

THE QUATERNARY DEPOSITS AT DONIFORD, WEST SOMERSET

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INTRODUCTION

At Doniford, near Watchet in west Somerset, abundant exposures of Quaternary loams, sands and cobbly gravels are displayed in river and marine cliffs which extend for a distance of well over 1 km. (Fig. 1). Although not previously studied in detail, they were mapped and partially described by A. N. Thomas (1940). The finds of woolly mammoth and palaeolithic implements reported by A. L. Wedlake (1950) and A. L. and D. J. Wedlake (1963) are of chronological interest in dating the gravels.

Recent discoveries of far-travelled erratic stones in north Somerset (A. B. Hawkins and G. A. Kellaway, 1971) suggested that ice sheets travelled up the Bristol Channel and penetrated well inland in the vicinity of Weston super Mare. If this were the case, then it may be that such ice sheets passed over the Doniford area. So the present investigation was started to determine the origin of the Doniford gravels and to find out if glacier ice played any part in their formation.

TOPOGRAPHIC RELATIONSHIPS OF THE QUATERNARY DEPOSITS

The Quaternary deposits form a wide apron which thins out as the ground gradually rises up the adjacent hillslopes, which here reach a maximum height of just over 35 m. This apron slopes gently eastwards from the jetties (Fig. 1) towards the mouth of the Doniford River (The Swill; ST 091432) which is incised into the gravels.

In Helwell Bay (Fig. 1) the drift surface slopes inland from the coast to a valley axis running parallel to the coast through the Memorial Ground (ST 076433). This valley floor is exposed in cross-section in Helwell Bay (Fig. 2).

The greater part of the deposits consists of coarse cobbly gravels, defined as gravels having long axis measurements in the range 2-60 mm. with cobbles in the range 60-200 mm. (Plate I). In the railway cutting behind Watchet Station (ST 073433), at the Coastguard Lookout (ST 077435) and in the western face of Helwell Bay, these gravels fill shallow valleys cut in the Lias bedrock, which run together to form a larger valley running parallel to the coast. These pre-gravel valleys are reflected in the present day surface.

In the cliff sections at the western end of Helwell Bay, the surface beneath the Cobbly Gravels is clearly shown to be erosional, since it abruptly truncates the steeply dipping Lias beds below. The Lias platform continues at 10-12 m. O.D. eastwards until it falls sharply to approximately 5 m. O.D. slightly to the east of the large breakwater (ST 083431). The platform then fluctuates at about this height before finally falling away to 3 m. O.D. at The Swill.

The origin of the surface on which the Cobbly Gravels rest is not clear. Along its entire length it may be fluvial, and the cliff section may preserve a long profile of

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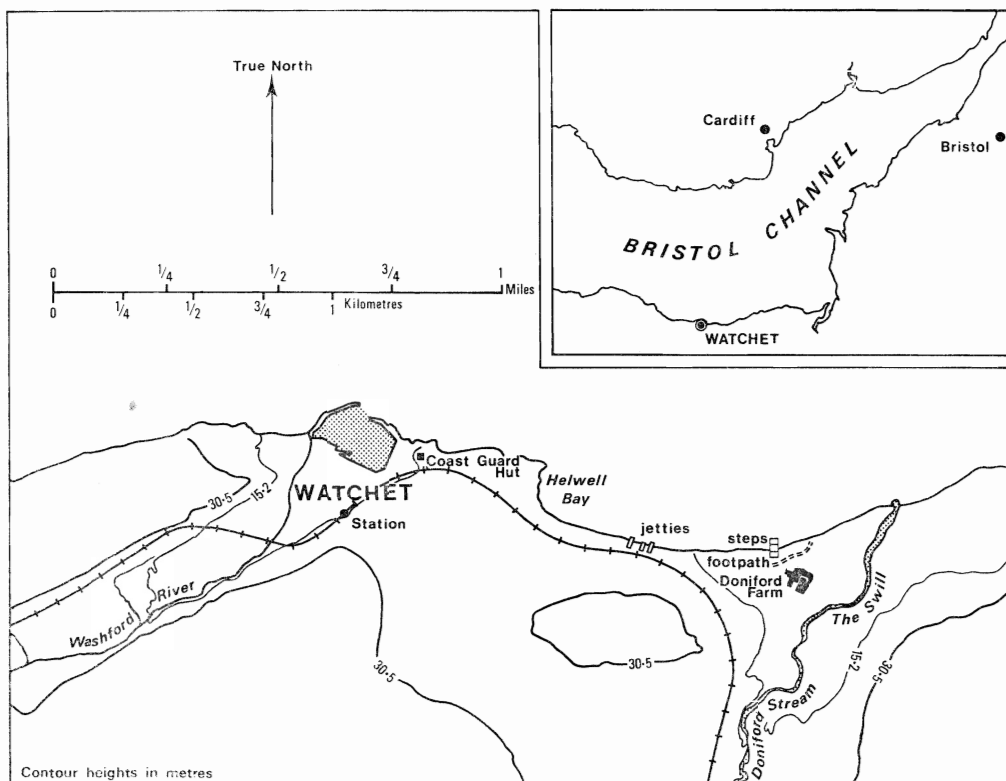


FIG. 1.
Location of the Doniford Gravels.

a former valley running west to east. This valley seems to “hang” above Watchet Station, suggesting that an ancestral Washford River used to flow to a downstream confluence with the Doniford Stream. Marine erosion has cut back the coast here by an average of 1 m. per year over the past 30 years (R. J. H. Werren, *pers comm.*), and so may in the recent geological past have breached the north wall of the pre-drift valley, causing the Washford River to flow directly into the sea at Watchet. Examples of dismemberment of drainage by marine erosion on this coastline include the Lyn west of Lynmouth (Mottershead, 1967) and the dry valley systems near Hartland Point.

The abrupt change between 5 m. and 10 m. in the height of the Lias platform is poorly exposed and may have originally been a marine cliff.

The Lias/gravel contact has been extensively affected by the development of contorted structures largely developed after the gravels were deposited.

THE DEPOSITS

The stratigraphy of the deposits is complex, with considerable variety of stratification. The gravel content, for example, ranges between 0 and 80 per cent. A number of surveyed, simplified profiles noted along the cliff section are presented in Figure 2. Several fairly continuous horizons can be traced along most of the section,



PLATE I.
Typical exposure of Cobbly Gravels and overlying Loams.

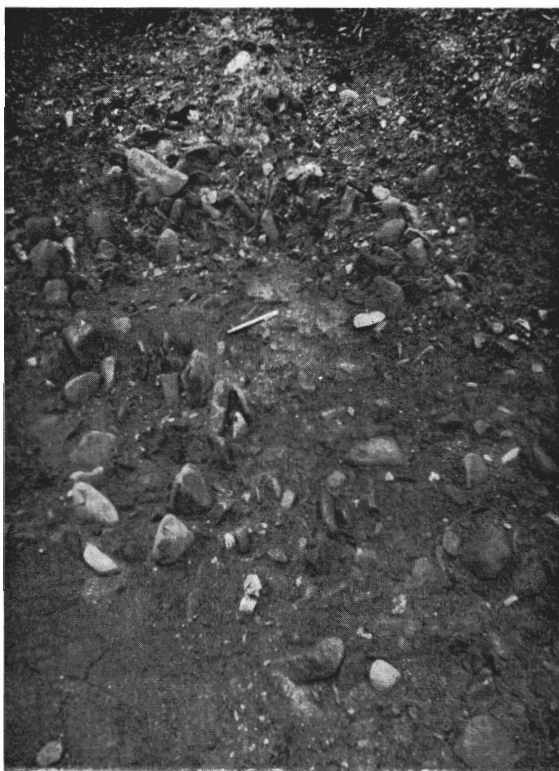


PLATE II.
Upright stones forming patterned ground on Lias clay surface. Pen measures 14 cm.

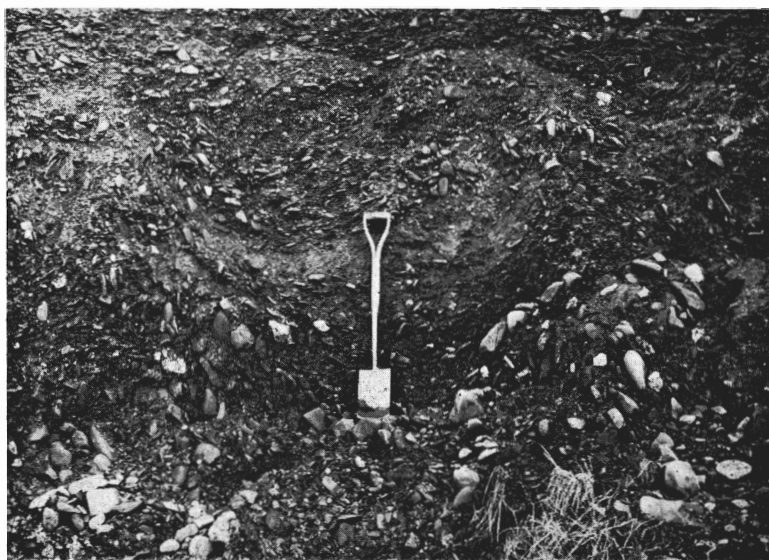


PLATE III.
Festoon structures in Cobbly Gravels.

although major changes do take place, especially within 200 m. of The Swill. A typical section west of the footpath (ST 087431) is recorded below:

<i>Depth (m.)</i>	<i>Unit</i>	<i>Description</i>	
0	-0.6	5	Structureless brown loam, occasionally with pebbles, thinly bedded.
0.6-1.2		4	Red clay-silt with marked prismatic fracture, frequent angular pebbles of Liassic material.
1.2-1.8		3	Buff silty loam with layers and lenses of angular stones, less well defined prismatic structure.
1.8-2.1		2	Red sandy silt, thinly laminated, with fine gravel throughout.
2.1-4.9		1	Cobbly gravels. Partially rounded to angular cobbles and boulders, often split, in a matrix of platy pebbles and fine silt. Very poorly bedded and poorly sorted.
4.9			Modern beach.

It must be emphasized that lateral variations occur and that the present grouping is an attempt to bring a degree of order to a series of highly variegated deposits.

The Cobbly Gravels (Unit 1)

These gravelly cobble and boulder (200 mm. long axis)-rich beds are the most distinctive and extensive deposits throughout the length of the section. They usually show little bedding although there is sometimes a tendency for the stones to lie with their long axes in the horizontal plane. Occasionally contortions occur and the stones can be seen with their long axes steeply dipping. Lenses of well sorted, cross-stratified sand and gravel sometimes occur up to several metres long and half a metre deep (Figs. 2 and 3), such as the Bedded Gravel of Table 1. Where present, these lenses may show that the deposit is contorted by large folds.

Table 1. *Particle size distribution and carbonate content of sediment samples*

	%Gravel	%Sand	%Silt	%Clay	%CaCO ₃
Red Loam (Unit 4)	6	49	18	27	—
Buff Loam (Unit 3)—stony	17	26	19	38	35.2
stoneless	—	6	32	62	29.7
Red Silty Loam (Unit 2)	4	46	39	15	0.7
Cobbly Gravels (Unit 1)	77	18	1	4	0.5
Bedded Gravel in Unit 1	79	18	3	—	—

Within 200 m. west of The Swill, these massive beds have in them large channels up to 8 m. across, containing cross-stratified sands and gravels. These are particularly well exposed in The Swill river cliff at right angles to the coast.

The cobbles are mainly purple and green slates, sandstones, grits and cherts, all of which may have been derived from the Devonian rocks of northwest Somerset. Occasional blocks of Lias clay can be seen in the section (Figs. 3 and 6). Between 1968 and 1970 one of these rafts 2 m. × 0.3 m. and weathered around its margin, was exposed just to the west of the footpath. The red to buff matrix of the cobbly beds may be derived by weathering from the nearby Devonian, Triassic and Jurassic deposits.

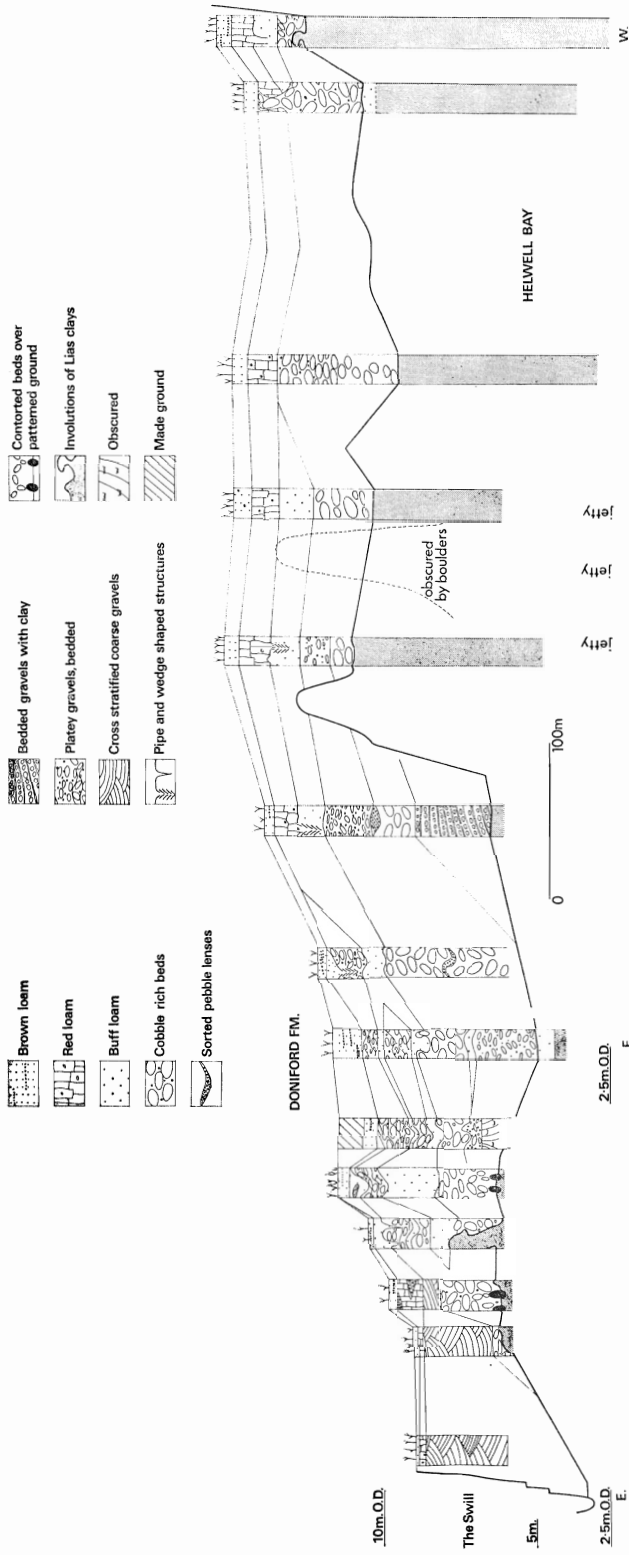


FIG. 2.
The Cliff Section through the Doniford Gravels from Helwell Bay to The Swill.

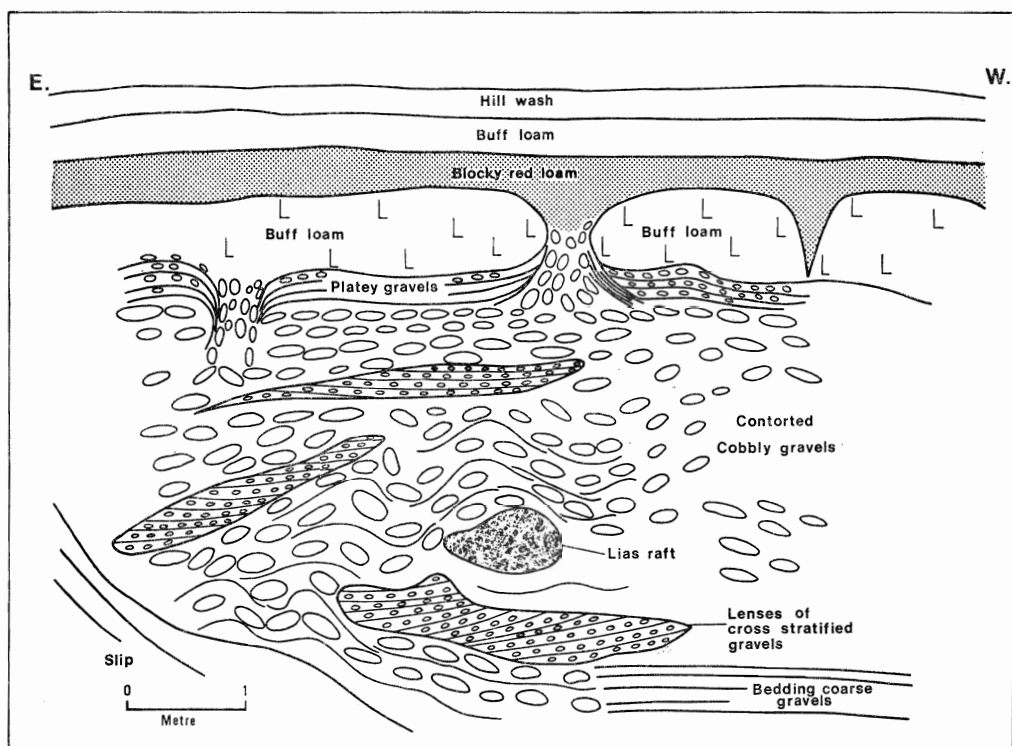


FIG. 3.

Typical section through the Doniford Gravels west of the footpath, showing lenses of cross-stratified sands and pipe structures affecting loams and gravels.

Stone shape was assessed by taking samples of 50 stones with a *b* axis more than 9 mm. in length. They were classified using the Powers (1953) visual comparison chart method. The results are set out in Table 2.

Table 2. *Particle Shape—Cobbly Gravels*

Sample	Well rounded	Rounded	Sub-rounded	Sub-angular	Angular	Very angular	Mean value	Modal class
1	—	5	17	17	11	—	0.346	SA
2	—	6	12	18	14	—	0.336	SA
3	—	4	16	21	9	—	0.342	SA
4	—	2	26	20	2	—	0.368	SR

The degree of rounding suggests that some transport by running water has taken place. On the other hand, the angularity and the fracture of some of the rounded cobbles suggests that subsequent breakage by frost action has also been significant.

Each of four samples of 25 stones (Fig. 4a) shows a mean orientation value lying in the range 320–360° true (Table 3). Samples 1 and 3 show a well marked preferred orientation, whilst 2 and 4 show two or three minor peaks distributed more widely around the compass. There is no clear-cut pattern of preferred orientation normal

Table 3. *Stone orientation data for the Cobbly Gravels*

Sample	Mean orientation ($^{\circ}$ true)	Orientation strength (%)
1	321	45.8
2	336	31.6
3	358	50.3
4	349	22.7

to the direction of slope, as described by Mottershead (1971) from periglacial head deposits in south Devon, and this may indicate a complex origin for the Cobbly Gravels.

The degree of preferred orientation has been calculated using G. S. P. Thomas's (1967) procedure. Though these values may not be strong enough or sufficiently well grouped to be considered diagnostic, they are at least consistent with the range found by Mottershead in south Devon. The dip of the individual stones rarely exceeded 25° and taken overall there was no preferential dip into or away from the exposure.

The Upper Loams (Units 2-5)

West of the footpath by Doniford Farm there are three upper loam horizons and a sandy silt, which can be distinguished by their colour, fracture and frequency of contained stones.

Unit 2 These red sandy silts are often thinly laminated with gravel and strongly weathered Jurassic stones which may have been incorporated together in this way by slopewash.

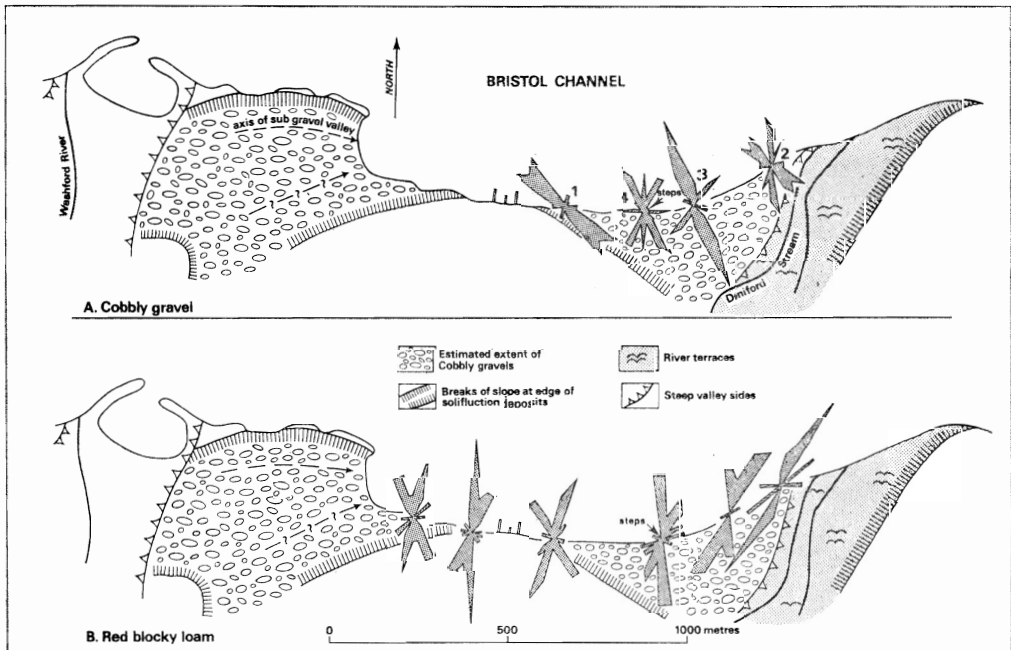


FIG. 4a.

Preferred long axis stone orientations in the Cobbly Gravel (Unit 1).

FIG. 4b.

Preferred long axis stone orientations in the Red Loam (Unit 4).

Unit 3 The buff loam is highly calcareous, its two subdivisions containing 35.2 per cent and 29.7 per cent calcium carbonate respectively. It contains scattered lenses and seams of angular chips and fragments of Liassic limestone. An occasional swirling structure in the stony lenses suggests some semi-fluid motion during the deposition of this material.

Unit 4 A blocky red loam, tough when dry, with 27 per cent clay content. It is very like the red Triassic deposits, to which it can be traced in the cliff section below the Coastguard Lookout (ST 077435), in the sand and gravel fractions, it contains material of Old Red Sandstone origin. It must antedate the frost heaving that has disturbed it. The long axes of the included stones have a marked preferred orientation (Fig. 4b), which, when traced along the exposure, tends to be approximately normal to the slope. Table 4 shows that, except for one sample site only, the mean values show a progressive change as they are followed around the slope. Orientation strength values are higher than for the Cobbly Gravels, indicating a more restricted alignment of the stones in this layer. This may be the result of a simple downslope mass movement process.

Unit 5 A brown loam, which often lies with marked unconformity on the lower deposits, is probably the horizon from which Mesolithic artifacts were obtained and incorporates fragments of weathered local limestones.

Table 4. *Stone orientation data for Red Loam*

Sample	Mean orientation (° true)	Orientation strength (%)
1	4	44.0
2	5	42.4
3	358	48.2
4	21	60.0
5	22	70.7
6	54	61.8

Samples are numbered 1 to 6 consecutively from west to east.

POST-DEPOSITIONAL STRUCTURES

Disturbances of the bedding of the deposits occur throughout the exposure at three levels:

- (i) at the Lias/Cobbly Gravel contact;
- (ii) within the Cobbly Gravels;
- (iii) affecting the Upper Loams.

Structures affecting the Lias/Cobbly Gravels Contact

At the western end of Helwell Bay large-scale wave-like structures (involutions) of 1–2 m. wavelength and amplitude affect the surface of the Lias platform and the superficial deposits above it (Fig. 2). They are caused by frost action on saturated ground under periglacial conditions (see West, 1968). A striking feature is the way a raft of Lias clay has been detached from the solid outcrop and caught up in an involution, which also affects both Cobbly Gravels and the Loams above (Fig. 5). Clearly considerable pressures have been at work here.

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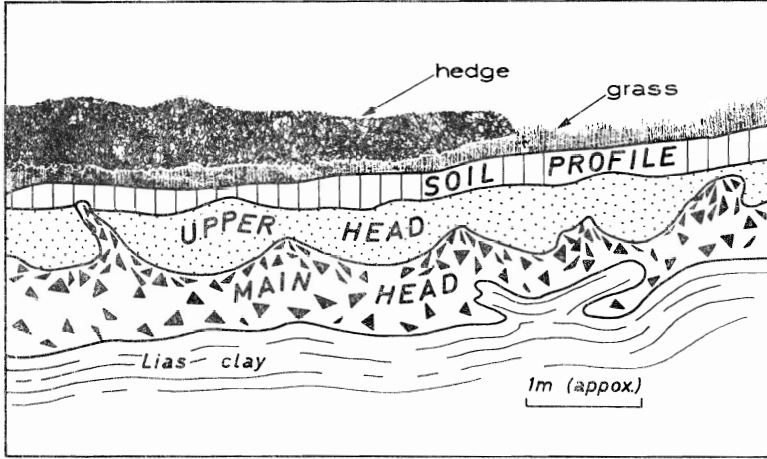
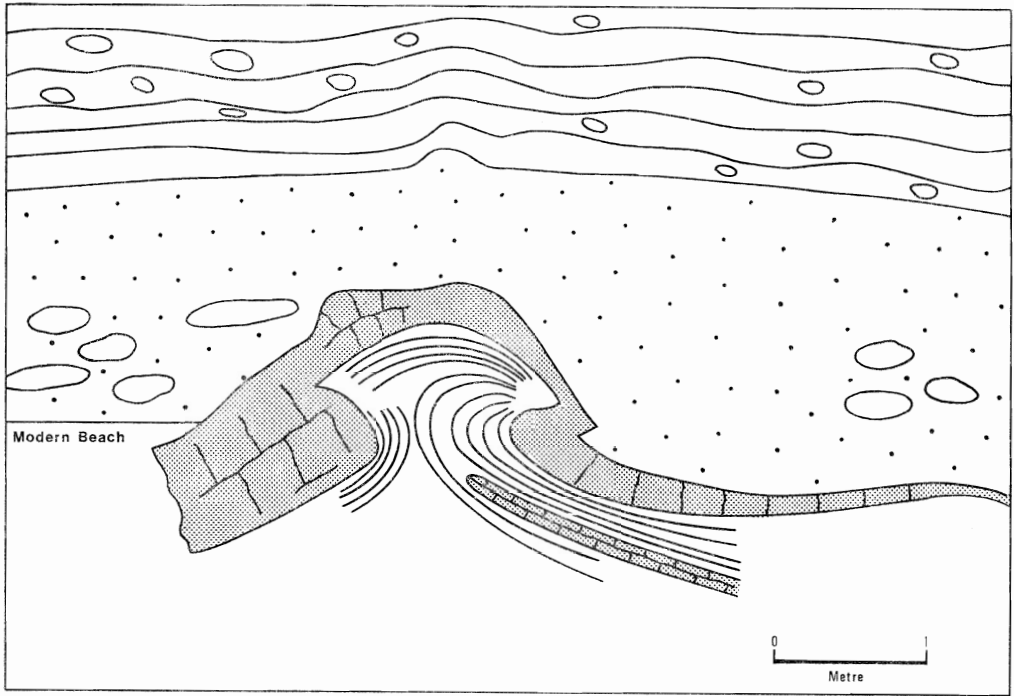


FIG. 5.
Contortions of the Lias, gravels and loams exposed in the cliffs in Helwell Bay.



- | | | | | |
|--|---|------------------|--|-------------------------------|
| | Contorted, poorly bedded, platy gravels | } Cobbly gravels | | More competent Lias Limestone |
| | Contorted cobbly buff loam | | | Contorted Lias paper shales |
| | Boulder rich horizons | | | |

FIG. 6.
Mushroom-like structure (diapir) east of footpath.

Approximately 200 m. east of the footpath a large mushroom-like structure (diapir) affects the Liassic rocks (Fig. 6). The otherwise gently dipping limestones and shales are projected upwards for well over 1 metre into the Cobbly Gravels. The upward burst of paper shales has been only partially contained by the overlying more rigid limestone band, which has buckled and partially fractured in response to the pressure.

Close by this structure the stones at the base of the Cobbly Gravels are set on edge into the surface of the Lias platform. Where the overlying deposits are stripped away, these stones appear to form a polygonal pattern in plan (Plate II) typical of the periglacial pattern formed by frost sorting in stony ground (A. L. Washburn, 1973).

Structures within the Cobbly Gravels

The dip measurements show that the stones of the Cobbly Gravels tend to lie with their long axis near the horizontal, which sometimes gives the impression of bedding. At the same time, at many points throughout the exposure, and at many different levels, stones can be seen with their long axis erect. This kind of structure is described by E. Watson and S. Watson (1971) from periglacial slope deposits elsewhere.

The lowest portions of this horizon are sometimes affected by powerful involutions (Plate III) which carry cobbles and boulders upwards. There appears to be a crude regularity about these features, which can be up to 2 m. deep.

Structures affecting the Upper Loams

Involutions often affect the Upper Loams. The structures already described from the western end of Helwell Bay (Fig. 2), pass up into loam layers representing a total depth of disturbance of 2–3 m. At the junction of the Cobbly Gravels and loam beds, the wave-like involutions have a wavelength 2–3 times the amplitude.

In the area of the footpath the red blocky loam and buff loam are affected by involutions. At several sites the red blocky loam is let down in pipes and V-shaped wedges; boulders and gravels sometimes carry upwards into these pipes (Fig. 3).

INTERPRETATION

Structures

The structures may all have formed in a periglacial environment. Although the mechanisms responsible are not clear, similar features elsewhere in the British Isles are generally accepted as having developed under periglacial conditions.

Patterned ground (Plate II) is not confined to periglacial areas but is nevertheless highly characteristic of arctic and sub-arctic regions (Sparks and West, 1972).

The origins of the diapiric structure (Fig. 6) are difficult to determine. Its immediate cause may be upthrust by the paper shales due to loading by boulders on either side of an unloaded central section. However, it may also be related to frost processes. The limestones and shales retain differing quantities of water and, on freezing, differential expansion coupled with the different strengths of the rock-types may have resulted in this disturbance.

The lenses of sorted, cross-stratified sands are rather contorted, and the contortions often seem to be transmitted through a substantial thickness of the Cobbly Gravels. Such folds may result from a buckling up during mass movement of the deposit in a periglacial environment (C. Embleton and C. A. M. King, 1968).

The pipe and wedge-shaped structures, let down into the buff loam (Unit 3) are filled with red blocky loam (Unit 4) at Doniford. At many British Quaternary sites similar features have been attributed to solution. Generally similar, but much larger structures, occur in the limestone terrace gravels at Long Hanborough, Oxfordshire (Kellaway, Horton and Poole, 1971). Here also pipes occur which are associated with distortions of the surrounding or lower deposits. It is difficult to see why solution, even with subsequent differential loading, should cause such a marked distortion and upward passage of boulders into pipes. These structures are tentatively regarded as the consequence of prolonged churning of the deposits by frost action, as at Long Hanborough.

These structures affect every horizon except the uppermost loam (Unit 5), and their distribution suggests that periglacial conditions prevailed throughout the period of accumulation up until the deposition of that loam.

Deposits

The fundamental question concerning the deposits is whether they, like the structures, are periglacial in origin or whether they might be entirely or in part glacial deposits which have been considerably affected by frost heaving.

Apart from local Jurassics and Triassics, the contained rocks are primarily of Devonian age, which implies an origin not far from Doniford. The implications of an ice sheet moving up the Bristol Channel are that the Cretaceous flints and cherts so common in the glacial deposits near Bristol (Hawkins and Kellaway, 1971) ought to be present at Doniford. Yet, despite careful searching, no such erratic material has been noted either in the loams or the Cobbly Gravels. So a directly glacial origin of the deposits is unlikely. A probable source for the Devonian rocks is the Brendon Hills inland of Doniford, and they could have been transported from a catchment inland by an early Washford River, confluent with the Doniford Stream. This accords with the interpretation of the dry channel system and infill gravels between Watchet Station and the Coastguard Lookout.

These Cobbly Gravels are not, however, simply the result of alluvial deposition. Stone orientation studies, though not entirely conclusive, suggest some stone long axis peaks parallel to the slope of the hill behind Doniford (Fig. 4), indicating that this may have been the final direction of movement. The general lack of sorting and abundance of frost shattered boulders suggests that the Cobbly Gravels are periglacial head deposits derived from former alluvial deposits. They are in many ways similar to the periglacial deposits in other parts of south-west England (Mottershead, 1971). The higher proportion of non-local rocks and the slightly higher degree of rounding are still consistent with a periglacial origin for the Doniford deposits.

The accumulation of the gravels and cobbles in their present attitude must have been a complex process of several stages. The lenses of sorted, stratified sands and gravels (Fig. 3) suggests reworking by small streams running temporarily over the surface of the accumulating material.

Fluvial activity becomes progressively more marked towards The Swill, where channels formed cut and fill stratification up to 7 m. across, which are filled with well sorted, cross-stratified sands demonstrating the importance of surface streams. Recent hydrological studies of periglacial streams in northern Canada (S. B. McCann, P. J. Howarth and J. G. Cogley, 1972) emphasize the role of spring snow melt in releasing large quantities of water in such an environment. The dip of the

stratification varies considerably but is generally towards north. This direction suggests transport from inland by some streams running off local hillslopes but primarily by a forerunner of the Doniford Stream.

The Upper Loams, though different from the Cobbly Gravels in structure and composition, nevertheless share the poor sorting and downslope orientation which are characteristic of solifluction deposits. They are comprised largely of local material and, topographically, they can be seen to form aprons sloping off the adjacent hillsides. The Red Loam (Unit 4) may represent the removal and redeposition of adjacent red Triassic deposits, with the occasional Devonian fragment incorporated from the Cobbly Gravels below. The Buff Loam (Unit 3) is taken as representing the redeposition of weathered Lias clays, with the incorporation of Jurassic and Rhaetic limestone fragments. The occasional thin bedding suggests local deposition by slopewash. The uppermost Brown Loam (Unit 5), sometimes structureless, at other times thinly bedded, is almost certainly the stratum from which the Mesolithic implements were collected, and is probably an accumulation of material due largely to hillwash.

Almost the entire section can thus be explained by reference to periglacial processes. This conclusion does not necessarily preclude a previous covering by ice sheets. The original glacial deposits may have been completely removed by the time the Doniford deposits collected. Alternatively the ice sheets may have merely butted against a coast further north than the present one, never actually depositing sediments in this part of Somerset.

DATING

Although variations in the stratigraphy do occur, there is no evidence at the moment for any major time break within the succession. Consequently almost the entire sequence can be related to one continuous cold periglacial phase. The only exception to this may be the uppermost loam, which is considered to be of Flandrian (post-glacial) age (Table 5).

Table 5. *Stage names of the middle and late Quaternary in Britain*

Flandrian	post glacial
Devensian	glacial
Ipswichian	interglacial
Wolstonian	glacial
Hoxnian	interglacial
Anglian	glacial

No plant and animal remains or weathering horizon has been found in the deposits which would facilitate correlation with the pollen-dated successions of south and south-east England (see West, 1968). No vertebrate remains or palaeoliths were found during the present investigation. However, the size and toughness of large vertebrate remains and flint implements, such as those described by the Wedlakes, would enable them to withstand reworking. Consequently the deposit in which they are found may be younger than the finds themselves. The finds, therefore, can only give a "not older than" type of date.

The ages of the finds are readily deduced from similar finds elsewhere. The type of Mesolithic implement, found in the Upper Loam, dates from 9500-6000 BP,

and this accords well with our interpretation of a Post-Glacial (Flandrian) age for the topmost loam.

Remains of tusks and molar teeth of *Elephas primigenius* (the woolly mammoth) were found by the Wedlakes in the Cobbly Gravels. This species, first known from the Wolstonian glacial stage, is present during the Ipswichian interglacial and becomes common during the Devensian glacial stage (West, 1968). It lived in open habitats, but it was present for such a long span of time that an accurate date cannot be attached to a find at Doniford.

Palaeolithic implements of Acheulian age are described by the Wedlakes from the lower gravels, presumably the unit that we have named Cobbly Gravels. The Acheulian culture is typical of the Hoxnian interglacial. The nature of the Cobbly Gravels suggest a cold environment; it is therefore likely that these artifacts were transported to their present position in a cold stage after the Hoxnian. Their abraded nature supports the hypothesis of reworking. Not enough evidence exists to determine if the Wolstonian or Devensian cold period was the one. The mammoth and artifact evidence would allow either for the age of the Cobbly Gravels. If these deposits are of Wolstonian age, and the topmost loam is Flandrian, the problem remains of how the Devensian stage is represented at this locality. As indicated earlier, there is no indication of a major time break in the deposition of the Doniford Gravels. Thus it may be more realistic to regard them as one continuous depositional sequence, which can then be referred to the Devensian stage. This interpretation is shown to be consistent with the occurrence of older material within the deposits.

CONCLUSION

The deposits and structures observed in the cliff section at Doniford are essentially periglacial in origin and, on the evidence available at present, are attributed largely to the Devensian glacial stage. They lie along what is apparently a former course of the Washford River and are interpreted as reworked river gravels.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. R. J. H. Werren (Surveyor to Watchet UDC) for providing valuable information on the rate of cliff recession at Doniford; Professor G. F. Mitchell and Mr. P. C. Sims for discussion of the site; Mr. J. K. Abrahams and the Cartographic Unit of Portsmouth Polytechnic for drawing the diagrams and Mrs. Chris Stratford and Mr. P. C. Sims for photographic work. Dr. A. Whittaker provided much useful information on the geology of the area. D. D. Gilbertson acknowledges the defraying of expenses occasioned during field work by the staff research fund of Plymouth Polytechnic.

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