THE RAISED BEACH AT TOUL AR ROUSSIN, PORT L'ÉPINE, TRÉLÉVERN (CÔTES D'ARMOR, BRITTANY): ITS SIGNIFICANCE FOR LAST COLD STAGE EVENTS

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Renouf, J.T. and James, H.C.L. 2001. The raised beach at Toul ar Roussin, Port l'Épine, Trélévern (Côtes d'Armor, Brittany): Its significance for last cold stage events. *Geoscience in south-west England*, **10**, 000-000.

A raised beach at and above mean high tide level at Toul ar Roussin, Trélévern, Côtes d'Armor in the Trégor country of northern Brittany is largely composed of near vertically aligned pebbles in a reddish silty matrix. Linked features are fractured bedrock and fractured pebbles filled with the same reddish matrix. Plume like structures of vertically inclined pebbles often peak beneath deeply weathered granitic boulders at the interface with overlying loessic sediment.

The raised beach is considered most likely to be Last Interglacial (Eemian) in age and the overall assemblage of features is explained by reference to a permafrost model, with thin overburden, operative during the last cold stage (Weichselian). Evidence from fractured bedrock beneath virtually undisturbed raised beach nearby and the thickness of the raised beach with vertical pebbles is thought to indicate a likely succession of permafrost episodes. Comparison with work at other localities along the northern Armorican seaboard suggests an extension of known sporadic permafrost westward from the Cotentin peninsula of Lower Normandy to include the Channel Islands and this more westerly area of north Brittany.

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INTRODUCTION

Investigations into the extent of permafrost conditions in the Channel Islands commenced with the discovery of vertically inclined marine pebbles in the raised beaches of Fort Clonque island and similar features along the low level coastline at Tourgis, western Alderney (James and Worsley, 1997). Further evidence was provided by the presence of a large frost-thrust boulder north of Fort Tourgis (James and Worsley, 1997). This structure, together with incomplete sections of stone polygons and the vertically oriented clasts through both the raised beach and overlying diamict, suggested significant cryogenic activity taking place within former active layers above a permafrost table in Alderney over sustained permafrost within the last cold stage. In 1997 the research area was extended to Guernsey where soft rock deformation features were identified together with a macrofabric of vertically inclined rounded marine clasts in raised beaches along the west coast of the island. A significant ice wedge cast was also recorded near Richmond Point (Gurney *et al.,* 1998). In addition, frost thrust boulders, tors and sorted patterned ground indicated that the northern and western coastal lowlands of Guernsey were affected by periglacial processes including permafrost, during the Last Cold Stage. Such a date is based upon the fact that the underlying low level raised beaches of the islands are believed to be of Ipswichian (Last Interglacial) age (Keen *et al*., 1981).

PRESENT INVESTIGATIONS

Recent research has extended to Jersey where evidence for permafrost conditions appears to be limited to a small section near the top of the Belcroute and Green Island exposures at the western end of St. Aubin' s Bay and eastern end of Grève d'Azette respectively (Lautridou *et al*., 1986). Further work on sections in Bonne Nuit Bay, north Jersey is progressing. As one of the main aims of the current programme is to determine the extent of last cold stage permafrost, continuous, discontinuous or sporadic, within the region of the Channel Islands and adjoining mainland, it was decided to examine similar low coastline exposures in north Brittany. A number of potential sites were examined at Port Béni (Pleubian), where some examples of frost disturbed sediments in the local diamict (head) and the overlying loessic unit were recorded. Patterned ground was located in indurated compacted loess forming the foreshore at Le Palud (Plougrescant) and at Roverc'h (Penvénan). Whilst frost disturbance may be indicated by these structures, the most significant site demonstrating probable permafrost conditions was at Port l'Épine (Trélévern) where a low level raised beach, at and above the mean high water mark, reveals evidence of disturbance (Figure 1).

The northern coast of the Trégor is noted for its extensive shingle bank festoons and several foreshore islets just north of Port l'Épine have such festoons attached to them. The presence of low level raised beaches at about mean high water mark (0 IGN = ±0 O.D.) at Pors Garo together with the periodic sea flooding of the Caravan Park between it and Port l'Épine, strongly suggests that both La Butte and Toul ar Roussin were tidal during the Last Interglacial. Toul ar Roussin (Figure 2) would have appeared as a low stack separated from the higher islet (La Butte) to the east by a tidal gully a little below, or near, mean high water tidal levels comparable to similar situations commonly found along present north Amorican and Channel Island coasts.

DEFORMATION FEATURES AT TOUL AR ROUSSIN

Distribution and main features

Figure 1 shows the location of the North Embayment extending westwards from Port l'Épine which terminates in the low isthmus of Toul ar Roussin projecting northwestwards into the sea. The distal end, which was probably a stack rising above the Last Interglacial shore platform, is linked to the mainland by surficial material consisting of marine, diamict and loessic deposits of probable last cold stage age. The exposed promontory of Toul ar Roussin is backed to the south east by a low elongated hill (La Butte) rising to 33 m (IGN). This former tidal island, formed the palaeo-cliff line for Toul ar Roussin (Figure 2).

The presence of a tidal gully between Toul ar Roussin and La

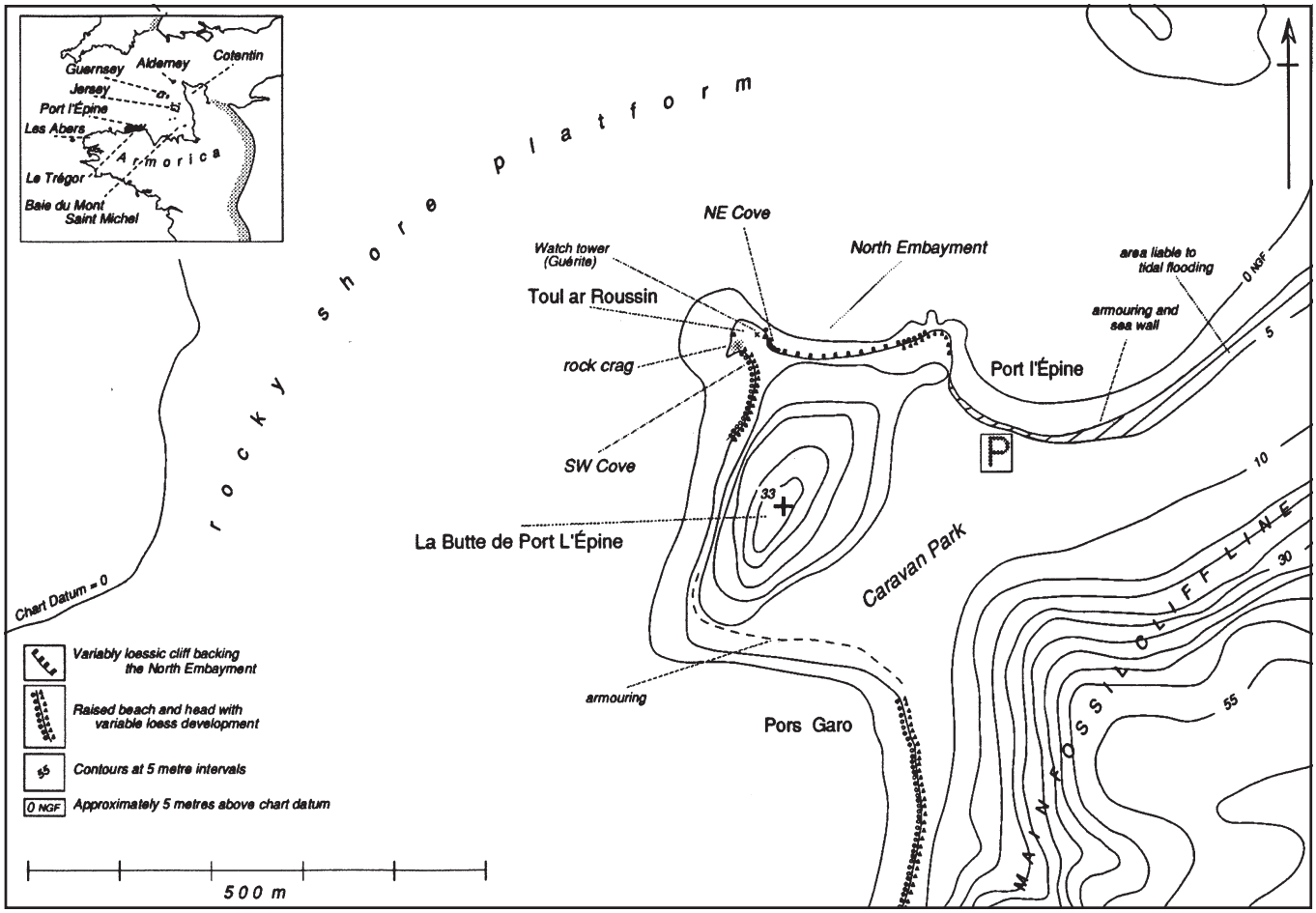

Figure 1. *Sketch map of the site and situation of Toul ar Roussin, Port l'Épine, Trélévern, Côtes d'Armor.*

Butte probably encouraged the development of raised shingle banks as a result of meeting tidal flows advancing from the northeast and southwest respectively. The sedimentological evidence from present exposures of the raised beach suggest that the bank was largely composed of coarse sub-rounded gravels up to a thickness of 1-2 m. Much reduced raised beach thicknesses of 20-30 cm with little pebble disturbance are recorded only tens of metres to the east and south of Toul ar Roussin at the foot of La Butte.

The disturbed raised beaches under consideration lie to the northeast and southwest of the flat col that forms most of Toul ar Roussin. Figures 3 and 4 show sub-rounded clasts within the upper 1.75 m of the 2 m thick raised beach unit which display a striking vertically inclined macrofabric similar to that previously recorded in Alderney (James and Worsley, 1997) and Guernsey (Gurney *et al.,* 1998). Exposures of the basal conglomerate (raised beach) eastwards of the northeastern section of Toul ar Roussin (Figure 5) are limited along the north embayment as a result of the extensive slumping of diamict and loessic deposits derived as slope units from the palaeocliff to the south. To the east of the near vertically inclined pebbles of the southwest section adjacent to the path descending to the beach, a transition from the disturbed macrofabric to raised beach sections which remain undisturbed is observed. The distinct thickening southwards of the overlying diamict (head) unit to about 6 m coincides with the disappearance of the disturbed macrofabric. This is in contrast to the combined 1-2 m thickness of head and loessic units overlying the 2 m thick raised beach unit exposure on both sides of the Toul ar Roussin promontory.

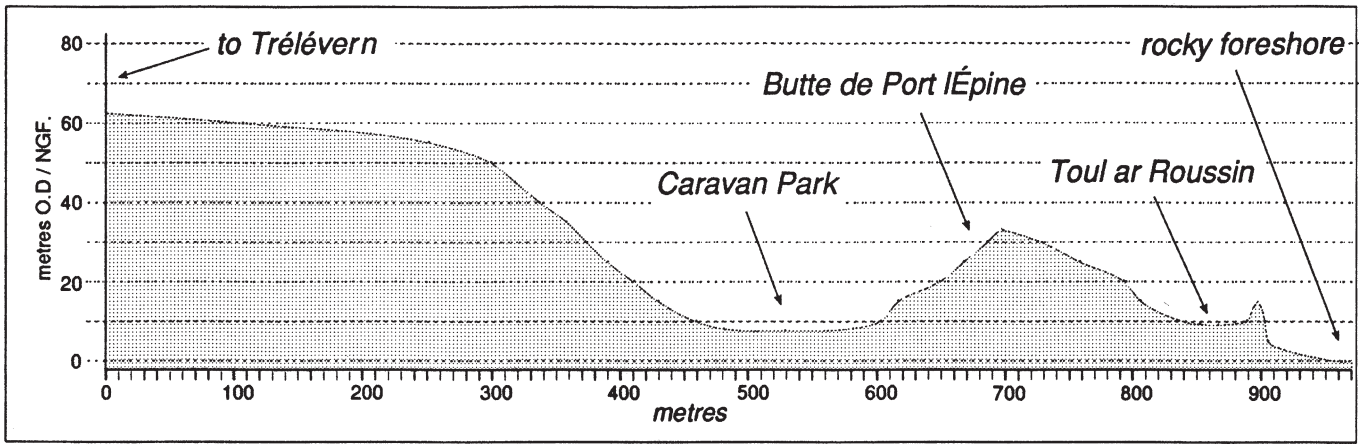

Figure 2. *Profile from the heights of Trélévern WSW over La Butte de Port l'Épine and down across Toul ar Roussin to the foreshore beyond.*

Figure 3. *Central section of the NE cove showing the full thickness of the raised beach and the strong vertical alignment of the pebbles. The sloping stone at the foot of the 2 m staff is shown in Figure 8. See Figure 7 for enlargement of the internally dislocated boulder seen to right of staff.*

Figure 4. *Close-up of part of Figure 3 showing the pebbles not only aligned vertically but forming a close network with most pebbles apparently in direct contact but which are in fact separated from each other by thin bands of the matrix (< 2 mm). Locally the matrix is more abundant and the pebbles scattered. The scale is 10 cm long*

Internal pebble and small boulder dislocations

The average mean diameter of the pebble component of the Toul ar Roussin raised beaches is about 2.5 cm with few pebbles greater than 6 cm. A number of instances of pebbles fractured and displaced *in situ* have been recorded along with much larger angular boulders and bedrock adjustments. In Figure 6 two fractured pebbles are shown with 1-3 mm displacements across the fractures. In both cases the opened fractures are filled with a reddish silt/clay matrix. Figure 7 (NE Cove) shows a fractured angular boulder of weathered granitic rock 'floating' in the raised beach. Note the pebbles curving round underneath the displaced rock.

Other macro features

Figure 8 shows wave smoothed bedrock emerging from below the raised beach and with significant matrix filled fractures and displacement (the bedrock figured lies at the left base of the staff in Figure 3). About 200 m to the east of the NE Cove, similarly fractured and displaced bedrock is found beneath the raised beach but the pebble beach above is thin and its pebbles are not vertically aligned. Thus deformed bedrock is found beneath both vertically inclined and non-vertically inclined pebble beaches.

The tilted pebbles across the face of the SW Cove show more irregularity than those of the NE Cove, are less thick and show a degree of separation into apparently discrete and less well defined clusters (Figure 9). These clusters give the strong impression of being conical rising to a roughly defined peak often associated with deeply weathered subangular boulders. There is a much greater amount of matrix across the section than in the NE Cove. To the east and south the pebble tilting rapidly vanishes beneath thickening head deposits with stratified loessic head becoming evident. At the western end of the section chaotically disposed head consisting of large angular jointed blocks is clearly linked to the presence of the adjacent crag of rock (a former stack).

Components of the raised beaches

NE facing section. The sub-rounded clast component of the raised beaches is almost exclusively of local origin comprising coarse granitic types some showing *in-situ* fracturing and also a tendency to incipient granulation and internally coherent microgranites from local dykes also tending to *in-situ* fracturing but not granulation. Other metadoleritic pebbles also occur. Granulometric analyses of the matrix material (Figure 10) show a significant silt content in excess of 50%. The bulk of the raised beach sediments by weight is made up of the pebble component, which, with an average mean diameter of 2.65 cm falls within the coarse gravel fraction. As noted above, there are few rounded clasts greater than 6 cm mean diameter. The upper section of the raised beach contains a number of small boulders of *c*. 50 cm

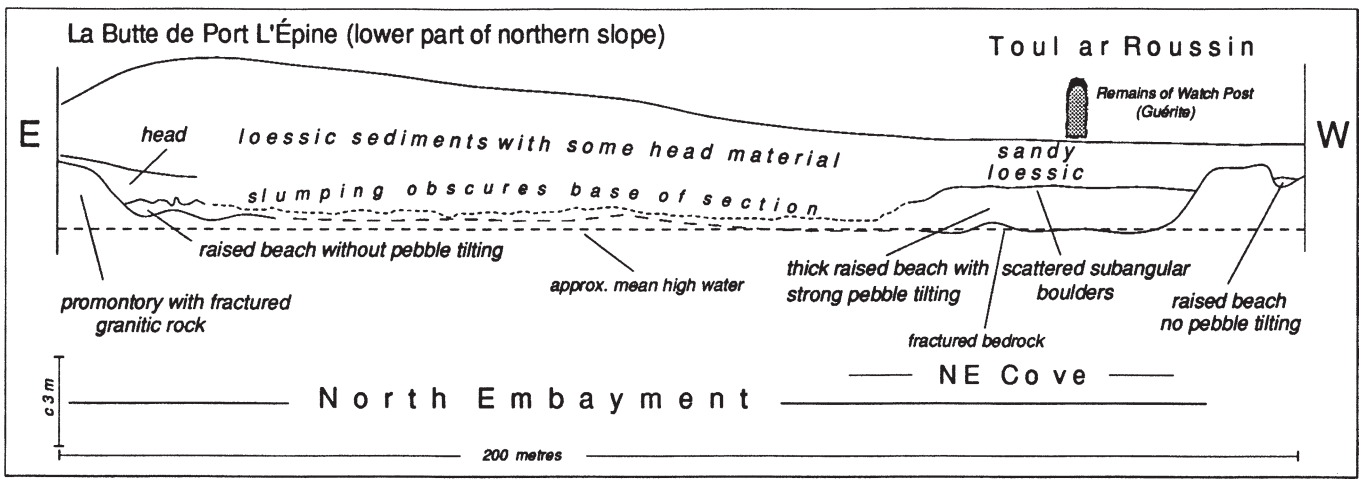

Figure 5. *A cartoon sketch section looking south showing the location of the superficial deposits across the North Embayment.*

Figure 6. *Fractured pebbles with matrix fill of the fractures and post-fracture displacement. The pebbles, from the NE Cove, are 55 mm long.*

diameter, largely subangular in form and in process of disintegration, with occasional ones near the base of the beach unit (Figure 3, bottom left). Reddening of the matrix is present throughout the thickness of raised beach in this section and that of the SW and is also present in the thinner beach beneath head at the eastern end of the North Embayment.

SW facing section. This exposure displays similar lithological and sedimentological characteristics to those described for the NE cove. Figure 9 reveals a relationship between the "columns" of vertically inclined pebbles and the small boulders, with the latter often forming the peak of the column. Increasingly towards the east of both coves, loessic units thicken at the foot of the palaeocliff. A sandy subsoil caps the loessic diamict in both coves.

Discussion

The most evident characteristic of the Toul ar Roussin exposures is the combination of thickness, structure and macrofabric of the vertically inclined clasts throughout the greater part of the raised beach. Furthermore, it appears that these pebbles have been sorted into plumes of vertically inclined material with a regular spacing of *circa* 50 - 100 cm, a feature particularly evident in the SW cove. In addition, there appears to be a degree of vertical movement with internal dislocations of

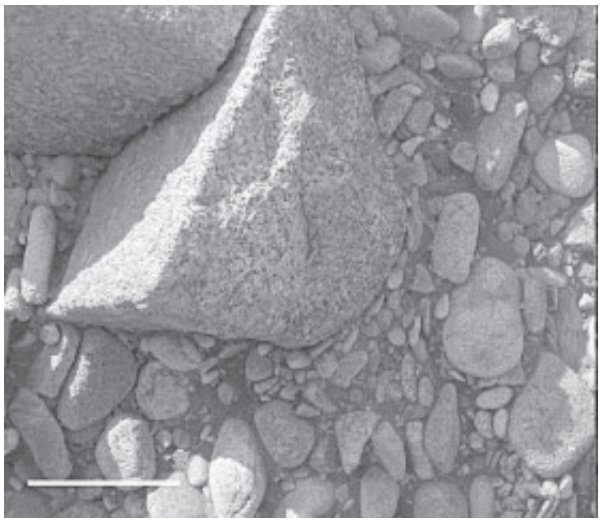

Figure 7. *Detail of the displacement of the two parts of the sub-angular granitic boulder shown in Figure 3. Note the alignment of the pebbles curving around the rock at bottom right. The scale is 20 cm.*

Figure 8. *Close up of part of Figure 3 showing the bedrock (microgranite) joints with their raised beach matrix already deeply eroded out by wave action. The resulting joint blocks are in process of dislodgment by the sea. The scale is 25 cm long.*

some of the large sub-angular boulders that occur within both the raised beach and the overlying head. As at similar low level coastal sites in the Channel Islands of Alderney and Guernsey and the northern Cotentin exposures at the Pointe de Jardeheu (Van Vliet Lanoë, 1988), it is considered significant that the total thickness of the surficial units at Toul ar Roussin is limited to *c*. 3 m.

The illustrations (*e.g*. Figures 3, 4 and 9) show sub-rounded gravels and pebbles within the upper 1.75 m of the 2 m thick raised beach unit displaying a macrofabric characterised by the vertical disposition of these elements. Detailed field mapping of the two exposures within an overall lateral extent of more than 50 m on either side of the narrow isthmus at Toul ar Roussin reveals compelling evidence for periglacial modification of these sediments. Van Vliet Lanoë (1988) described a raised beach with pebbles aligned in vertical plumes at the base of low cliffs backing the shore platform at Jardeheu on the north coast of the Cotentin. James and Worsley (1997) and Gurney *et al*. (1998) recorded vertical alignment of raised beach pebbles in Alderney and Guernsey respectively.

Both Gurney *et al*. (1998) and Van Vliet Lanöe (1988) describe the range of possible re-orientation processes which lead to the formation of vertical clast fabrics. These depend upon the exact circumstances, for example, in an active layer over permafrost or simply within seasonally frozen ground. One of the most important processes (Van Vliet Lanoë, 1985) is frost heaving (or "up-freezing") which pushes (or pulls) clasts towards the surface, during which time they rotate to align their long axes with the vertical taking up a position of least resistance. Clasts with their long axes oriented at angles higher than 50° are generally only observed in areas with very low slope angles since on higher angle slopes mass wasting processes readily disturb and/or destroy the formation or retention of the vertical orientation.

The other mechanism believed to be responsible for the vertically oriented clasts in such deposits has been described by James and Worsley (1997) for last cold stage deposits in Alderney. Here it was postulated that high pore water pressures build up during autumnal freeze-back of the active layer, when the active layer may be freezing both from the surface downwards and from the permafrost table upwards. Periodically excess pressure exerted by the pore water is released by rupture of the confining upper frozen layer where it is weakest. The pressure is released through water escaping to the surface and, during this escape, clasts in the vicinity are rotated in the still unfrozen matrix to reflect in their final positioning, least resistance streamlining of shape. Finally, Gurney *et al.* (1998) point out that care should be exercised with some interpretations of vertical fabric since frost shattering of bedrock, patterned ground formation (see Hallet and Waddington, 1991) and the processes forming involutions can also create fabrics involving vertically oriented clasts and hence in this respect they are in many senses, polygenetic.

Figure 9. One of the less well defined discrete structures on the face of the SW Cove. The pebbles seem to be streamed up towards the disintegrating boulder in the centre upper part of the view and is bounded to west (left) by an area with more matrix and a lower top to the beach. The scale is 25 cm.

Recent work, for example, Murton *et al*. (1995), has re-emphasised the important role of permafrost degradation phases in creating conditions whereby there is a potential for soft-rock deformation structures to form. It is envisaged that during thaw events sediment strengths are lowered due to the presence of high pore water pressures whilst free drainage is impeded by an underlying impervious layer (permafrost). Gravitational instabilities in sediments with contrasting densities are often assigned a key role in involution genesis. Whilst it was argued by James and Worsley (1997) that these mechanisms were not directly transferable to the relatively coarse diamicts which formed the host materials of the Alderney macrofabrics, granulometric analyses of the Toul ar Roussin matrix (> 1500 mm) within the raised beach indicate a much finer and, incidentally bimodal, sediment. Frost susceptibility of the matrix is largely dependent upon granulometric characteristics and soil density in their effect upon the size and geometry of the soil pores (Harris, 1981). Thus coarse sands are classed as non-frost susceptible (Beskow, 1935) because high permeability and void ratios severely restrict segregation ice growth in coarse soils in contrast with finer sediments. Thus analysis of the matrix component (<2 mm fraction) would appear to be a sensitive indicator of bedrock controlled granulometric variations within sediments.

On the basis of previous work in Cornwall, the Channel Islands and Armorica, together with the sedimentological evidence from the described site at Toul ar Roussin, it is proposed that a gravel festoon deposit first received an input of littoral (probably wind blown) sand (*c*. 1 mm grade) from the increasingly exposed beach during initial regression and was secondly, subsequently covered by a loessic unit which likewise infiltrated the coarse gravel unit. Post depositional periglacial processes disturbed these units as demonstrated by the vertically disposed clasts extending through at least 1.75 m of raised beach and loessic sediments with the plumes representing incomplete sections of stone polygons. It is thought likely that regular polygonal forms (possibly patterned ground phenomena) were present but their surface expression would have been destroyed by much later human disturbance following such activities as military constructions during the eighteenth century. Frost action alone could cause the formation of involutions which include vertically inclined clasts, but the regularity, frequency and depth of these features suggest the presence of at least seasonally frozen ground and possibly fluctuating thickness of an active layer over permafrost.

As in Alderney, the presence of active layer structures in the loess and raised beach units to a total thickness of at least 1.75 m suggests former deep active layer formation. James and Worsley (1997), pointed out that during a period of permafrost presence, active layer thickness would vary with time and would be at its shallowest depth during the most severe climatic phases since the active layer progressively thins as mean annual temperatures are reduced (Worsley, 1994). Consequently, a palaeoactive layer, as defined by the total thickness of surficial sediment displaying a macrofabric characterised by vertically disposed clasts at a given locality, might not be coeval in age throughout its extent. Thus a number of separate periods of active layer formation beneath a stable land surface might each contribute towards the total fabric. However, it is unlikely that the cryoturbation structures affecting the top of the raised beaches of Toul ar Roussin are older than the maximum of the last cold stage since loessic material on top of the raised beaches is affected.

The deformation (fissuring and displacement) of sub-raised

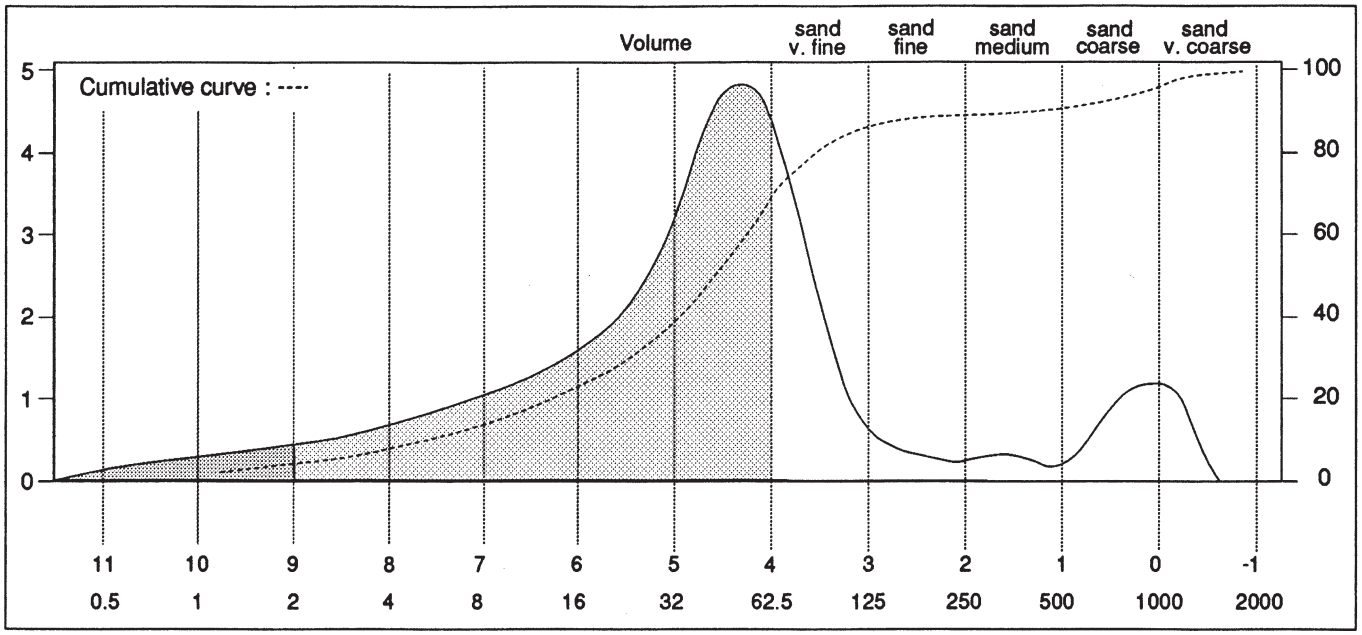

Figure 10. Granulometry for the fraction below 1500 mm for typical matrix sediment in the NE Cove. Note the strong loess/fine sand peak and the distinct but small peak of sand at about 1000 mm. There is very little clay in any of the samples taken.

beach bedrock at Toul ar Roussin and at the eastern end of the North Embayment is not explained in a totally convincing way by post-beach, cold stage cryoturbation since the beaches at the level of the bedrock and just above are not apparently as deformed as the bedrock beneath. The strong possibility exists that this bedrock deformation occurred before the raised beach accumulation prior to Oxygen Isotope Stage (OIS) Sub-Stage 5e.

Hallégouët and Van Vliet Lanoë (1986) reported a range of cold climate phenomena associated with a number of localities in the Côte des Abers section of the Pays de Léon to the west of the Trégor. Four notable features of their lithostratigraphic and palaeoclimatic conclusions are regarded as significant in explanations offered for Toul ar Roussin.

1. Several regressive dune sand phases occurred in the later substages of OIS 5 at, for example, Brouennou (Aber Benoît), and it is suggested that Sub-Stage 5c is the most likely of these events to account for the presence of the medium-coarse sand component found as matrix in the raised beach sediment and overlying deposits at Toul ar Roussin. The reddening is a distinctive feature of sands of this time period (Hallégouët *pers. comm*., 2000). He went on to comment "questions can also be asked about the age of the fossil beach. Some beaches are composite and can correspond to stacked littoral deposits". The almost 2 m thick beach deposit found in the NE Cove is rather thick for the area and such an explanation cannot be ruled out at this stage (see Keen *et al*., 1996).

2. Raised beaches were recorded for four different substages of OIS 5, the last being as young as the top of 5a, although the main raised beach deposits were believed to relate to OIS 5e. In view of the strong evidence for the regressive sands belonging to OIS 5c, an age of 5e for the raised beach appears most likely unless, of course, it is a relict beach of even greater age such as OIS 7 or even earlier.

3. With the exception of the loess input identified as of OIS 6 age near the base of the Brouennou section, the only other recorded loessic phase belonged to the latter stages of the last cold stage, that is, OIS 2.

4. A number of cold phases with frozen ground penetration of tens of centimetres have been noted with the most severe being at the beginning of OIS 4 and suggesting a maximum depth of last cold stage penetration of 2 m.

Van Vliet Lanoë (1994), on the basis of wide ranging analyses of periglacial data linked to the controlling influences of seasonal insolation fluctuations and annual preciptitation rates, concluded that continuous permafrost reached the west coast of Normandy. Lautridou and Coutard (1995), focussing on Normandy, were reluctant to equate the observed ice wedge phenomena from the western coast of the Cotentin and the Baie du Mont Saint Michel as proof of other than intermittent permafrost conditions. Hallégouët and Van Vliet Lanoë (1986) accepted a 2 m depth of frozen ground at the beginning of OIS 4 in western Brittany and other periods of less deep frozen ground later during the last cold stage but did not propose extensive permafrost conditions, preferring to relate such phenomena to localised site features such as northerly aspect and poor drainage. Finally, Van Vliet Lanoë (1996) proposed that at the last Glacial maximum (18,000 B.P.), the continuous-discontinuous permafrost boundary extended just west of the Cotentin peninsula across the Channel to about Dorset.

Conclusion

The discovery of deep seated periglacial disturbance of raised beach sediments at Toul ar Roussin in northern Brittany together with the identification of epigenetic periglacial structures in Cornwall (James, 1994), northern France (Van Vliet Lance, 1996), Alderney (James and Worsley, 1997) and Guernsey (Gurney *et al*., 1998) suggest that the southern permafrost limit for the last cold stage needs to be redrawn to include west Cornwall, the Channel Islands and the northern coastline of Brittany. In each case, the range of possible/probable frozen ground phenomena overlying former discontinuous or continuous permafrost has, to date, been limited to low coastal terraces fringing palaeocliff lines.

Acknowledgements

M. Guy Mahé of the Mairie at Trélévern assisted with nomenclature, interest and encouragement. Dr Steve Gurney of the Geography Department at Reading University organised the granulometric analyses. M. Bernard Hallégouët made valuable comments on the text while in preparation.

References

BESKOW, G. 1935. Tjälbildningen och tjälyftningen med särskildhänsyn till vägar och jarnägar. *Sveriges Geologiska Undersökning, Arsbok*, **26**, No. 375.

GURNEY, S.D., JAMES, H.C.L. and WORSLEY, P. 1998. The nature of last Glacial periglaciation in the Channel Islands. *Proceedings of the Ussher Society*, **9**, 250-254.

HALLEGOUET, B. and VAN-VLIET LANÖE, B. 1986. Les oscillations climatiques entre 125000 ans et le maximum glaciaire, d'après l'étude des formations marines, dunaires et périglaciaires de la côte des Abers (Finistère). *Bullétin de l'Association Française pour l'Etude du Quaternaire*, Paris, **23**, 127-138.

HALLET, H. and WADDINGTON, E.D. 1991. Buoyancy forces induced by freeze-thaw in the active layer : implications or diapirism and soil circulation. In: DIXON, J.C. and ABRAHAMS, A.D. (eds), *Periglacial geomorphology*, Wiley, Chichester, 251-279.

HARRIS, C. 1981. *Periglacial Mass Wasting: A Review of Research*. British Geomorphological Research Group, Research Monograph, **4**, Geo Abstracts, Norwich.

JAMES, H.C.L. 1994. *Late Quaternary coastal landforms and associated sediments of West Cornwall*. Unpublished PhD Thesis, The University of Reading.

JAMES, H.C.L. and WORSLEY, P. 1997. Evidence for Last Glacial periglacial activity in Alderney. *Proceedings of the Ussher Society*, **9**, 177-181.

KEEN, D.H., HARMON, R.S. and ANDREWS, J.T. 1981. U-series and amino acid dates from Jersey. *Nature*, **289**, 162-164.

KEEN, D. H., B. VAN VLIET-LANÖE and J.-P. LAUTRIDOU. 1996. Two long sedimentary records from Jersey, Channel Islands: Stratigraphic and pedological evidence for environmental change during the last 200 kyr. *Quaternaire*, **7**, 3-13.

LAUTRIDOU, J.-P. and COUTARD, J.-P. 1995. Le problème de l'extension et de la profondeur du pergélisol pléistocène en Normandie (France du Nord-Ouest). *Quaestiones Geographicae*, Special Issue, **4**, 201-203.

LAUTRIDOU, J-P., KEEN, D. and MONNIER, J.-L. (eds). 1986. *Symposium of the INQUA Loess Commission of the significance of periglacial phenomena: Normandy-Jersey-Brittany August 20-27 1986*. Centre de Géomorphologie du CNRS, Caen.

MURTON, J.B., WHITEMAN, C.A. and ALLEN, P. 1995. Involutions in the Middle Pleistocene (Anglian) Barham Soil, eastern England: A comparison with thermokarst involutions from arctic Canada. *Boreas*, **24**, 269-280.

VAN VLIET-LANÖE, B. 1985. Frost effects in soils. In: BOARDMAN, J., (Ed.), *Soils and Quaternary landscape evolution*. John Wiley and Sons, Chichster, 117-158.

VAN VLIET-LANÖE, B. 1988. *Le rôle de la glace de ségrégration dans les formations superficielles de l'Europe de l'Ouest: Processus et héritages*. Thèse de Doctorat d'État, Université de Paris I Sorbonne, Centre de Géomorphologie du C.N.R.S.

VAN VLIET-LANÖE, B. 1994. Histoire et dynamique du pergélisol européen au Weichsélien. *Biuletyn Peryglacjalny*, **33**, 165-176.

VAN VLIET-LANÖE, B. 1996. Relations entre la contraction thermique des sols en Europe du Nord-Ouest et la dynamique de l'inlandsis nord-européen au weichsélien. *Comptes Rendus de l'Académie des Sciences*, Paris, **2**, 322

WORSLEY, 1994. Effects of short and long term changes on permafrost-sedimentological data. In: DUPLESSEY, J.-C. and SPYRIDAKIS, M.-T., (eds), *Long term climatic variations, data and modelling*. Springer-Verlag, Berlin, 379-387.