Proc. Hampsh. Field Club Archaeol. Soc. **40**, *1984*, *5–20*

PERIGLACIAL FEATURES EXPOSED IN THE COASTAL CLIFFS AT NAISH FARM, NEAR HIGHCLIFFE

By M E BARTON

ABSTRACT
Superficial structures of periglacial origin have been examined in the cliff top scarp exposures at Naish Farm, near Highcliffe. They include a presumed valley bulge, frost wedge casts and involutions and cryoturbation structures. They are compared with similar fossil structures seen elsewhere in Southern England and their affinities, origin and possible ages are discussed. It is suggested that in view of the frequently comparable, but usually less well exposed, geological conditions in the Hampshire Tertiary Basin, such features may be of rather more common occurrence in the region than has been realised hitherto.

Fossil structures produced by periglacial activity in south west Hampshire have been reported by Lewin (1966), Swanson (1970) Fisher (1971) and Keen (1980). Features produced by periglacial activity are currently exposed in the coastal cliffs at Naish Farm, near Highcliffe (see location plan, Fig 1). They include a presumed valley bulge, frost wedge casts, involutions and cryoturbation structures. They are recorded here not only for their own intrinsic interest but also because of the ephemeral nature of the exposures due to the rapid rate of cliff recession in the area.

The area is part of the coastal cliff outcrop of the Barton clay which is overlain by the Plateau Gravel and Brickearth. The cliff profile is markedly stepped with a steep back scarp (Barton 1973) except in the vicinity of the presumed valley bulge (in the east of the area shown in Fig 1). The back scarp is generally 3 to 4m high and exposes 1·5 to 3m of Plateau Gravel overlying Zone F of the Barton Clay (as defined by Burton 1933). Zone H is just visible to the east of the area but the thin Zone G is not (its dip would bring it up at the site of the presumed valley bulge but, as discussed below, the disturbance there has effectively removed it). Brickearth is present in an extensive sheet up to 3·2m thick to the east but over the area itself it is too thin to be mapped as a geological deposit although (as described by Fisher 1971) it is present in sufficient quantity to influence the character of the topsoil.

Presumed Valley Bulge. A sketch section of this

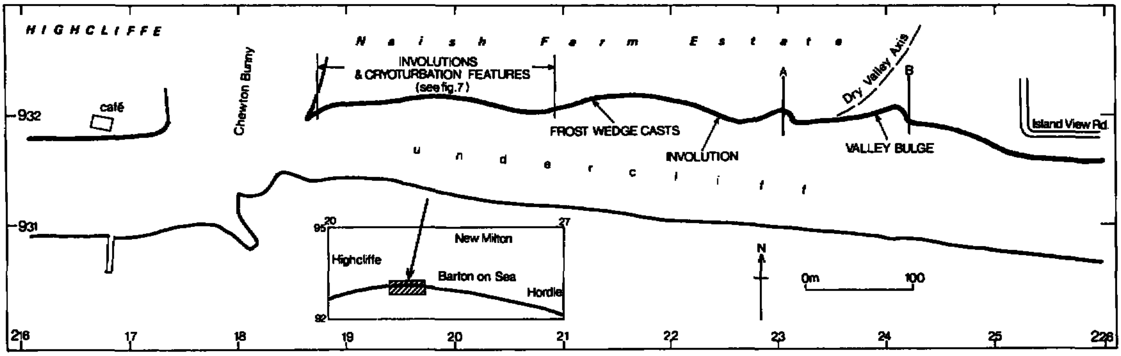

Fig 1. Naish Farm. Sketch map showing locations of the periglacial features. Lines A and B mark the extent in the cliff face of the dry valley solifluxion material.

feature is shown in Fig 2 and a photograph of part of it in Fig 3. The exposure occurs in the cliffs below a shallow dry valley and is seen on the west face of a narrow ridge extending down from the cliff top. There are no other clear exposures in the immediate vicinity owing to the abundance of scree and other colluvial debris.

The exposed face covers about 5m change in elevation and shows a sharply angled fold with a slight overturning in Zone F of the Barton Clay. The fold is clearly displayed by the 12 to 15cm thick band of red clay, together with its associated concretions, which is a very prominent and persistent horizon in Zone F (being recorded by Burton, 1933, as a layer of concretionary clay-ironstone). The concretions take the form of impersistent, up to 3·5cm thick, tabular layers contained within the red clay and large nodules which periodically take the place of the red clay band. The nodular concretions elsewhere can be up to 30cm thick by 130cm long and frequent but in the exposed face only one such nodule of 27cm thickness is present. The tabular concretions are rusty red on the outside but grey inside; the nodules are brownish red to yellowish buff outside but dark grey inside when freshly broken. The red colouration of both the clay and concretions is due to the oxidation of siderite (whose presence has been determined by X-ray diffraction analysis by Mr T Clayton, pers comm). Oxidation of the siderite has not occurred in the interior of the concretions presumably owing to their relative impermeability to air. The hardness or induration of the concretions is thought to be due to cementing, mainly by calcite (T Clayton, pers comm).

The exposed face shows a slight offset (of about 8cm) in the line of the red clay below the nodule suggesting that minor thrust faulting has taken place. Bedding planes in the Barton Clay are just discernible and conform to the fold seen in the red clay. At 0·25m above the red clay is one of the prominent fossil lenses with *Turritella* which are abundant around this level in Zone F (the 'shell drifts' of Burton 1933). The fossil lens clearly displays the folding before it is cut off by the erosion surface at the top of the exposed face. Bedding planes are not discernible beyond a small distance above the fossil lens and the clay, where it appears from under the scree covering, takes on a rubbly texture.

A gravelly and clayey silty sand, up to 0·6m thick and very different in grading from the Plateau Gravel, is present at the top of the face.

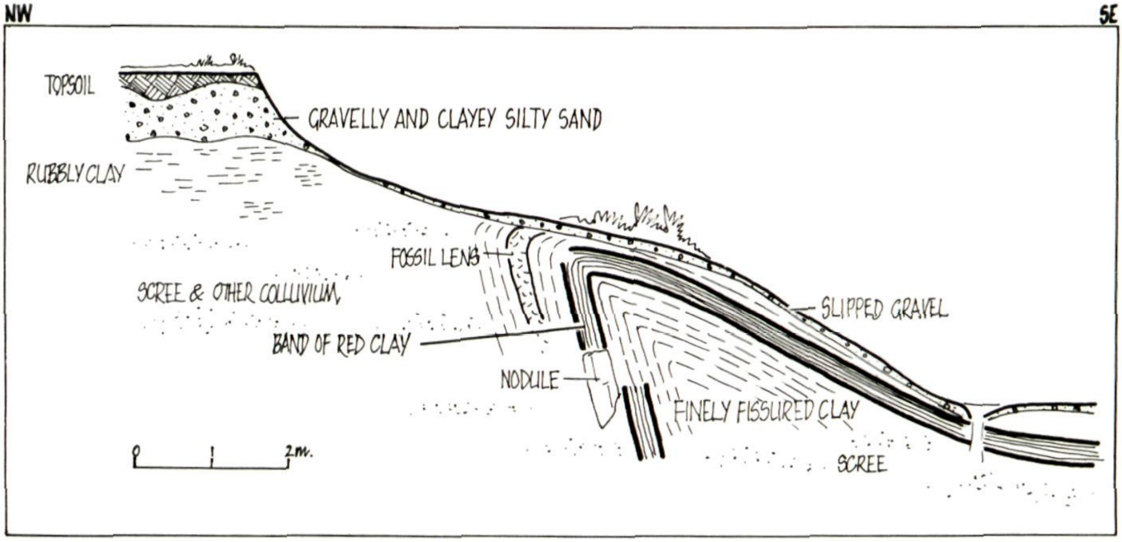

Fig. 2. Naish Farm. Presumed valled bulge structure showing overfolded anticline with minor thrust fault. The exposure is aligned transverse to the cliff-line (ie, with an average orientation of E 55° S to W 55° N).

Fig 3. Naish Farm. Photograph of part of the presumed valley bulge structure showing the up-ended nodular concretion. The distorted shelly lens (pale grey) can be seen above and to the left of the nodule (just to the right of the ranging rod). The ranging rod is marked in ½m divisions. This photograph should be compared with the sketch in Fig 2.

Unfortunately owing to lack of exposures on either side its continuity with, or relation to, the Plateau Gravel has not been investigated. The base of this material, although irregular, shows no trace of the folded structure in the Barton Clay and evidently post-dates the folding.

To investigate the relationship between the fold and general dip in the area, levels have been determined on the top of the red clay using E D M (electronic distance measurement) surveying by Mr B J Coles. The results are shown in Fig 4 together with some elevations determined for the cliff edge. A section has been drawn through the levelled points and it indicates that the sharp fold of Fig 2 rises 3·3m above the assumed original elevation of the red clay. The apparent regional dip of the Barton Clay throughout the undercliffs at Highcliffe is actually less than 1° and it is evident, therefore, that the assumed uniform dip of 3° shown in Fig 4 is anomalous. It seems that all the elevations recorded at the western end of the section line in Fig 4 are higher than they should be given the regional dip of the strata. Allowing for this regional dip, the maximum elevation of the red clay in the sharp fold becomes about 3·7m above what should be its true elevation. The superficial crustal shortening due to the intense folding of Fig 2 is about 3m but taking a 60m length of the western end of the section line in Fig 3 the shortening is about 20m.

The folding could be ascribed to four possible modes of origin. The first would be to suppose that it represents contemporaneous slumping of the sediments and the second that it is of tectonic origin. The former is unlikely since no really similar structures, and certainly none on this scale, are seen or recorded in the Barton Clay coastal outcrop (although slumping occurs in both the Bracklesham and Barton Sands: I M West, pers comm). The fold is superficial since Zones C and D of the Barton Clay, in the lower part of the undercliffs of the area depicted in Fig 4, continue the uniform regional dip without trace of disturbance. The axis of the fold appears to run approximately N E to S W(ie parallel to the line of the dry valley). A tectonic origin is consequently thought unlikely in view of the superficial character, the axial trend (which is approximately normal to the axial trend of the shallow folds in the region as shown by Curry 1976) and the absence of any similar structures away from the vicinity of the dry valley. A sharp anticlinal fold with other deformation in Headon Beds occurs at Linstone Chine, Isle of Wight (at a distance of 6 miles from Naish Farm). This structure is assumed to be of tectonic origin (White 1921) but its exact nature and origin requires further study in the light of modern knowledge concerning valley bulges before a tectonic origin can be definitely established.

A third explanation would be that it is

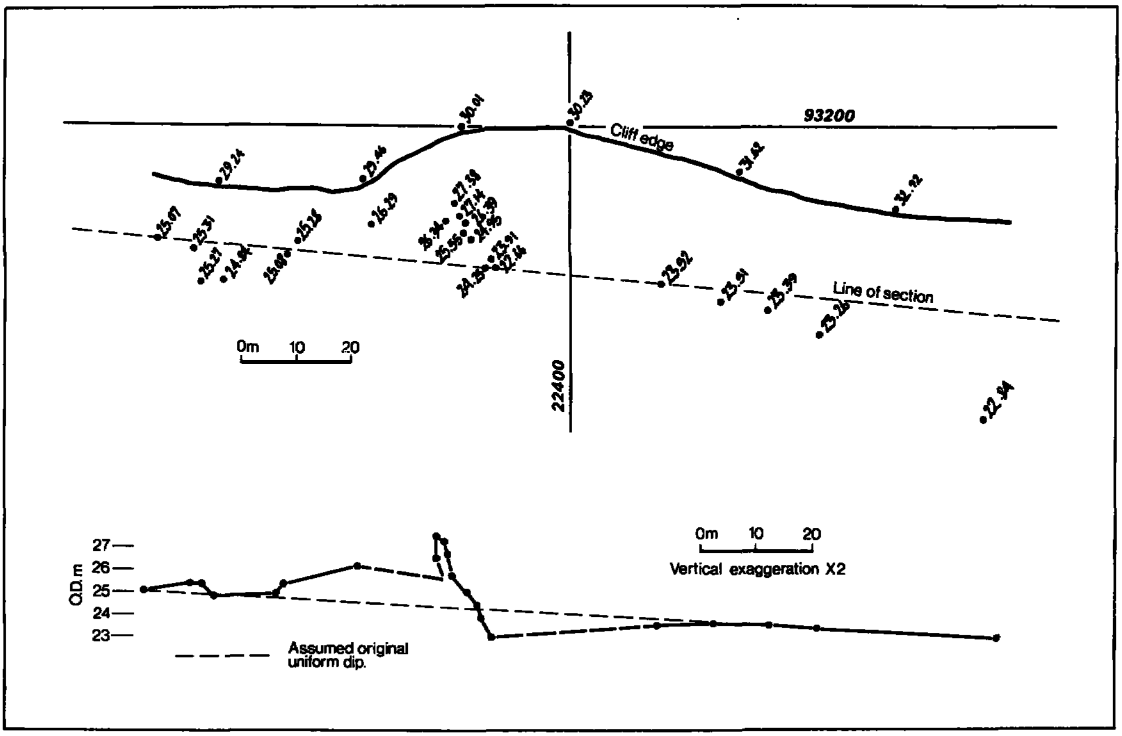

Fig 4. Naish Farm. Above: levels (m OD) on the top of the red clay band with levels on the cliff top (behind cliff edge). Below: projected line of section through levels on the red clay.

produced by the modern mass movement activity present throughout the undercliffs. However, even a cursory examination indicates that the form of the structure is unlike any other feature produced by the local landslide activity (Barton 1973). Slumping of the cliff top, or of scarp slopes within the undercliff, is accompanied by rotational movements with back tilting but the back tilted strata show only a fairly uniform tilt away from the free face of the slump block towards a rotational shear surface (Barton *et al* 1983). There is no sign of a shear surface behind the exposure or between the exposure and the cliff top. Furthermore, as demonstrated by Fig 4, the beds show an elevation considerably above the level expected from the average dip and even where back tilting occurs the tilt is compensated by reduction in elevation due to slumping. The feature is clearly not produced by the modern landslide activity in the undercliffs.

The fourth, and most plausible explanation, as adopted here, is that it is a valley bulge and belongs to the same general class of such structures as originally described by Beeby Thompson (1903) and discussed in detail by Hollingworth, Taylor and Kellaway (1944). Valley bulges similarly showing overturning and the development of minor thrust faulting have been recorded among the well documented examples occurring at the site of the Empingham Dam in Rutland (Horswill and Horton 1976). Thrust faulting is seen in the valley bulge at the Weir Wood Dam in Sussex (Walters 1971). The former valley bulges have elevations up to 18 to 25m and the latter about 7m. Sharply angled and in part over-folded strata forming valley bulges with amplitudes ranging from 5m to 9m were recorded in the Yorkshire Coal Measures by Shotton and Wilcockson (1951). If we take the bulge at Naish Farm to be 3·3m in amplitude it is slightly smaller than the example recorded in the Weald Clay at Hubbard's Hill in Kent (about 5m) by Skempton and Weeks (1976) and approximately of the same order as those recorded at Keynsham in the Lias Clay by Tutcher (1923, which is re-illustrated with additional information in Chandler *et al* 1976) and Leese *et al* 1958. A superficial anticline of about 3m amplitude (T I Longworth, pers comm) recorded in Oxford Clay is illustrated in Burland *et al* 1978 and appears to be a similar class of structure.

The valley beneath which the Naish Farm structure is seen is a dry and shallow one of only 5·5m depth with very gentle side slopes averaging about 30:1. It extends inland as a recognisable feature for at least 200m and over most of this length it is orientated NE to SW. On approaching the cliff edge it curves into an ENE to WSW path and hence its axis reaches the cliff edge at about 50m west of the exposed valley bulge. Due to the curvature of the valley axis the valley bulge at its nearest point (i e, inland from the cliff edge) is about 15m distant. Exposure of the strata in the upper part of the cliff is poor for a distance of about 100m west of the valley bulge but so far no trace of folding on a similar scale has been seen in this region. Thus it appears that the more intense deformation of the strata occurs slightly to the east of the modern valley axis. It is important however to appreciate that the valley may have been modified subsequent to the valley bulging and that formerly the axis could have been further to the south east. These modifications may also have reduced the relative depth of the valley consequent upon both the bulging and possible erosion of the surrounding areas but, nevertheless, the valley still seems a remarkably shallow one beneath which to find such deformation of the strata.

The gravelly and clayey silty sand overlying the presumed valley bulge can be traced as a deposit mantling the floor and sides of the dry valley. In places it is cryoturbated in a complex manner with the top of the Barton Clay. The cliff top in this area does not show the typical steep, exposed scarp face seen in the rest of the cliffs, presumably because of the relative ease with which the material, and its cryoturbated zones, weather down. While the relationship of this material to the other drift deposits cannot be examined in detail, the general appearance is that it is a valley infill deposit formed by solifluxion.

In view of the limited size of the valley, the absence of associated cambering, dip and fault structures and its relative small size, it could be argued that the Naish Farm structure is not a true valley bulge but some other kind of periglacial feature. Thus anticlinal folding of several metres amplitude is recorded in chalk muds at Dover Hill, Kent by Kerney 1963 (and very similar structures in Berkshire by Patterson 1971). However, this latter structure is developed in soils which mantle a valley slope and the folding is clearly the result of the mass sliding down the hillside, foreshortening the strata and resulting not only in the anticlinal folds in the valley bottom but in thrusting and imbrication of the chalk muds within the slope itself (Kerney 1963). The mechanism is similar to that described by Jahn 1956.

Other sharp anticlinal structures with overturning have been recorded by Bradshaw and Ingle Smith (1963) in Triassic rocks on Sully Island, Glamorgan and in Rhaetic Clay and White Lias at the Stanton Wick Reservoir in Somerset by Higginbottom and Fookes (1970). In both of these cases there is clear evidence of injection of the lower strata into the upper. Thus the folds with an amplitude of about 1m on Sully Island involve separation and injection of blocks of sandstone into marls and Bradshaw and Ingle Smith suggest that there has been no superficial crustal shortening across the fold axes. At the Stanton Wick Reservoir the White Lias overlying the fold is clearly pierced by the sharp fold and Higginbottom and Fookes describe the structure as an involution.

The Naish Farm structure does not show injection into higher strata (although the latter may have been eroded away) and is clearly very different in character to the involutions to be described below. While some doubt must remain concerning the exact status of the Naish Farm structure, particularly in view of the present limitations of knowledge about the origin of valley bulges, the considerable difference from the typical involutions seen further east together

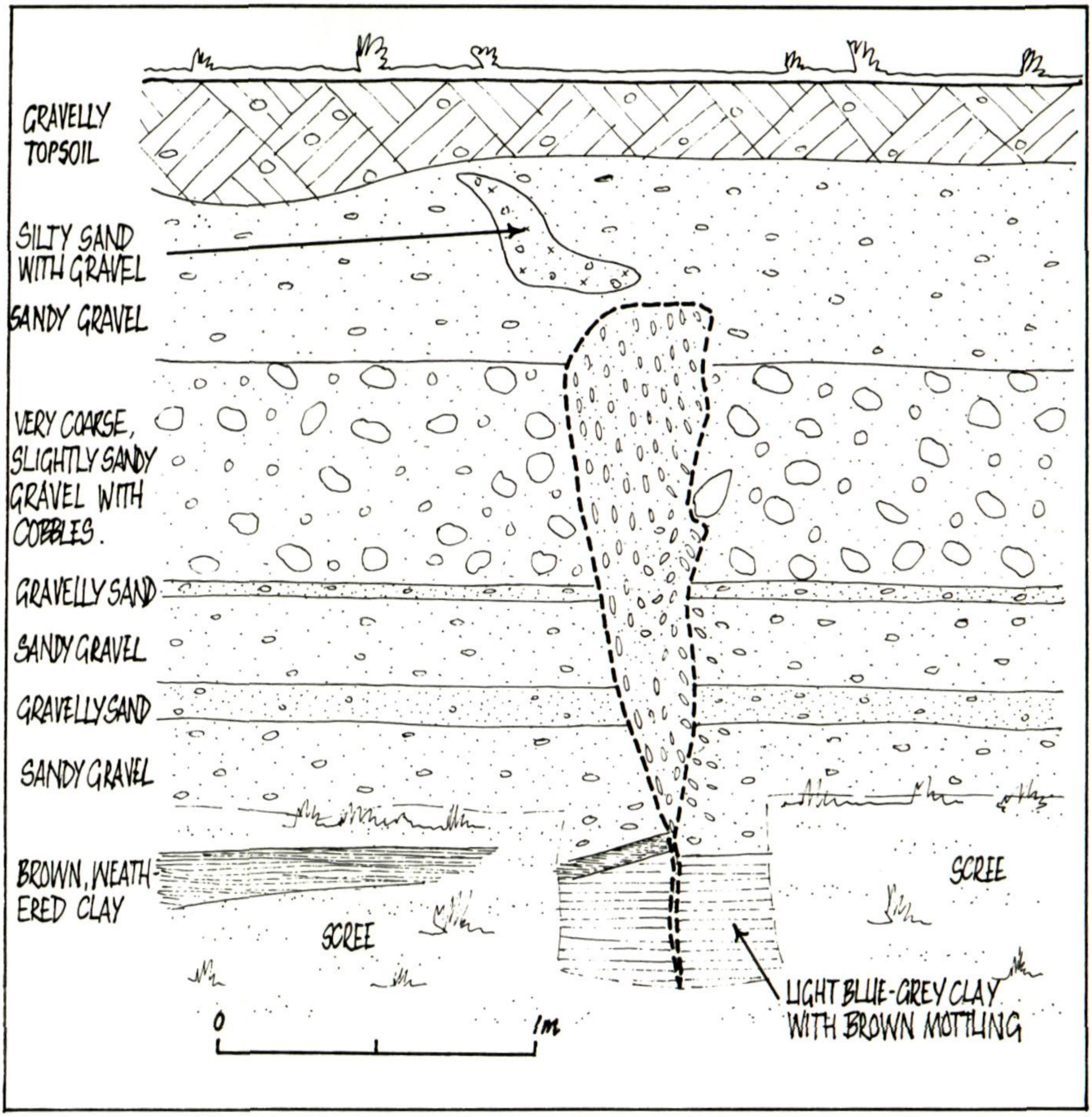

Fig 5. Naish Farm. Frost Wedge Cast (NGR 2213 9321). The cast continues to the base of the excavation as a fissure of approximately 1·5mm thickness. Just above the visible base it broadens to 5mm and is filled with coarse sand and fine gravel.

with the similarities to the structures so described suggest that the classification applied here is the most appropriate one at the present time.

During study of the cliff top slumping (Barton *et al* 1983) little attention was paid to periglacial features. The locality was regarded as being an area subject to much cryoturbation and its true nature has been recognised only subsequently. The bulge clearly disrupts the expected stratigraphical sequence in this part of the cliffs. Thus horizon G (which

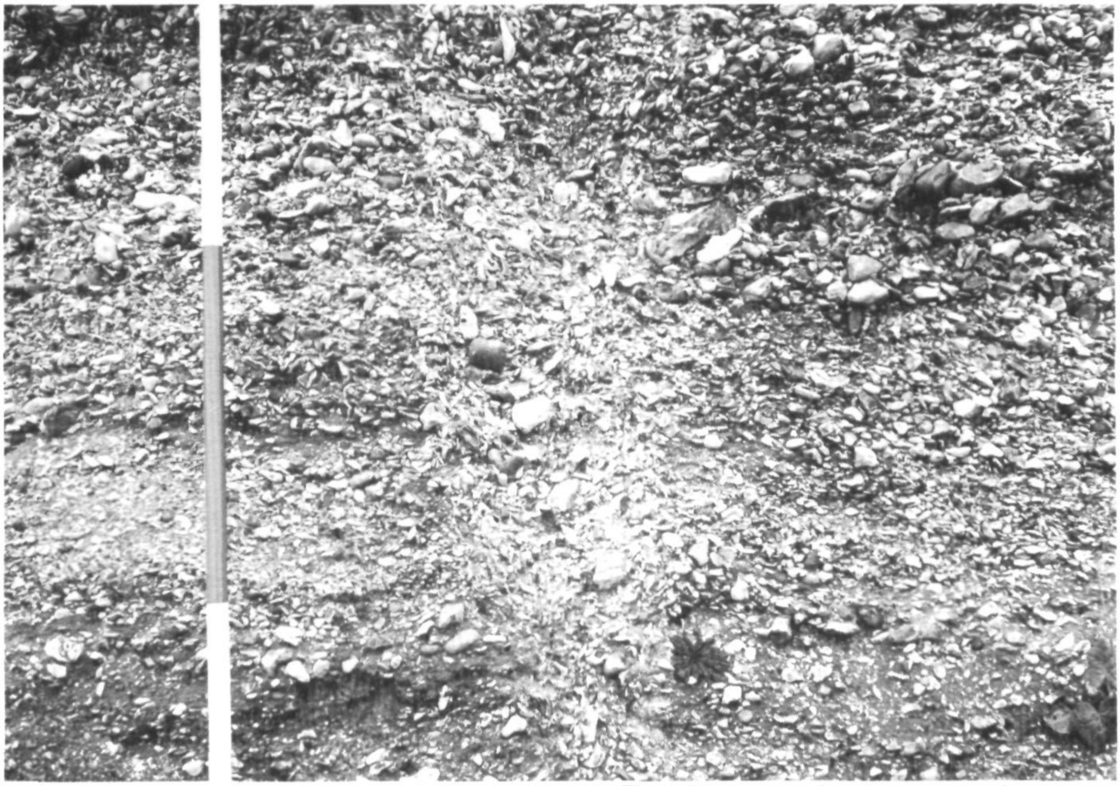

Fig 6. Naish Farm. Portion of frost wedge cast sketched in Fig 5. The cast can be picked out by the pebble alignment within its boundaries. The rough layering of the Plateau Gravel can be seen and in particular the coarse layer with small boulders; one of which appears to jut into the cast on the right hand side (see Fig 5). The ranging rod is marked at ½m intervals.

is 5·7m above the red clay with concretions, Barton 1973) should be present at this locality but has clearly been uplifted and eroded away. The section through the Highcliffe-Barton on Sea cliffs shown in Curry and Wisden (1958), and reproduced in Hooker (1975) and in Melville and Freshney (1983), does not recognise this disruption and extends the outcrop of G and the base of H too far to the west in the present cliff-line. Owing to the curvature of the valley axis combined with the rate of cliff recession the outcrop of the disturbed strata (supposing that they continued in that direction) would have been further west (possibly by more than 50m) in the nineteen fifties. Hence while the section may have been approximately correct at that time, it is certainly in error now.

Frost Wedge Casts.

A search was made for signs of these features in the cliff top at the Naish Farm estate during the Spring of 1983 but only two indisputable examples were found at the location shown in Fig 1 (NGR 2213 9321). They were approximately 2m apart; the easternmost one being the larger of the two and the more clearly seen. A sketch of this one is given in Fig 5 and a photograph of part in Fig 6. The base of the cast was not exposed and the scree was excavated to reveal that it continued for at least 0·43m into the Barton Clay as a narrowing crack, still filled to a depth of 0·35m with sand and fine gravel and from there continuing as a narrow fissure whose base could not be reached.

The top of the cast merged into the upper part

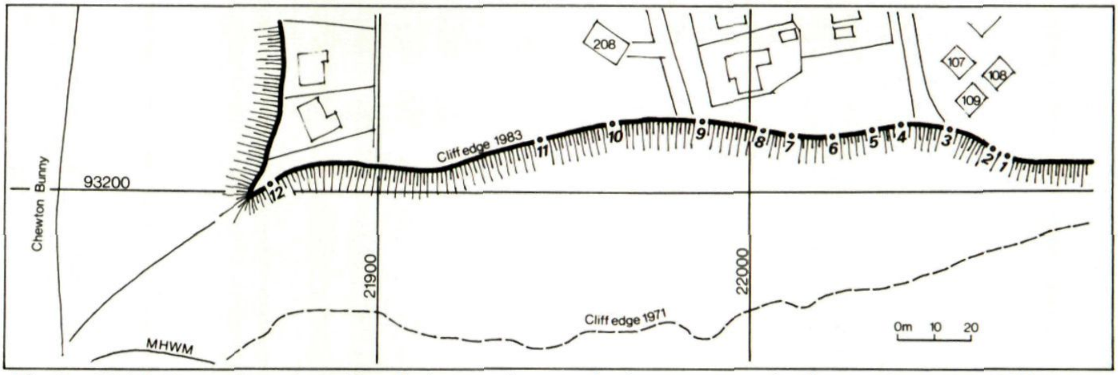

Fig 7. Naish Farm. Location of involutions and cryoturbation structures in the area just east of Chewton Bunny (see Fig 1). Nos 1 to 9 inclusive and No 12 are involutions while between points Nos 10 and 11 there is a complex zone of cryoturbation structures.

of the Plateau Gravel. Above the recognisable top, a separated and irregular lens appears as seen in Fig 5. This lens appears to be a continuation of the frost wedge cast but interestingly is filled by material containing abundant silty fine sand suggesting an affinity with the Brickearth, as does the topsoil which is also rich in the same material and an example of a brickearth-soil (Fisher 1971).

The main part of the frost wedge cast is filled with a sandy gravel indistinguishable in grading from the rest of the Plateau Gravel except that it tends to lack the very coarse gravel and small boulder fraction. The infilling is notably of a pale, apparently bleached, colour and causes the cast to appear prominently in the cliff face in contrast to the yellowish brown colour of the surrounding material. Orientation of the pebbles is seen; these are generally aligned vertically although there are some curved patterns traced by the pebbles. Regular orientation of the pebbles in the ambient material is restricted to the immediate vicinity of the cast but was especially noted on the eastern (right-hand) side, low down.

The total depth of the cast from the base of the topsoil is 2·6m with a width at the top of 0·45m. It is similar in scale and character to a 2·0m deep frost wedge cast in Devon described by Waters (1961) where similar upturning of the surrounding material occurs. The general pattern is also similar to frost wedge casts illustrated by Te Punga (1957) and French (1976) and the general form is consistent with photographs of active frost wedges illustrated by Washburn (1973). Comparison with the three types of ice wedges of Shoezov (in West, 1968) suggests an epigenetic formation. The character of the Naish Farm example also accords fairly well with the description of three examples found nearby at Highcliffe (at about 300m to the west of Chewton Bunny) by Lewin (1966). These appear to be slightly larger with top widths of 0·9 to 1·2m and a maximum depth of 3·0m. The bleached colour of the sandy gravel infill, the pebble alignment and indications that the frost wedges left surface depressions in which the 'loamy' soil (i e, the brickearth-soil) accumulated are other similarities.

The extension of the Naish Farm frost wedge cast into the underlying Barton Clay and carrying coarse sand and fine gravel down into that horizon is significant. It has previously been noted that gravel can occur at considerable depths below the expected top of solid strata elsewhere in the Hampshire Tertiary Basin. Thus I have personally seen borehole samples bearing gravel at depths of up to 4m below the surface of the Bracklesham Beds (sandy facies) in the area of Southampton Container Docks and gravel has been recorded on borehole logs at depths up to 6·5m into the Bracklesham Beds in the same area. A gravel filled fissure in Eocene Clay was encountered during the construction of

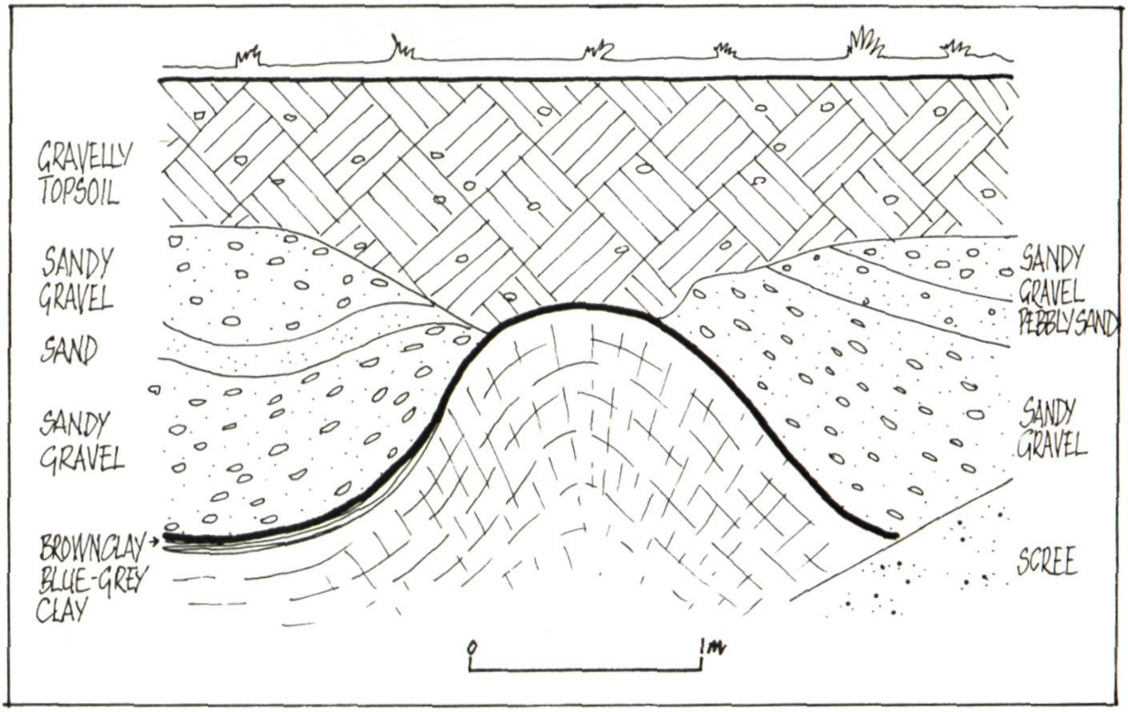

Fig. 8. Naish Farm. Involution of Barton Clay into Plateau Gravel. This feature is No 7 shown on Fig 7.

Fig 9. Naish Farm. Involution with a plug of Barton Clay extending up into the Plateau Gravel. A deformed sand lens is seen on either side: to the left it is just above the top of the metre rule (held by Mr B J Coles) and to the right it can be seen under the spade handle. The gravelly brickearth-soil is seen to thicken up above the clay plug and come into contact with the latter. A radiating fissure pattern can be seen in the clay plug. This involution is No 7 in Fig 7 and is sketched in Fig 8.

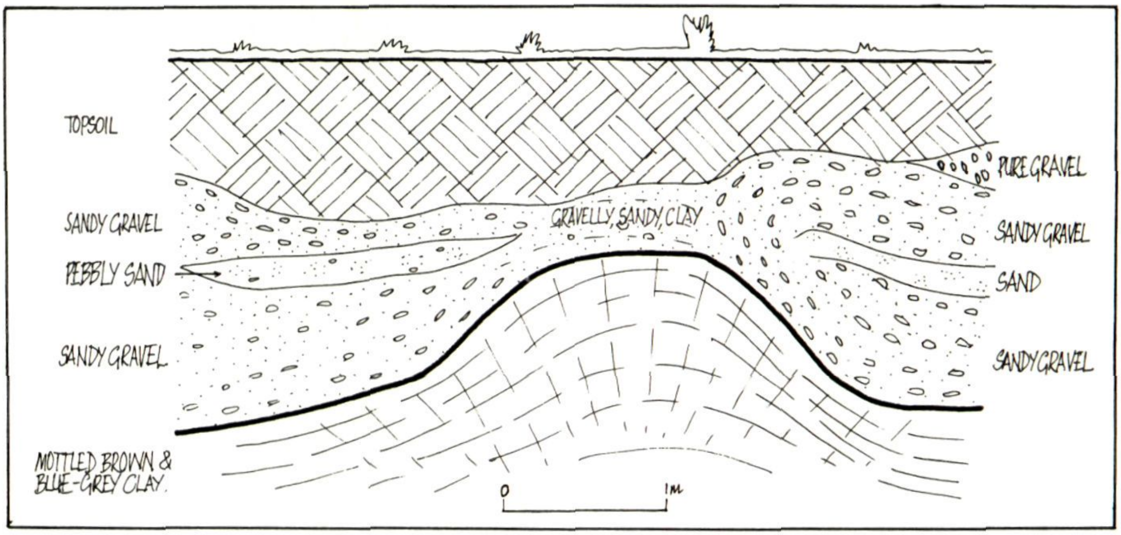

Fig 10. Naish Farm. Involution recorded in Spring 1982. This is believed to be in the vicinity of No 8 shown in Fig 7 but further seawards.

the tunnel beneath Southampton Water and caused engineering difficulties (I M West, pers comm). These occurrences would appear to be examples of frost wedge casts extending deeply into the solid strata (from within or from below the Valley Gravel) with evidently much larger dimensions than those recorded at Highcliffe. It is relevant that deep frost wedges have been reported elsewhere: Shotton (1960) records that in the South Midlands although they are usually about 1m deep, the maximum was at least 5·2m.

Involutions and Cryoturbation Structures.

The definition of these structures adopted here is that of French (1976). He makes a distinction between 'cryoturbation structures' which are irregular deformations and displacements of strata and 'involutions' which are the more regular examples of these types of phenomena. This is in contradiction to some authors such as Washburn (1973) who do not draw a distinction between these terms. All the structures to be described under this heading obey the four characteristics for involutions suggested by Worsley (1977).

The structures seen in the Naish Farm undercliffs affect the interface between Plateau Gravel and Barton Clay. They can be seen in the cliff top scarp from the eroded edge of the Plateau Gravel at the side of Chewton Bunny valley eastwards for a distance of 200m (see Fig 1). Beyond this, the Plateau Gravels are notably undisturbed by such features for approximately 150m when another involution can be seen in the vicinity of the dry valley (Fig 1). During Spring 1983 the locations of individual structures in the 200m east of Chewton Bunny were plotted as shown in Fig 7. Numbers 1 to 9 and No 12 on the plan represent individual involutions while between points Nos 10 and 11 there was a more or less continuous zone of cryoturbation structures.

The involutions on the classification scheme of French (1976) are 'plug' type involutions. They appear to represent a diapiric intrusion of the Barton Clay into the Plateau Gravel. They range in size from a slight upwelling of only 7 cms (No 9 in Fig 7) to an upwelling of 1m in the largest (No 7). The latter is shown in Figs 8 and 9. At the base the clay involution is 2·6m wide while the Plateau Gravel has a general depth of 2·0m from the cliff top on either side. Deformation of a sand layer and orientation of pebbles occurs in the Plateau Gravel. The gravelly topsoil (a brickearth-soil) notably increases in thickness above the involution suggesting the

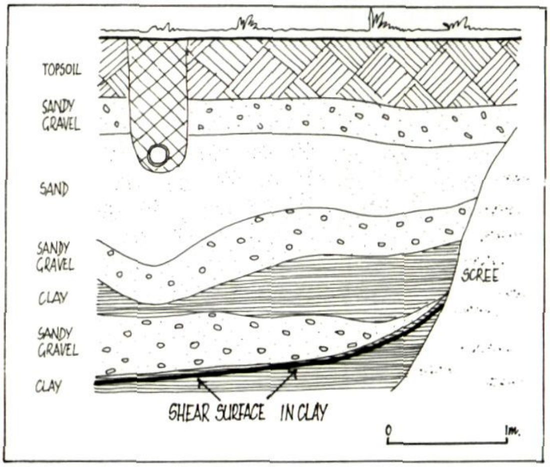

Fig 11. Naish Farm. Sketch of the western side of an involution recorded in Spring 1982. A shear surface is present at the top of the Barton Clay and was apparently formed in association with the involution. The major part of the involution was covered by scree. An old drainage pipe at 1m depth was intersected by the cliff face.

presence of a slight hollow after the structure was formed and in which the brickearth-soil could accumulate.

Sketches made of other involutions during the Spring of 1982 are shown in Figs 10 and 11 and a photograph taken at that time (Fig 12). The cliff top scarp at that time was variously between 1 to 7m further seawards. The involution shown in Fig 10 was in the vicinity of No 8 in Fig 7 and shows separation of a sand layer due to the upward movement of the clay plug. The example sketched in Fig 11 (which was in the vicinity of point No 11 in Fig 7) and photographed in Fig 12 is interesting in showing the development of a shear surface in the clay, sloping away from the involution at an angle of about 5°. There is no sign of a shear surface around the top of the plug but clearly the intrusion of the clay plug generated a shear stress in the clay to one side sufficient to overcome what was then its peak shearing resistance. The shear surface itself is similar to those produced in the Barton Clay in the undercliffs by the present mass movements.

The zone of cryoturbation structures was too complex and irregular to be adequately sketched and rather inaccessible for photography. It shows a series of plug to flame type involutions (averaging about 0·5m in height) with irregular boundaries. Lenses of disturbed Barton Clay and apparently also a mixed gravelly clay occur in the Plateau Gravel. Similar examples involving involutions of clay into overlying gravels have been reported by Tomlinson 1940 (with cryoturbation structures in Lias Clay) and Patterson 1971 (with Gault Clay). Diapiric injection of limestone into the Portland raised pebble beach is reported by Pugh and Shearman (1967) and irregular involutions in tourmalinised granite in Devon are illustrated by Waters (1961). Both of these examples suggest an upward movement of the lower strata into the upper as at Naish Farm.

Further examples of involutions and cryturbation structures, seen by the author but not studied in detail, occur at Highcliffe, west of Chewton Bunny at NGR 2097 9317 (near to the site of the former Beacon Lodge). These similarly affect the Barton Clay and Plateau Gravel. The intervening ground from there eastwards to Chewton Bunny is apparently free from such disturbances (apart from the frost wedge casts reported on by Lewin 1966). Thus whatever mechanism is invoked to explain the origin of these features it is also necessary to explain why the intervening areas of ground are not so affected.

Origin and Age of the Features.

Least doubt concerning the origin of the features exists in the case of frost wedges. It is generally considered that they originate from the thermal contraction cracking associated with the existence of permafrost (French 1976). The presence of frost wedge casts is therefore taken to indicate unequivocally the former existence of permafrost (West 1968). In the case of involutions and cryturbation structures the mechanism may be either the development of cryostatic pressures in the active zone between the permafrost and a newly frozen crust, or else connected with ice segregation where the finer sediments expand rapidly in volume on freezing and intrude the adjacent, still unfrozen coarser materials

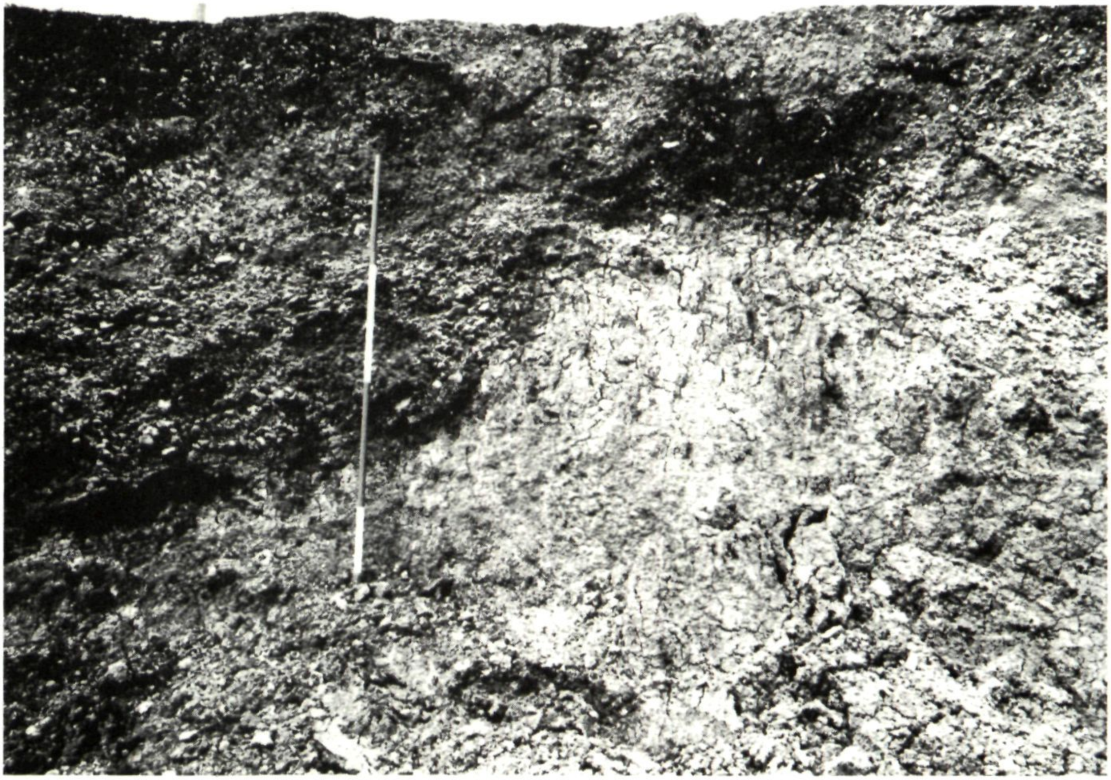

Fig 12. Naish Farm. Involution with Barton Clay plug photographed during the Spring 1982. The ranging rod is marked in one foot divisions. Just below the interface between Plateau Gravel and Barton Clay on the left hand side of the clay plug, is a well developed shear surface parallel to the interface: it dips at about 5° away from the clay plug. This involution is a more complete example of the involution sketched in Fig 11.

(Embleton and King 1968). These two mechanisms have been considered by French (1976) as likely to lead to involutions in the first case and the less regular, cryoturbation structures in the second. The ice segregation mechanism if applied to the Naish Farm structures requires active freezing to take place from below: this does not necessarily imply the existence of permafrost because it could be that the gravels were only partially saturated and water was being drawn up from below. Thus the presence of involutions and cryoturbation structures cannot be taken as definitive indicators of permafrost (French 1976), so that although they may belong to the same periglacial episode as the frost wedge casts they may not be exactly contemporaneous.

Considerable doubt exists as to the mechanism, or mechanisms, causing valley bulges although a periglacial regime is generally thought essential. After considering various theories, Vaughan (1976) suggested the most likely cause of the Empingham bulges was ground freezing (with downslope creep under gravitational loading) superimposed on an initial shear and bulge caused by the relief of horizontal stress during valley formation. In the case of the superficial anticline recorded in Oxford Clay by Burland *et al* (1978), Mr T I Longworth (pers comm) considers that differential temperature gradients acting under periglacial conditions could have been an important factor. Alternative views for valley bulges have been expressed; notably by Kellaway (1972) who suggests stress relief by the formation of a melt water tunnel beneath an ice sheet but this theory, like his theory of the former glaciation of Southern England (Kellaway 1971), meets with very little support. Mechanisms not requiring periglacial conditions have been suggested by Simmons (1966) for non-tectonic anticlines in Kentucky. These include, firstly, plastic flow due to the differential stress relief resulting from stream erosion in the valleys and, secondly, the relief of swelling pressure generated during moisture absorption by clay minerals. Neither of these acting alone can adequately account for the Naish Farm structure which is more readily explained by the severe conditions encountered during a periglacial regime.

Although no definite age can be given for any of the structures, some probable limits can be suggested. The frost wedge casts, involutions and cryoturbation structures clearly post-date the Plateau Gravel and although the age of the latter is unknown, it is likely to be pre-Devensian (Keen 1980). The indications that both the frost wedge casts (Lewin 1966 and this paper) and the involutions were marked by hollows in which brickearth material was later deposited suggests that these structures may be intraformational such that they pre-date the latter material. The Brickearth belongs to an extensive series of sheets covering much of southern England (Catt 1977). The Naish Farm material is probably continuous with that at Barton-on-Sea for which a late Devensian date has been given by thermoluminescence dating (Wintle 1981). There are at least 8 known periods of periglacial activity (Jones 1981) but in view of the known severity and widespread distribution of (together with the greatest likelihood of structures surviving from) the Devensian episode, it is tempting to conclude that this applies to the Naish Farm structures.

Williams (1975) presumes, from their liability to subsequent erosion, that the majority of involutions surviving today developed after the Upton Warren Interstadial (dated by Coope 1975 to 43–25,000 years B.P.). While the cold phases at the end of the Devensian are thus very plausible dates (ie, during the time of maximum expansion of the ice sheets from 25–13,000 years B.P. or even during the short period of climatic deterioration from 11–10,000 years B.P.; Coope 1975) it would be necessary in the case of the later dates, to allow for some re-distribution of the Brickearth material following the periglacial episode in order to fit the date (18,800 years B.P.) given by Wintle for undisturbed Brickearth. It is thus inferred that the most likely date for the Naish Farm frost wedges, involutions and cryoturbation structures is between 25 to 19,000 years B.P.

The dry valley in the east of the area was eroded (or re-excavated) subsequent to the deposition of the Plateau Gravel and Brickearth. The formation of the bulge need not date from this period of erosion since the valley may have existed at an earlier date. Valley bulges of both Devensian and Wolstonian ages have been reported from the Weald (Shephard-Thorn 1975; Worssam 1976) and there is no reason why either age could not apply to the Naish Farm structure. Much further work is needed to examine the relation of the gravelly and clayey silty sand above the bulge to the other Pleistocene deposits in order to provide more definite evidence for the relative age and origin of the valley and, by inference, of the underlying bulge.

Distribution of Periglacial Features in the Hampshire Tertiary Basin.

Maps showing the wide distribution of periglacial features in England have been given by Williams (1969) and Jones (1981). Considering that these maps are limited by the availability of exposed evidence it is obvious that such features must actually be very common. Furthermore, it appears that neither map includes all the reported occurrences since Christchurch Bay is not marked as a locality despite the discovery of frost wedge casts by Lewin (1966). The importance of periglacial activity in moulding the landscape of Southern England has been particularly emphasised by Te Punga (1957), Williams (1968) and Castleden (1977), and more recently the importance of (and past tendency to mis-interpret) periglacial landforms has been emphasised by Jones and Derbyshire (1983).

Valley bulges have been discovered in the

Weald (Skempton and Weeks 1976; Shephard-Thorn 1975; Worssam 1976), have been thought to occur in Dorset near Weymouth and Charmouth (Arkell and Lang respectively: see discussion in Hollingworth *et al* 1944), are widespread in Somerset and Avon (Hawkins and Kellaway 1971; Chandler *et al* 1976) and continue into Gloucestershire (Ackermann and Cave 1967). These occurrences form an arc which extends across the Hampshire Basin and hence there is good reason to expect that such structures should be present there. Curry *et al* (1968) reported the discovery of a minor steep sided fold in Eocene Beds in the tunnel beneath Southampton Water. They considered that it could be of either tectonic or periglacial origin but it is suggested here that the latter is the more probable. It seems pertinent to consider, therefore, whether all the main valleys in the Hampshire Tertiary Basin (including the Hamble, Itchen and Test, where these are floored by clays) contain traces of valley bulge structures. Further study of this could prove very instructive.

Reference has already been made to other occurrences of involutions and cryoturbation structures at Highcliffe. Further evidence for the wide distribution of these features is given by White (1915 and 1917). In the railway cuttings north east of Milton he observed the Headon Beds to be 'puckered and contorted' in many places beneath the gravels, and in mapping Plateau Gravels over the area covered by the Bournemouth sheet he often noted 'contortion and trail' in the superficial parts of the gravels at various altitudes. Cryoturbated contortions in the upper part of the Bracklesham Beds beneath Plateau Gravel have been examined by the author in the company of Mr R Cater in a cutting slope on the Chandler's Ford By-Pass (NGR 438 192). The contortions were highlighted by the folding and overfolding of a thin lignite band within a clay facies. The Plateau Gravel was about 1·5m in thickness and the contortions extended to about 3·5m below the ground surface (Hampshire County Council Report 1981).

Various factors are likely to control the development of these features such as the elevation, degree of exposure to the weather, slope angle, type and thickness of Drift cover and the character of the bedrock. The geological environment at Naish Farm does not appear to have any very special characteristics (it would also have been well inland at least until relatively late since it appears that Christchurch Bay itself dates only from the Devensian and that much of the coastal erosion there is of Flandrian date, Wright 1981) and hence it can be expected that similar structures will be widely distributed. It is noteworthy that there appears to be some clustering of the features with gaps in which the Plateau Gravels are not so disturbed (see Figs 1 and 7). Thus while the chance of a random exposure showing periglacial structures is not high, the chances of an extended exposure, or group of exposures, showing such features is good.

ACKNOWLEDGEMENTS

I am grateful to Mr C W Salter of Naish Estates Ltd for permission to enter the Naish Farm Estate and undertake surveying and sampling in the area. I wish to thank Messrs B J Coles and R I Thomson, research students at Southampton University, for carrying out the E D M survey of the red clay band and Mr T Clayton of the Geology Department for carrying out an X-ray diffraction examination of samples of this stratum and its associated concretions and confirming the presence of siderite. I wish to thank Professor J A Small and Dr I M West for commenting on the manuscript and also Mr T I Longworth of the Building Research Establishment for discussion concerning the structure recorded by him in the Oxford Clay. Finally I must thank Mr A Brookes for assistance in preparing the illustrations for publication.

REFERENCES

Ackermann, K J and Cave, R 1967 Superficial deposits and structures, including landslips in the Stroud District, Gloucestershire, *Proc Geol Assoc* **78** 567–586.

Barton, M E 1973 The Degradation of the Barton Clay Cliffs of Hampshire, *Quart Journ Eng Geol* **6** 423–440.

Barton, M E, Coles, B J and Tiller, G R 1983 A statistical study of the cliff top slumps in part of the Christchurch Bay coastal cliffs, *Earth Surf Processes & Landforms* **8** 409–422.

Bradshaw, R and Ingle Smith, D 1963 Permafrost structures on Sully Island, Glamorgan *Geol Mag* **100** 556–564.

Burland, J B, Longworth, T I and Moore, J F A 1978 A study of ground movement and progressive failure caused by a deep excavation in Oxford Clay, *Building Research Establishment Current Paper* CP33/78.

Burton, E St J 1933 Faunal horizons of the Barton Beds in Hampshire, *Proc Geol Assoc* **44** 131–167.

Castleden, R 1977 Periglacial pediments in Central and Southern England, *Catena* **4** 111–122.

Catt, J A 1977 Loess and Coversands in *British Quaternary Studies: Recent Advances* Shotton, F W (ed), Oxford.

Chandler, R J, Kellaway, G A, Skempton, A W and Wyatt, R J 1976 Valley slope sections in Jurassic strata near Bath, Somerset, *Phil Trans Roy Soc Lond Ser A* **283** 527–556.

Coope, G R 1975 Climatic fluctuations in northwest Europe since the Last Interglacial, indicated by fossil assemblages of Coleoptera in *Ice Ages: Ancient & Modern, Geol Journ Spec Issue* **6** 153–168.

Curry, D 1976 The age of the Hengistbury Beds (Eocene) and its significance for the structure of the area around Christchurch, Dorset, *Proc Geol Assoc* **87** 401–407.

Curry, D, Hodson, F and West, I M 1968 The Eocene succession in the Fawley transmission tunnel, *Proc Geol Assoc* **79** 179–206.

Curry, D and Wisden, D E 1958 Geology of the Southampton Area, *Geologists Assoc Guide* **14** Benham and Co. Colchester.

Embleton, C and King C A M 1968 *Glacial and Periglacial Geomorphology*, Arnold, London.

Fisher, G C 1971 Brickearth and its influence on the character of soils in the South-East New Forest, *Proc* **28** 99–109.

French, H M 1976 *The Periglacial Environment*, Longman, London.

Hampshire County Council 1981 Site investigation of the landslip on the A33; Chandler's Ford Bypass (1981), *Report by Surveyors Department*, County Materials Laboratory.

Hawkins, A B and Kellaway, G A 1971 Field meeting at Bristol and Bath with special reference to new evidence of glaciation, *Proc Geol Assoc* **82** 267–291.

Higginbottom, I E and Fookes, P G 1970 Engineering aspects of periglacial features in Britain, *Quart Journ Eng Geol* **3** 85–118.

Hollingworth, S E, Taylor, J H and Kellaway, G A 1944 Large-scale superficial structures in the Northampton Ironstone Field, *Quart Journ Geol Soc Lond* **100** 1–44.

Hooker, J J 1975 Report of field meeting to Barton, Hampshire, October 12th 1974 *Tertiary Times* **2** 163–167.

Horswill, P and Horton, A 1976 Cambering and valley bulging in the Gwash Valley at Empingham, Rutland, *Phil Trans Roy Soc Lond Ser A* **283** 427–451.

Jahn, A 1956 Some periglacial problems in Poland, *Biul Peryglac* **4** 169–194.

Jones, D K C 1981 *The Geomorphology of the British Isles: Southeast and Southern England*, Methuen, London.

Jones, P F and Derbyshire, E 1983 Late Pleistocene periglacial degradation of Lowland Britain: implications for Civil Engineering, *Quart Journ Eng Geol* **16** 197–210.

Keen, D H 1980 The environment of deposition of the South Hampshire Plateau Gravels, Proc **36** 15–24.

Kellaway, G A 1971 Glaciation and the stones of Stonehenge, *Nature* **233** 30–35.

——— 1972 Development of non-diastrophic Pleistocene structures in relation to climate and physical relief in Britain, *Int Geol Cong* **24** (No 12) 136–146.

Kerney, M P 1963 Late-Glacial deposits on the Chalk of South East England, *Phil Trans Roy Soc Ser B* **246** 203–254.

Leese, C A, Ross, F S and Vernon, W F 1959 A temporary exposure of Rhaetic and Lower Lias at Fry's Factory, Keynsham, *Proc Bristol Nat Soc* 4th Ser **29** 493.

Lewin, J 1966 Fossil Ice Wedges in Hampshire *Nature* **211** 728.

Melville, R V and Freshney, E C 1982 The Hampshire Basin and Adjoining Areas, *British Regional Geology* 4th Edn HMSO London.

Patterson, K 1971 Weichselian deposits and fossil periglacial structures in North Berkshire, *Proc Geol Assoc* **82** 455–467.

Pugh, M E and Shearman, D J 1967 Cryoturbation structures at the South End of the Isle of Portland, *Proc Geol Assoc* **78** 463–471.

Shephard-Thorn, E R 1975 The Quaternary of the Weald – a review, *Proc Geol Assoc* **86** 537–547.

Shotton, F W 1960 Large scale patterned ground in the valley of the Worcestershire Avon, *Geol*

Mag **97** 404–408.

Shotton, F W and Wilcockson, W H 1951 Superficial valley folds in an opencast working of the Barnsley Coal, *Proc Yorks Geol Soc* **28** 102–111.

Simmons, G C 1966 Stream anticlines in Central Kentucky, *US Geol Surv Prof Paper* 550–D D9–11.

Skempton, A W and Weeks, A G 1976 The Quarternary history of the Lower Greensand Escarpment and Weald Clay Vale near Severnoaks, Kent, *Phil Trans Roy Soc Lond Ser A* **283** 493–525.

Swanson, E H 1970 Pleistocene geochronology in the New Forest, Hampshire, *Bull Inst Archaeol London* **8** and **9** (for 1968–69), 55–100.

Te Punga, M T 1957 Periglaciation in Southern England, *Tijdschrift Kon Ned Aardrijksk Genoot* **74** 400–412.

Thompson, Beeby 1903 Geology of Northamptonshire (Reprint from the *Victoria History of the Counties of England*) London.

Tomlinson, M E 1940 Pleistocene Gravels of the Cotswold sub-edge plain from Mickleton to the Frome Valley, *Quart Journ Geol Soc* **96** 396.

Tutcher, J W 1923 Some recent exposures of the Lias and Rhaetic about Keynsham, *Proc Bristol Nat Soc* 4th Ser **5** 268–278.

Vaughan, P R 1976 The deformations of the Empingham valley slope, Appendix to Horswill, P and Horton, A *Phil Trans Roy Soc Lond Ser A* **283** 451–462.

Walters, R C S 1971 *Dam Geology* 2nd Edition, Butterworths, London.

Washburn, A L 1973 *Periglacial Processes and Environments,* Arnold, London.

Waters, R S 1961 Involutions and ice-wedges in Devon, *Nature* **189** 389–390.

West, R G 1968 *Pleistocene Geology and Biology,* Longmans, Green & Co, London.

White, H J O 1915 The geology of the country near Lymington and Portsmouth, *Mem Geol Surv Eng & Wales,* HMSO, London.

——— 1917 The geology of the country around Bournemouth 2nd Ed *Mem Geol Surv Eng & Wales,* HMSO, London.

——— 1921 A short account of the geology of the Isle of Wight, *Mem Geol Surv Eng & Wales,* HMSO, London.

Williams, R B G 1969 Some estimates of periglacial erosion in Southern and Eastern England, *Biul Peryglac* **17** 311–335.

Williams, R B G 1969 Permafrost and temperature conditions in England during the last glacial period in *The Periglacial Environment,* Péwé, T L (ed) McGill-Queens Univ Press.

——— 1975 The British climate during the last glaciation; an interpretation based on periglacial phenomena, In *Ice Ages: Ancient & Modern, Geol Journ Spec Issue* **6** 95–120.

Wintle, A G 1981 Thermoluminescence dating of late Devensian loesses in Southern England, *Nature* **289** 479–480.

Worsley, P 1977 Periglaciation in *British Quaternary Studies,* Shotton, F W (ed), Oxford U Press.

Worssam, B C 1976 Discussion on Skempton, A W and Weeks, A G *Phil Trans Roy Soc Lond Ser A* **283** 525–526.

Wright, P 1981 Aspects of the coastal dynamics of Poole and Christchurch Bays, Dorset, Ph D Thesis, University of Southampton.

Author: Dr M E Barton, Department of Civil Engineering, University of Southampton.