

THE ENVIRONMENT OF DEPOSITION OF THE SOUTH HAMPSHIRE PLATEAU GRAVELS

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INTRODUCTION

The Plateau Gravels of the New Forest and Bournemouth form a conspicuous feature of the superficial geology of southern England. Considerable discussion has continued about the origin of these gravels since their first comprehensive description in the mid-nineteenth century (Codrington 1870).

Three depositional environments have been postulated for the gravels: a fluvial environment (White 1917); a marine environment (Codrington 1870; Everard 1954); and a glacio-fluvial environment (Kellaway, Redding, Shepard-Thorn, Destombes 1975). Additionally, Palmer and Cooke (1923) and J. F. N. Green (1946) suggested that both fluvial and marine action were responsible for the deposition of the gravels and the cutting of the benches on which they rest.

Closely associated with the gravels are areas of fine-grained deposits—the brickearth—largely neglected by previous authors, although White (1917) describes this loam as a fluvial silt. Swanson (1970) and Fisher (1971,

1975) also agree on a non-aeolian origin for this deposit.

Fossiliferous Pleistocene deposits are known only from one site in the area. This is Stone Point (SZ 458984) where West and Sparks (1960) and Brown, Gilbertson, Green and Keen (1975) describe peats and silt with brackish mollusca and a pollen spectrum of Ipswichian zone IIb age.

THE GRAVELS

The gravels of South Hampshire are arranged as a series of terraces. Below 40 m O.D. these terraces are only moderately dissected. Above this height the gravel spreads are separated into eroded remnants. The general arrangement of the terraces can be seen in Everard (1954, Fig. 1) and Green (1946, Pl. 5). No general agreement on the heights of the major terrace stages can be found between these two authors, but below 40 m three well-marked height ranges seem to occur: between 40 and 25 m, between 22 and 14 m and below 10 m. These groupings are taken in this account to represent high, middle and low terraces (Fig. 1).

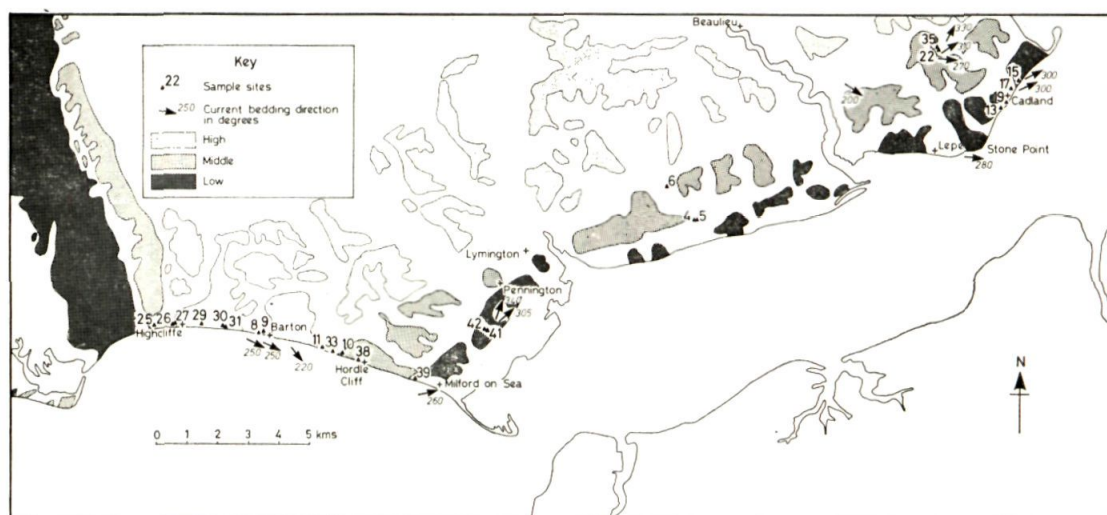


Fig. 1. Map showing the high, middle and low terraces, sample sites for pebble counts, and current bedding directions. (Distribution of terrace gravels from Green (1946) and Everard (1954) with amendments by the present author.)

All authors who have examined the terraces agree that they have a low west-east slope (Everard suggests under 1 ft per mile, 0.2 m/km), but a steeper transverse slope (Everard states that at maximum this slope is 25 ft/mile, 5 m/km). Between the Avon and Southampton Water the terrace slopes west to east are so gentle that they were termed by Green (1946) 'horizontal segments'.

The gravels rest on benches cut in the Eocene and Oligocene rocks. At the coast, in the long Christchurch Bay section, the base of the gravel appears to be a plane surface. Inland, in pits at Pennington (SZ 211936) and Blackfield (SU 450019), and at Stone Point, the gravel has an irregular base and lies in

channels cut into the Tertiary rocks. The maximum gravel thickness known is 6.5 m. It is a uniform, medium to coarse gravel but with occasional channel-fill deposits of coarse sand in it, as at Cadland (SU 473003) or west of Milford (SZ 282917). Pebble counts of the gravels were conducted at 24 points in the study area. Samples were taken from as near to the middle of the gravel thickness as possible. Samples of *c.* 2 kg in weight were collected and all the stones over 3 mm in diameter were identified and counted. The mean number of stones in each sample was, for the low terrace 412 (range 214–735), for the middle terrace 629 (range 361–827), and for the high terrace 341 (range 189–442) (Table 1 and Fig. 1).

TABLE 1. Stone counts of the south Hampshire gravels (in per cent).

a. Low terrace

Grid Reference	Sample No.	Flint	Quartz	Greensand chert	Other far-travelled rocks	Sample size
SZ 374 965	4	73.3	19.3	3.8	3.6	735
SZ 381 971	5	72.2	21.7	2.6	3.5	234
SU 472 001	13	84.2	11.0	0.9	3.9	354
SU 478 009	15	78.6	16.9	2.2	2.3	407
SU 476 007	17	64.2	27.2	2.6	6.0	463
SU 473 004	19	77.2	15.0	2.9	4.9	344
SZ 281 917	39	78.6	15.4	0.9	5.1	214
SZ 308 935	41	83.3	12.6	0.3	3.8	597
SZ 309 935	42	70.4	25.1	1.4	3.1	360
Mean for low terrace		75.7	18.3	1.9	4.0	412

b. Middle terrace

SZ 365 977	6	72.0	20.3	2.7	5.0	404
SZ 271 919	10	72.6	18.9	2.4	6.1	445
SU 451 019	22	71.8	22.4	1.8	4.0	501
SZ 268 921	33	69.5	20.1	3.6	6.8	413
SU 451 021	35	78.7	17.2	1.1	3.0	361
SZ 276 918	38	69.8	24.8	0.7	4.7	827
Mean for middle terrace		72.4	20.6	2.1	4.9	629

c. High terrace

SZ 241 928	8	85.9	9.1	1.1	3.9	362
SZ 245 927	9	78.2	12.7	2.6	6.6	417
SZ 260 923	11	82.7	7.4	3.7	6.2	271
SZ 205 930	25	87.7	2.3	3.8	6.2	342
SZ 208 930	26	94.0	0.8	3.5	1.7	398
SZ 209 930	27	92.5	2.3	1.3	3.9	442
SZ 221 931	29	95.4	2.7	0.8	1.1	259
SZ 229 930	30	90.5	4.8	1.6	3.1	189
SZ 230 929	31	91.3	1.3	2.0	5.4	391
Mean for high terrace		88.7	4.8	2.3	4.2	341

The gravels consist largely of sub-angular flints. In the low terrace the mean flint percentage (nine counts) was 75.7, in the middle terrace (six counts) 72.4, and in the high terrace (nine counts) 88.7. The other main constituent of the gravels is quartz. Unlike flint, quartz occurs almost exclusively as well-rounded pebbles less than 3 cm in long axis. The mean quartz percentage in the low terrace is 18.3, in the middle terrace 20.6, and in the high terrace 4.8 per cent. Greensand chert is present in all three terraces at mean levels around 2 per cent. Also present in quantities of less than one per cent in each case are greywacke, schorl, sarsen and lignite. In addition to these

constituents of the gravel, large sarsens also occur. Blocks up to 2 m in length occur in the low terrace at Pennington, and Everard (1952) notes rounded boulders in the gravels at Milford. All of the sarsens examined were water-worn on all their visible faces, with boulders under 30 cm in diameter being in general sub-rounded in shape.

The gravel also contains mud clasts. At Cadland, 10 cm long axis pebbles of Headon beds clay are incorporated into the base of the gravel, while at Barton (SZ 239929) silt blocks up to one metre long occur, also in the base of the gravel.

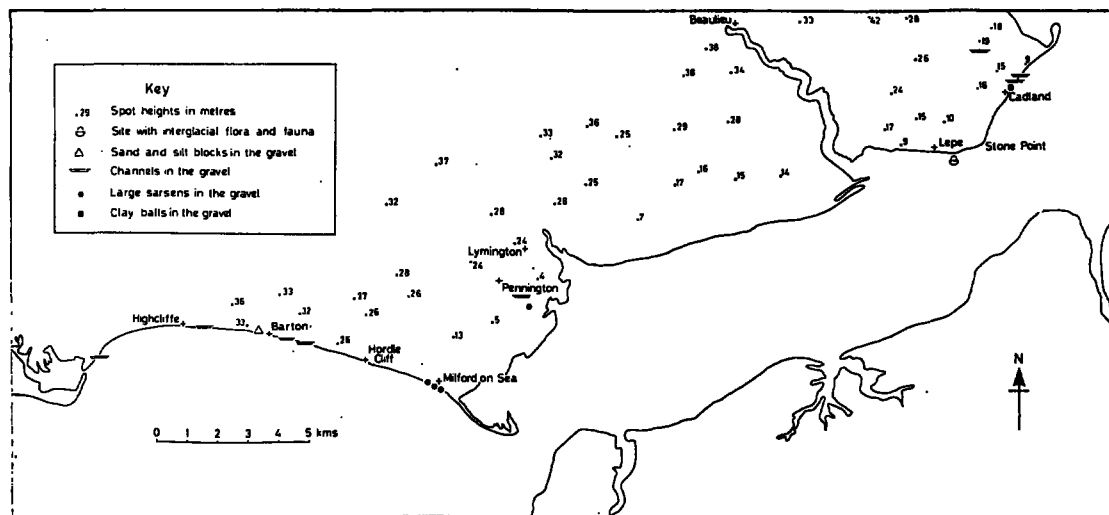


Fig. 2. Map showing the location of channel features, mud clasts, clay balls and sarsens in the gravel.

The general appearance of the gravels has been described as a series of horizontal beds (Everard 1954). In detail, however, the gravels exhibit cross-bedded sequences. Where such features occur, they are usually confined to sand lenses in the gravel and have a maximum amplitude of 0.7 m. The mean direction of current orientation (from thirteen sites) was 275°N (with extremes of 340°N and 220°N). These current bedding orientations suggest a broadly easterly flow for the current which

deposited the gravels of all three terraces (see Fig. 1).

In addition to the current bedding, large-scale lineations can be seen in the channels occupied by the gravels in the pits at Blackfield and Pennington. At both of these sites the gravel-filled channels are separated by linear features of Tertiary rocks which have a broadly west-east trend agreeing with the flow direction shown by the current bedding. Other channels occur in the gravel at Barton, but

these can only be examined in two dimensions because of the nature of their exposures, so their trend cannot be determined.

The gravels generally lack periglacial structures. Two ice wedge pseudomorphs have been observed in the high terrace at Highcliffe (SZ 202931) but these can only indicate a post-depositional periglacial episode. Other ice wedge casts noted by Lewin (1966) in the same area may prove intraformational periglacial conditions as the wedges are partly filled by brickearth, perhaps indicating continuing fluvial deposition under a periglacial climate.

Flame-type involutions occur in sands at Hall's Pit, Blackfield (SU 449021), below a layer of gravel perhaps also indicating intraformational periglacial activity.

THE BRICKEARTH

This deposit always occurs in close association with the gravel. It is of variable thickness. On the low terrace it is seldom more than 0.3 m thick, on the middle terrace up to 2 m occurs, while on the high terrace a maximum of 3 m is present. Fourteen samples were taken through the thickness of the brickearth at Hordle (SZ 276918), Barton (SZ 227930) and Highcliffe (SZ 221931). Grain-size analyses of the samples show the following mean percentages of grain size fractions: fine sand, 50 per cent; silt, 30 per cent; and clay, 20 per cent. In most samples examined, small flakes of flint up to 1 cm across also occurred. Analysis of these samples taken through the full thickness of the brickearth shows no variation in grain size with depth. The brickearth is entirely structureless, without either sedimentary or post-depositional structures being present. The brickearth characteristically rests with a planar boundary on top of the gravel, with only slight mixing of the two deposits. This mixing takes the form of fine lines of small flints which occur most strongly in the lowest 0.3 m of the brickearth. The top 0.3 m of the gravel contains only small quantities of silt as a result of this mixing.

DEPOSITIONAL ENVIRONMENTS

Marine

The advocates of a marine origin for the gravels (Codrington 1870; Everard 1954) stress that the deposits have no marked west-east slope. This is held to be characteristic of marine strandlines rather than of fluvial deposits. The angular nature of the gravels, a normal feature of river gravels composed of flint, is explained by the suggestion that the gravels are basically fluvial material reworked by marine action. At each marine stage reworking of the gravel occurred, but rounding of the pebbles was limited because of the lack of fetch available in the narrow 'Solent Bay' between the chalk ridge of the Isle of Wight and the high ground to the north of the Plateau Gravel outcrop. Although the negligible west-east slope of the terraces suggests the possibility of a marine strandline, the great width of the terraces, particularly the high terrace in the Beaulieu area—up to 4 km wide at maximum—is difficult to explain in terms of the limited fetch available in the Solent. This objection is increased if it is assumed that the Wight-Purbeck ridge was intact until the Upper Pleistocene (Everard 1954), thus allowing wave generation only from the east or south-east. Waves from these directions would probably be inadequate for any degree of marine planation, because at present the southern-facing Solent coastline between Lymington and Calshot is only slightly eroded by such waves. It is unlikely that waves from the east would have been any more effective in the Pleistocene.

The only site known with Pleistocene organic material in the Solent area (Stone Point) has evidence of a brackish environment (West and Sparks 1960; Brown *et al.* 1975), not the full marine condition such as would be necessary to cut wide benches and deposit thick beach gravels. A marine origin for the gravels also takes no account of the brickearth which is unlike any known marine deposit, yet is always closely associated with the gravel.

The platform on which the gravels rest is not like the type of erosion surface usually associated with marine planation. The channels, at maximum 6 m deep at Blackfield, are more indicative of fluvial action than marine activity.

Fluvio-glacial

The arguments for a fluvio-glacial origin for the gravels depend on their relationship either to an ice lobe extending south-east from a Bristol Channel glacier (Kellaway 1971), or to the erratic boulders at Selsey which have been suggested to be part of the terminal moraine of an English Channel glacier (Kellaway *et al.* 1975). This large icesheet is held to have originated on the continental shelf south of Ireland during a low glacial sea level, and flowed eastwards up-channel to a terminal position at Selsey. In either of these hypotheses the Hampshire gravels are suggested to be outwash from such ice sheets. The gravels themselves show no evidence of a fluvio-glacial origin. The directional structures in them (current bedding and channel lineation features) with their general west-east alignment do not require a fluvio-glacial origin. The composition of the gravels shows no evidence of far-travelled material such as would be expected to occur had they been deposited as outwash. The bulk of the gravels are flint, readily available from the chalk outcrops of Salisbury Plain, the Dorset Downs and the Wight-Purbeck ridge.

The minor constituents of the gravels are dominated by quartz which characteristically occurs as small, well-rounded pebbles. Other minor constituents of the gravels which also occur as small, rounded pebbles, such as schorl or greywacke, share a similar origin to the quartz in the Lower Tertiary pebble beds of Dorset (Reid 1896; Bury 1923). The remaining pebble types are derived either from the local Tertiary formations in the case of lignite, or from the Lower Greensand outcrop in the headwaters of the Avon and Stour in the case of the chert (Green 1973).

The slight increase of quartz at the expense of flint in the middle and low terraces is difficult to explain. It may result from a

decrease in the contribution of the Stour to the gravels of the Solent. Bury (1923) states that the gravels of the Stour contain up to 90 per cent flint and only 2 per cent quartz, while those of the Solent west of its confluence with the Avon and Stour contain between 34 and 26 per cent quartz and thus correspondingly smaller quantities of flint. Alternatively, the increase in quartz in the two lower terraces may be due to the decrease in the amount of reworked high-level gravel in the Solent system as the lower terraces were deposited. Bury describes these gravels (those over 50 m O.D.) as being almost deficient in quartz both around Bournemouth and in the New Forest. The high-terrace gravels formed from an amalgam of the quartz-free high-level gravels and Solent gravels thus have more flint in them than the middle and low terraces which are largely derived from reworked high-terrace gravels, with some quartz, plus new contributions of relatively quartz rich gravels from the Solent.

None of the gravels of any of the terraces exhibit any major influx of material which has a source outside the Hampshire basin. This is in marked contrast to the appearance of gravels deposited by streams which have been influenced by known sources of glacial material such as the Thames (Walder 1967; Green 1973). In the absence of any far-travelled material which cannot be attributed to existing outcrops in the area, a glacial contribution to the gravels must be discounted.

Fluvial

If marine and glacial origins for the gravels are discounted, their formation as the deposits of the Pleistocene River Solent then becomes their most probable mode of origin.

The main lines of evidence which indicate fluvial deposition for the gravels are the directional structures in them, and their close association with the brickearth.

The directional structures in the gravel are consistent with deposition in a generally east-flowing river such as the postulated Pleistocene River Solent. These structures are incompatible with a marine origin. The sandy channel fills in the gravels are also more indi-

cative of a fluvial than of a marine environment. Suggestions by some authors (Palmer and Cooke 1923; Green 1946) that the bench on which the gravels rest is marine, but that the gravels are fluvial, also seems unlikely. The difficulty of cutting a wide marine bench in the sheltered Solent has already been discussed, and the cutting of the bench by fluvial action at the same time as the gravel was being deposited seems the most likely process of origin.

The brickearth has been shown to be most similar in grain size to fluvial silt by Fisher (1971, 1975) thus echoing White (1917) who considered this deposit to be a 'flood loam of

little later date than the underlying gravel'. Both Swanson (1970) and Catt (1977) regard the brickearth as being of partially loessic origin, but both these authors conclude that the deposit is water-laid in its present form.

The grain size analyses in Fig. 3 for brickearth from the high terrace at Barton (SZ 239 930), and samples of loess from Pegwell Bay, Kent, La Motte, Jersey, and St. Sampson's Harbour, Guernsey, Channel Isles, show the differences in grain size between South Hampshire brickearth and undoubted loess. The lack of silt in the Barton brickearth and the relatively large amounts of clay (below 2 microns) and sand (over 64 microns) is clearly different to the seventy to eighty per cent silt content of true loess. The occurrence of flint flakes in the Hampshire brickearth also precludes an aeolian origin.

Swanson (1970) suggests that in a small number of localities in the Southampton area true loess overlies the brickearth. He suggests, however, that this is a localised deposit and that the bulk of all the Hampshire brickearths are of fluvial origin.

THE CLIMATIC ENVIRONMENT

If it is accepted that the gravels and brickearths of south Hampshire are of fluvial origin, the problem of the environment of their formation then arises. The coarseness of the gravels indicates a fluvial regime unlike those prevailing in southern Britain at present. There are, however, few climatic indications in the gravels themselves. Faunal or floral remains have not been found in them, although in the case of the low terrace, the relationship of the gravels to the organic deposits at Stone Point indicates a radical change in conditions from the full interglacial episode in which these estuarine deposits were formed (Brown *et al.* 1975). The gravels are also deficient in structures indicative of their climate of deposition. The poorly developed involutions in the middle terrace at Blackfield may show evidence of a contemporary cold climate, and Lewin (1966) suggests that the

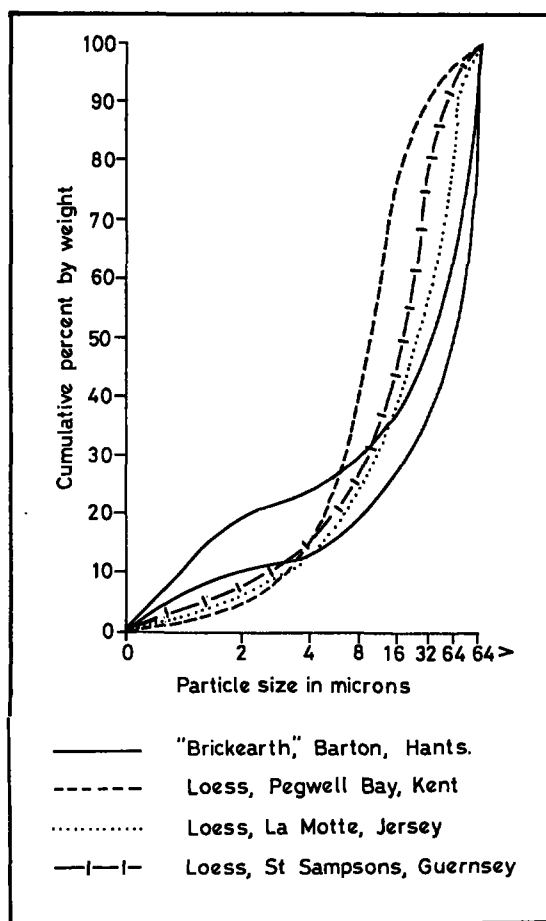


Fig. 3. Grain-size analyses of the South Hampshire brickearth compared with analyses of loess from Kent and the Channel Islands.

frost wedges at Highcliffe are filled with brick-earth at their tops, perhaps indicating periglacial conditions during the deposition of this terrace. Despite the lack of direct evidence of climatic conditions, three lines of evidence combine to suggest that the gravels are the product of a cold climate.

i *The calibre of the gravels*

Coarse gravels such as those of south Hampshire, with their large sarsens and angular flints, cannot be seen to be forming anywhere in southern Britain at present. Deposits of this type are, however, common in modern high arctic areas characterised by a seasonal fluvial regime (Tricart 1970; French 1976). The shallow west-east slope of the terraces may also suggest a periglacial/fluvial environment. Only the extreme discharges of such a regime could move gravels as coarse as those of the New Forest down such a shallow slope.

ii *Mud clasts and silt blocks*

The inclusion of mud clasts and silt blocks within the gravel also suggests a high energy environment unlike that of present-day streams in southern Britain. Such fragile sedimentary aggregates would only survive intact in the conditions of rapid erosion and reburial typical of streams in a periglacial environment. Silt blocks such as those at Barton may have been incorporated into the gravel in a frozen state, as occurs in modern periglacial rivers in Siberia and has been reported from periglacial fluvial deposits in Poland (Dylik 1969). The width of the terraces may also suggest a periglacial environment for their origin. Castleden (1977) has recently ascribed such wide flat surfaces below undoubted fluvial deposits in Northamptonshire and the Thames basin to 'periglacial pedimentation'. The suggested mechanism of the cutting of these surfaces is a combination of the high seasonal discharge of the periglacial zone coupled with frequent changes of channel direction. This process results in the formation of wide, but channelled, benches overlaid by thick sheets of coarse gravel exactly as occurs in south Hampshire.

STRATIGRAPHIC RELATIONSHIPS AND THE AGE OF FORMATION OF THE GRAVELS

The presence of the terraces of south Hampshire at levels above Ordnance Datum suggests that, despite their cold-climate origin, they were deposited by rivers controlled by the high base levels of interglacials. The buried channels between the Isle of Wight and Spithead (Dyer 1975) show that at some stages of the Pleistocene the Solent River was cutting to a far lower base level than that at which the terrace gravels were deposited. Even if these 'buried channels' were solely Devensian in age, the Solent must have deposited the gravels of the low terrace under cold conditions but before base level fell to the - 46 m O.D. depth described by Dyer. If, as is generally assumed (West 1977), the maximum fall in sea level in the Devensian was near the end of that glacial stage, it is probable that the gravels of the low terrace of south Hampshire were formed early in the glacial. The interglacial deposits at Stone Point are dated to zone Ip II of the Ipswichian, that is, to the time of maximum warmth of the interglacial, so it is possible that the gravels of the low terrace were deposited in the transition between the full interglacial conditions represented by the estuarine muds at Stone Point and the glacial maximum represented by the buried channels off-shore. The effects of such climatic change on fluvial regimes in Norfolk have been noted by West, Dickson, Catt, Weir and Sparks (1974) where full interglacial deposits are overlain by coarse sands and gravels containing fauna and flora indicating a deteriorating climate. Thus, it seems possible that the gravels of the low terrace formed in response to the higher stream discharges associated with climatic cooling at the end of the Ipswichian interglacial.

Despite the probability that the gravels formed in a transitional climate between full interglacial and full glacial conditions, the climate under which the gravels were deposited may have been a cold one. No faunal or floral evidence for the exact nature of the climate has yet been found in the gravels, but

the occurrence of involutions in the middle terrace at Blackfield and of ice wedges at Highcliffe suggests severe conditions. Péwé (1966) states that mean annual temperatures of -6°C are necessary for ice wedges to form, so if the pseudomorphs at Highcliffe are really intraformational the brickearth at least may have been deposited under a very cold climate. The involutions at Blackfield are indicative of a less severe climate, but these require discontinuous permafrost or severe freeze/thaw for their development (French 1976), which perhaps suggests a mean annual temperature of around 0°C .

If the gravels formed in a periglacial climate, it is probable that the brickearths also formed under such conditions. The brickearths share a fluvial origin with the gravels and always overlie them in section. It seems very likely that, as White (1917) suggested, the brickearths are a 'flood loam of little later date than the underlying gravel'. The exact environment under which the brickearths were deposited is not certain. Their lack of structures allows no clear postulation of an exact environment on a flood plain. However, the fine-grained nature of the brickearth, compared with the gravels, suggests lower energy conditions than those responsible for the deposition of the gravel, so it is possible that the brickearth was deposited in the late summer after the high-flow conditions of the spring melt had passed. Such loams are deposited at present on river flood plains in the periglacial zones of Canada and Siberia (French 1976).

Deposition of the brickearth as flood-plain loam at low stream-flow rates in the late summer may also account for the loessic character of some of the brickearth noted by Swanson (1970) and Catt (1977). It is common in modern periglacial environments for dust clouds to be deflated from unvegetated surfaces on river flood plains in late summer (French 1976). Such activity would result in a more sorted sediment than the brickearth, which when redeposited would exhibit many of the grain-size characteristics of loess. Alternatively, some of the silt particles in the

brickearth may have been introduced into South Hampshire by easterly winds from the loess province of Central Europe as suggested by Catt (1977).

It is uncertain how long the phase of gravel and brickearth deposition lasted. The varying thickness of the brickearth on the three terraces identified in South Hampshire suggests a longer time period for the deposition of the high terrace than for the middle and low terraces. Alternatively, it is possible that during middle and low terrace times deposition rates were slower.

Whatever the significance of the thickness of brickearth for the length of time during which the terraces developed, terrace formation finally ceased due to the fall in base level resulting from the world lowering of sea level as the build-up of land ice in North America and Scandinavia proceeded.

Thus, it is suggested that the South Hampshire terrace deposits, both gravel and brickearth, formed during the transition between interglacial and glacial conditions. Only in the case of the low terrace can a named interglacial stage be correlated with gravel and brickearth deposition. The relationship between the interglacial deposits at Stone Point and the overlying gravels and brickearth clearly suggests a late-Ipswichian, early-Devensian age for the low terrace.

The middle and high terraces were then also deposited at the ends of earlier interglacials, but in the absence of datable material in these terraces, which interglacials they relate to is uncertain at present.

CONCLUSIONS

The gravels and brickearths of South Hampshire were deposited under a periglacial fluvial regime at the transition between interglacial and glacial conditions. They rest exclusively on surfaces cut during the course of their deposition. Some elements of the brickearths may be derived from aeolian activity, either the reworking of local fluvial sediments or the result of longer-distance transport from the European loess province.

A sequence of events can therefore be suggested: (i) full interglacial-estuarine conditions in the former Solent Bay with the deposition of silts and peat exemplified by such deposits at Stone Point; (ii) end interglacial, early glacial—a periglacial climate with braided streams depositing coarse gravel in the spring and finer loams (the brickearth) in late summer. Perhaps some partial reworking of the loam by wind, also in late summer; (iii) later in the glacial—fall in sea level due to build-up of land ice further north resulting in the abandonment of the terrace complex and the cutting of buried channels.

The low terrace can be dated to the end of the Ipswichian interglacial/early Devensian glacial by means of its relationship to the interglacial deposits at Stone Point. The middle and high terraces cannot at present be correlated with any named interglacial stage.

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