240-300	10.19	10.41	15.93	39.88	23.59

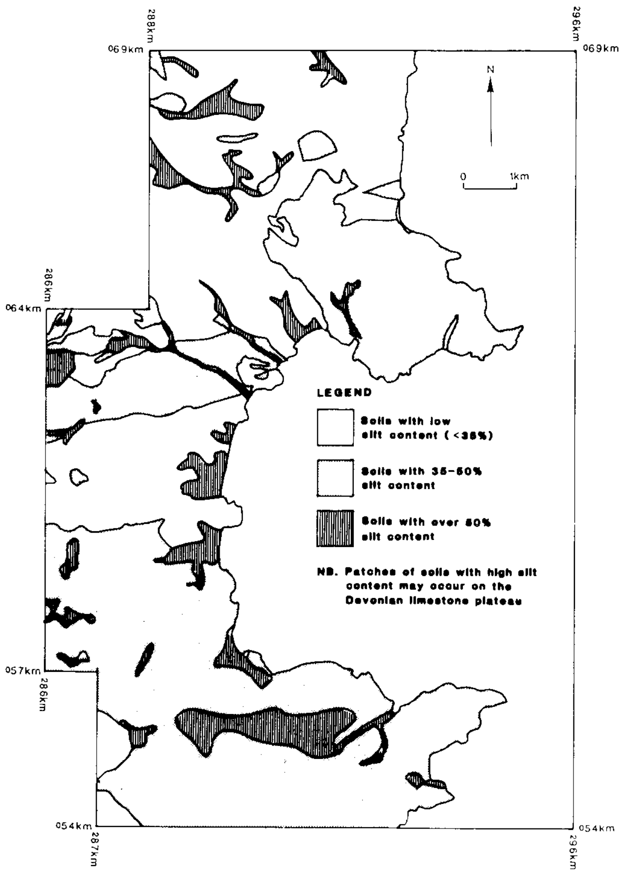

Figure 1. Variation in silt content within the soils of Torbay.

The presence of periglacial head deposits and wind-blown loess sheds light on the nature of landscape evolution and climatic change during the Quaternary. Although deeply weathered subtropical soils developed in southern England during the Tertiary (Green 1985) these would have been rapidly removed as a result of stream incision, mass movement and erosion over the last 2 million years stimulated by about 150m of tectonic uplift in the Early Pleistocene.

Whilst it is generally accepted that southern England remained ice free during the Pleistocene, the fluctuations in climate would have led to the repeated development of periglacial conditions. Much erosion, including solifluction activity and shallow landsliding, was associated with the cold periglacial conditions, especially at the end of each cold phase when the increased snow-melt, rising rainfall and gradual thawing of ground ice made slopes particularly susceptible to failure. All these processes would have acted many times during the Pleistocene, and as a result soil profiles will have been stripped away and the weathered materials reworked on numerous occasions. It is probable that the area was covered by a thin deposit of windblown loess during the Late Devensian period (Catt 1985). This silty material would have been subsequently reworked during the final cold episode (the Loch Lomond Stadial) when there was probably considerable mass movement activity (Catt 1987).

No evidence of soil development from previous warm phases (paleo-argillic horizons; Avery 1980) has been found in the Torbay area, giving an indication of the intensity of erosion during the last phase of periglacial conditions, associated with the Devensian glaciation of northern Britain. As a result of the repeated cycles of erosion and deposition, the present-day soils reflect soil development over only the past 10,000 years, since the last cold phase.

Since the Pleistocene, rates of soil development have been controlled by cycles of slope stability and erosion. Phases of

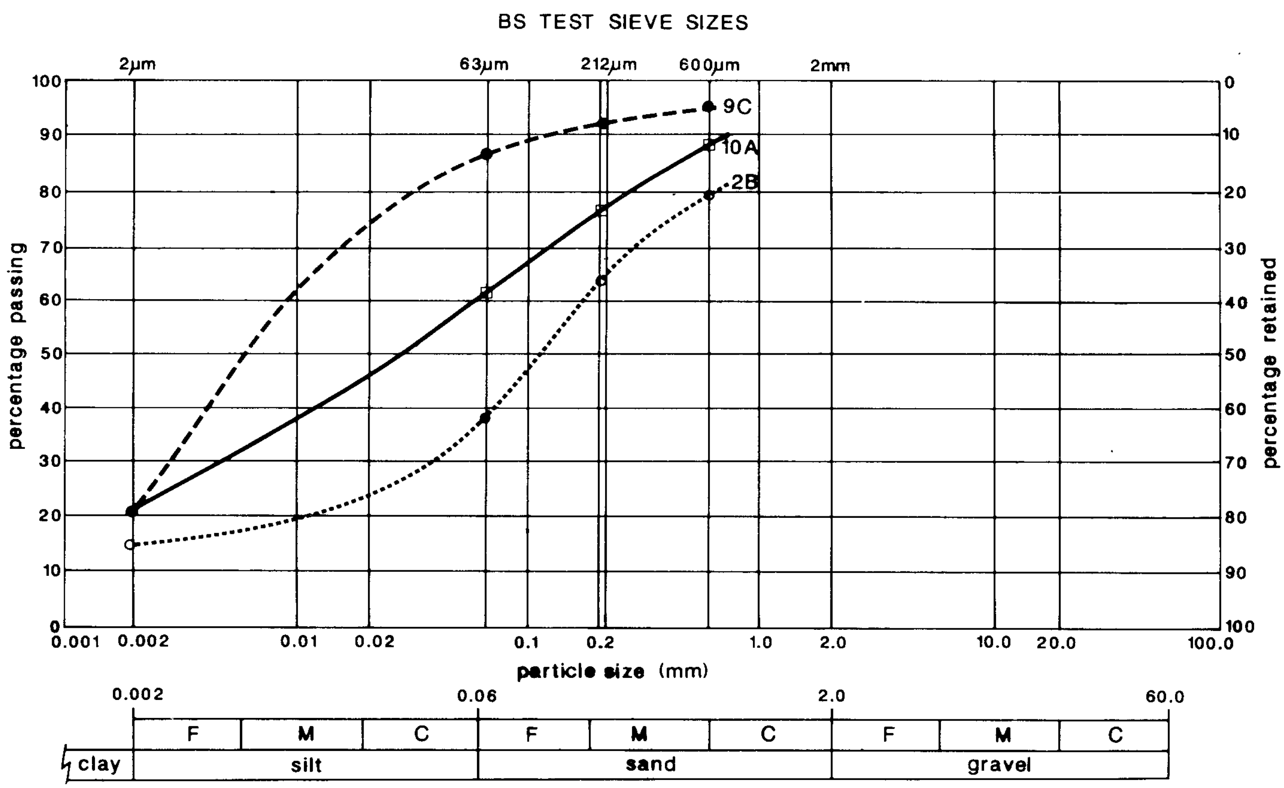

Figure 2. Composite grading curve showing variation in silt contents between soil units.

erosion probably coincided with climatic deterioration and more recent vegetation and land use changes, and resulted in the truncation of soil profiles and removal of material with subsequent deposition on lower slopes as colluvium. Much of the silty, loess material was removed from all but the interfluves and flat plateaux sites, and redeposited in alluvial basins. However, as indicated earlier, traces of loess still remain within the majority of profiles within the area. Soil development proceeded as mechanical erosion and deposition was restricted, allowing material within the profile to be modified *in situ.*

Soil profiles developed from the underlying bedrock in the Torbay area are generally shallow, often less than 30cm thick, reflecting both the intensity of Holocene erosion and also the slow weathering of the bedrocks. Elsewhere, periglacial processes have had a considerable effect on the nature and distribution of soil types, with the deepest most fertile soils having formed from the silty head and colluvial deposits. It is clear that by removing earlier strongly weathered material and replacing it with highly fertile loess and other deposits formed by the physical weathering, the Devensian cold phase was responsible for the development of the highly productive soils of this area.

Acknowledgements. The `Applied Earth Science Mapping for Planning and Development in the Torbay Area' study was funded by the Department of the Environment as part of its planning research programme.

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