EVIDENCE FOR LAST GLACIAL PERIGLACIAL ACTIVITY IN ALDERNEY

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The limited previous work on Alderney periglaciation has concentrated upon the characteristics and distribution of the coastal head (diamict) and the silty (loess) deposits of the Blaye. Hitherto, direct evidence for permafrost *per se* has been lacking. Macrofabric evidence relating to former active layers above a permafrost table is now identified along with an example of a frost thrust boulder. Hence permafrost sustaining temperatures must have affected Alderney. Facies analysis and geomorphological context yield a pattern of environmental change during the Last Glacial Stage comparable to south-west England.

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BACKGROUND

Beyond Alderney (Figure 1), in other parts of the Channel Islands, inferences relating to former Pleistocene cold environmental conditions have concentrated on the origin of the the head (diamict) which is often found overlying raised beaches (cf Collenette, 1916; Dunlop, 1911; Mourant, 1933, 1935; George, 1973 and Keen 1978). Reference to other cold climatic phenomena include descriptions of the extent of wind-blown loess (Keen, 1978); and basal organic (peaty) rich deposits indicative of treeless conditions similar to those found at Ecalgrain on the the Cotentin Peninsula (Coope *et al., 1986,* 1987). Reports of fossil hone material, such as that from mammoth found in the cave at La Cotte de St Brelade, Jersey (Callow and Cornford, 1986) are consistent with cold climates. Most of these kinds of materials have been found in Jersey and to a lesser degree in Guernsey, with much more limited extents in Alderney and the other smaller islands.

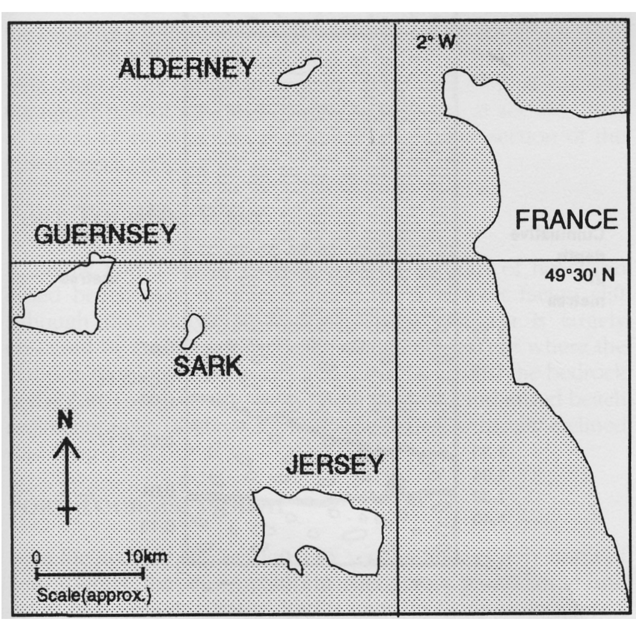

Figure 1. The location of Alderney

CURRENT WORK

The extent of Pleistocene sediments in Alderney, including those indicative of cold environmental conditions, were first systematically mapped by D.H. Keen during the period 1972-75 as part of the British Geological Survey Channel Islands Sheet 1 programme. This was published in 1986. Besides extensive head, a rather patchy cover of loess was identified on the Blaye plateau of the island (Keen, 1978).

Undoubtedly the most widespread periglacial facies on Alderney is an angular rubbly head which crops out above bedrock cliffs at a number of sites around the coastline. A magnificent oblique longitudinal section through a bedrock wave cut platform with overlying raised beach and associated fossil cliff is exposed on the mainland at Hannaine Point [WA 557 072], immediately east of Clonque Island. This feature is enveloped by a head sheet which appears to have moved seawards after regression had led to the abandonment of the marine eroded cliff.

Recent surveys confirm the maximum thickness of head to be about 15 m thick, for example, Hannaine Point. This facies of rubbly head has no reported direct modern analogue although its field relationships indicate that mass movement of variously saturated sediment derived from bedrock degradation of the high ground at the western edge of the Blaye plateau was involved in its emplacement. The inclusion within the head of rhythmic stratification with alternating coarse and fine beds suggests that this deposit probably accumulated as debris flows during a substantial cold period during which repetative 0.05 - 0.5 m increments of sediment accumulated. Occasionally the main diamict is interspersed with finer sandy-clay wash (water-laid) lenses.

Following a cliff fall in 1990 at the mouth of the re-entrant stream at Val des Pommiers [WA 559 074], a new exposure at the base of the diamict (head) was created. Instrumental levelling indicates a total thickness of 14.7 m of diamict above the basal raised beach, (Figures 2 and 3). The lower part of the head succession consisted of numerous thin units of fine gravels, sands, silts and clays with a total thickness of more than 3 metres, (see Figure 2 in James and Dillon, 1992). These sandy clays overlie a thin angular stony bed (probably local scree) and extend laterally >100 m to the north and >50 m to the southwest, with the contact between the sandy clay unit and the overlying head also declining in altitude and thickness with distance from the mouth of the stream.

Textural and mineral analysis of the sandy clay unit reveals a local

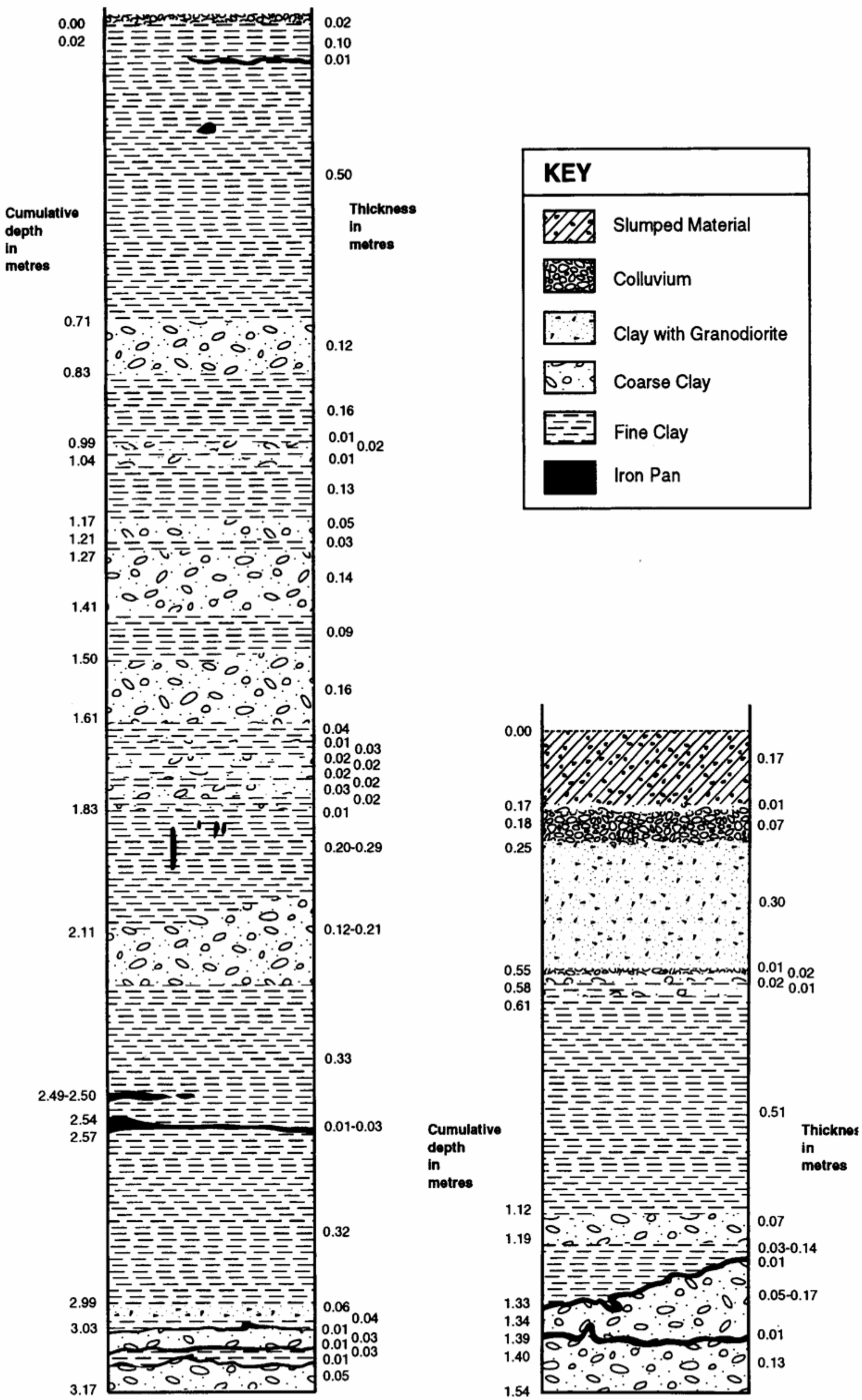

Figure 2. Sections from Val des Pommiers (left) and Druid's Altar (right) Alderney

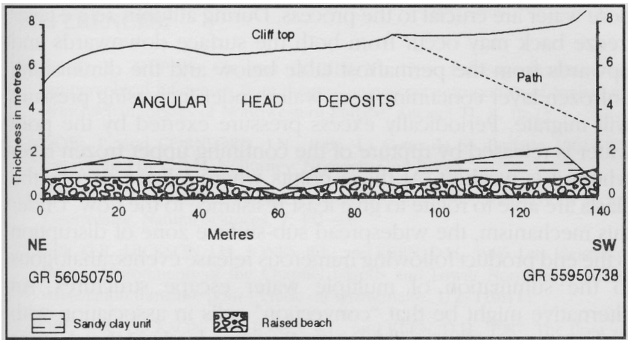

Figure 3. Sandy clay unit, Val des Pommiers, Alderney.

origin derived from both the local granodiorite and weathered silts on the north-western edge of the Blaye plateau. The sedimentology is indicative of a water-borne origin with the sediment being washed out of the small re-entrant valley on the edge of the plateau, while the reconstructed palaeogeomorphology suggests an alluvial fluvial fan spreading across the ancient beach and into a basin-like structure. A similar sandy clay fan structure may be seen further north within Clonque Bay opposite a small re-entrant valley or col at Druid's Altar [WA 562 076]. The two fans appear to merge at a point between the two valleys.

It is worthy of note that the basal exposures at Val des Pommiers and Druid's Altar are in a parallel stratigraphical position to deposits at Ecalgrain on the Cotentin Peninsula (Coope *et al.,* 1987), that is below the base of the head succession.

Recent detailed re-examination of the angular head and the underlying raised beach extending from Fort Clonque [WA 555 073] in the southwest to Fort Tourgis [WA 563 081] along the shore of Clonque Bay has revealed striking additional physical evidence for former cold climate activity. This is best exhibited by the exposures on the east facing side of Fort Clonque island and again for some 400 m around the north westward facing low promontory of Fort Tourgis. In both instances the combined thickness of both the raised beach and the overlying head ranges between 3-4 m.

FORT CLONQUE

At Fort Clonque, two exposures of surficial sediments adjacent to the causeway connecting the small island to the mainland, lie on a wave-trimmed granodiorite platform. The latter is 7.5 m. OD (n.b. all levelled heights are related to Alderney Ordnance Datum) and dips towards the north-east. The exposure north of the causeway is located on a continuation of the shore platform at 4.6 m OD and may well continue for a further 50 m to the northwest. Most of the pebble and greater sized clast long axes within the upper part of the head lie near to the vertical and this kind of macro fabric was also peresent in the upper section of the raised beach, (Figure 4).

Figure 4. Disturbed rised beach deposits, Fort Clonque'.

FORT TOURGIS: WEST

Below Fort Tourgis, extensive lateral sections of head and raised beach may be traced along the low west facing cliff although the underlying bedrock shore platform is largely obscured by contemporary beach sediments, except where the platform terminates at a notch at 8.6 m OD, against the bedrock of the Fort Tourgis promontory. Both the head and raised beach sediments again display a macro fabric of near vertically inclined clast long axes.

FORT TOURGIS: NORTH

In the actively eroding low cliff section immediately north of Fort Tourgis, the shore platform cuts across granodiorite and dykes of porphyritic felsite, and is overlain by approximately 2 metres of raised beach sediments and a similar thickness of coarse head. The platform lying at 7.5 m OD may be traced eastwards for some 250 m before being replaced by the contemporary sandy coastal deposits of Saline Bay. At this locality, the vertical orientated clasts long axes extend throughout the superficial sequence on the underlying platform, a thickness of more than 3 metres.

At one site a prominent elongate boulder 1.5 m in length was separated by more than 20 cm from a very low rise in the platform, (Figure 5). It displayed a clear vertical alignment of its long axis and appeared to have been detached from a platform source. The enclosing matrix material consisted of coarse head with clast long axes similarly aligned. Also within this section were a series of involutions. These macrofabrics are considered to be relict active layer phenomenon signifying a previous permafrost palaeoclimate.

Figure 5. Frost thrust boulder, Fort Tourgis.

DISCUSSION

With the single exception of a small exposure on the west side of Longis Bay [WA 080 596], the ubiquitous head deposits are always found to *overlie* the raised beaches in Alderney. The low-level raised beach and allied platform, levelled to 9.9 m OD in Hannaine Bay [WA 072 557], is *probably* the equivalent of the Last Interglacial (Oxygen Isotope substage 5e) interglacial 8 m beach which in Jersey has yielded a uranium series age estimate of some 121 Ka BP (Keen *et al.,* 1981). However, amino acid ratio data from the Black Rock raised beach at Brighton in Sussex and raised beach fragments at Godrevy in Cornwall are possibly of penultimate interglacial age and some caution needs exercising in assuming that the 8 m beach correlates with the Last Interglacial. Nevertheless applying the principle of "Occams Razor" it is presumed that the overlying periglacial head units are of Last Glacial Stage age.

The sandy clays containing numerous bands of fine gravels, sands, silts and clays at Val des Pommiers and Druid's Altar in Clonque Bay are interpreted as minor alluvial fan deposits fed by meltwater which flowed out of nivation (snow-accumulation) hollows at the edge of the Blaye plateau and were deposited upon clast supported deposits or scree that overlay the low level raised beach. The current morphological structure of Clonque Bay opposite the re-entrant valleys suggests that these alluvial sub-units were deposited in shallow basins. There is a general coarsening-upwards of the sandy clay unit before replacement by typical soliflucted head units which lack evidence of significant fluvial sorting processes.

The stratigraphical position of the sandy clays above the raised beach and below the head suggests a Late Last Interglacial/Early Glacial age for their deposition in shallow basins, during a period of marked cooling following the previous interglacial climatic optimum. These loess derived silty sub-units contrast with the generally accepted age for the loess deposits in southern Britain. The latter have been dated as Late Devensian (Wintle, 1981) although more recently pockets of older loess beneath the late Devensian loess have been identified (Parks and Rendell, 1992). Early loess deposits nearby in mainland France have been ascribed to the penultimate cold stage, possibly OI Stage 7 or earlier (Balescu *et al.,* 1986) as have others in Jersey (Coope *et al.,* 1986).

The presence of relict active layer structures in both the head and in the underlying raised beach material to a total thickness of at least 3 metres suggests former deep active layer formation. It has to be born in mind that during a period of permafrost presence active layer thicknesses will vary with time and will be at their 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 necessarily be coeval in age throughout its extent. Further, a number of separate periods of active layer formation beneath a stable land surface might each contribute towards the total fabric. Recent work (e.g. 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 structure formation. 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.

However, these mechanisms are not directly transferable to the relatively coarse diamicts which form the host materials of the Alderney macrofabrics. Clearly an explanation of the way in which clasts reorientate is required. Although currently there are no ruling hypotheses (Washburn, 1979), the re-orientation is likely to be progressive and here it is postulated that a combination of numerous freeze-thaw events and the release of trapped pore water are crucial to the process. During autumn active layer freeze back may occur from both the surface downwards and upwards from the permafrost table below and the diminishing unfrozen layer containing pore water under increasing pressure will migrate. Periodically excess pressure exerted by the pore water is released by rupture of the confining upper frozen layer where it is weakest. At those points where release occurs, the clasts are able to rotate to give least resistance to the flow. Under this mechanism, the widespread sub-surface zone of disruption is the end product following numerous release events, analogous to the summation of multiple water escape structures. An alternative might be that "convection" cells in association with surface patterned ground formation are involved but the absence of a significant fines content in the surficial materials suggest that this is less likely.

The large boulder below Fort Tourgis is interpreted as the product of an incomplete ejection from the active layer. The mechanism of frost push has been reproduced by physical modelling by Kaplar (1965). In summary this arises from the differing thermal conductivities of the constituent elements which contribute to the mass of the ground being frozen. Large rock clasts have relatively higher conductivities in comparison with the matrix and as a result tend to cool to the freezing point ahead of the adjacent material with lower conductivities. At the horizon corresponding to the base of a large clast, the base of the clast achieves a freezing temperature first. This causes ice lens formation beneath the clast and once such a lens is initiated more water is drawn to the point of freezing. Growth of the lens causes an upward force and consequent uplift of the the clast. Repeated cycles of ice lens formation can push clasts to the surface to cause cultivated fields to display the well-known phenomenon of fields which "grow" stones. The oriented mega-clast below Fort Tougis is considered to be an example of this mechanism on a larger scale and generally the process is known as frost heaving (Price, 1970). A related feature may develop in well jointed rock where differential ice lens growth can cause vertical block displacement of over 1 m above the adjacent bedrock surface (Dyke, 1984, 1986).

CONCLUSION

The duration of permafrost presence in western Europe during the Last Glacial Stage is still a matter of conjecture but since the stage as a whole lasted for some 100 ka it is probable that permafrost was present for over a quarter of the stage. The above proposed summation of release event effects should be viewed in terms of varying permafrost palaeoclimates during this time span. From the sedimentological evidence discussed above, it appears that severe periglacial climatic conditions occurred on Alderney during the Last Glacial stage. Such phenomena have not been previously recorded in the Channel Islands although relict permafrost structures are reported from the French mainland. Van Vliet-Lanoe (1996) has proposed that at the Last Glacial Maximum (18 ka BP) the continuous-discontinous permafrost boundary extended just west of the Cotentin Peninsula across the English Channel to about Dorset. Our evidence is wholly consistent with that reconstruction.

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