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VISTULIAN PERIGLACIAL ENVIRONMENTS IN THE LLEYN PENINSULA

Abstract

Periglacial phenomena are more widespread in the Lleyn Peninsula than has been hitherto recorded. They are found at three distinct horizons inter-stratified with glacial and glacio-fluvial deposits of the Vistulian glaciation. The climatic significance of the phenomena are considered in an attempt to assess the nature of the periglacial environments in which they were formed.

The periglacial phenomena in the Lleyn Peninsula of North-west Wales are geographically more extensive and stratigraphically more frequent than they have hitherto been described in the literature. An analysis of the glacial succession (Saunders, 1968a) clearly indicates (Fig. 1) that the region has been glaciated on at least two occasions during the Vistulian glacial maximum. During these occasions composite ice-streams from both the Irish Sea Basin and the Snowdonian-Harlech Dome uplands invaded the region. During the first recorded glaciation the ice sheet completely inundated the peninsula depositing calcareous Irish Sea till over the peninsula to the west of Pwllheli and an argillaceous, Welsh till containing slate erratics in the eastern half of Lleyn. The extent of the ice sheets was more limited during the second glacial phase: the ice limits during this phase and the location of the unglaciated areas is indicated in figure 2. The occurrence of a number of periglacial environmental conditions associated with the advance and retreat stages of these ice bodies is witnessed by the profusion of deposits, structures, and landforms of periglacial origin. Moreover, the preservation of these phenomena is evidence of the ineffective nature of post-glacial erosion in the areas where periglacial phenomena are preserved.

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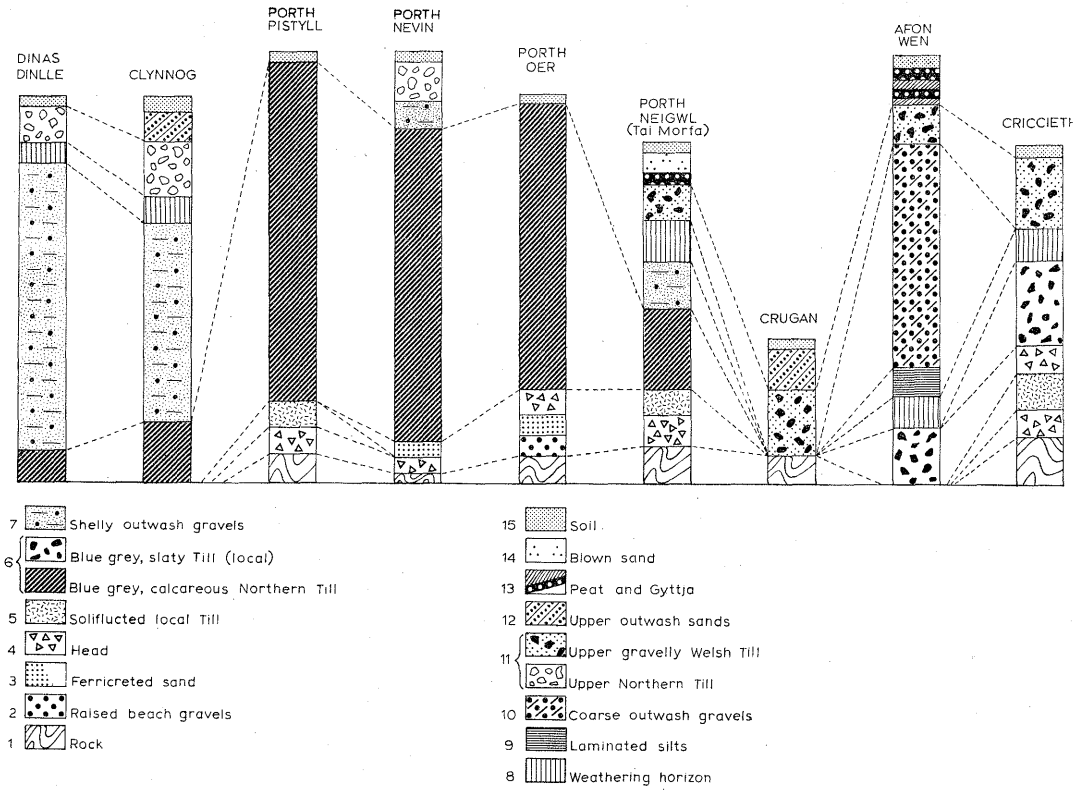


Fig. 1. A tentative correlation of the major drift sections in the Lleyn Peninsula

THE NATURE AND EVIDENCE OF THE PERIGLACIAL DEPOSITS

The periglacial deposits represent the most widerspread of the periglacial phenomena in the Lleyn Peninsula. Although the lithological character of these deposits varies considerably according to local environmental controls especially parent rock materials, aspect and angle of slope, nevertheless four main types of periglacial deposit have been recognised:

(a) Bedded Screens
- (I) Buried bedded screens
- (II) Bedded slope deposits

(b) Head deposits
(c) Solifluction deposits
(d) Hillwash

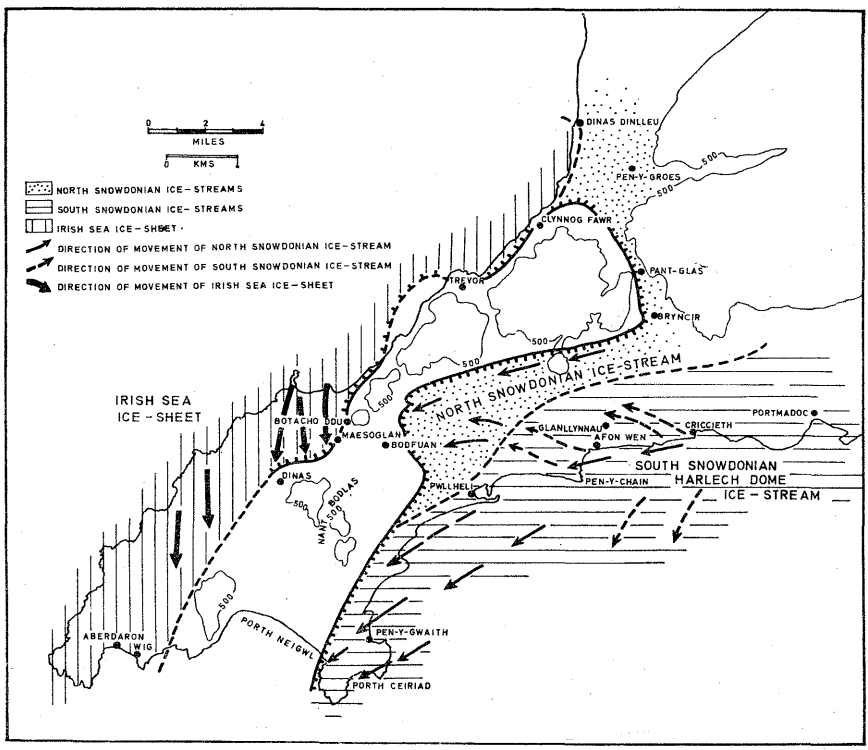


Fig. 2. The Lleyn Peninsula showing the relationship between the invading ice-streams during the deposition of the upper till, and the direction of ice flowage

BEDDED SCREES

Accumulations of angular rock fragments which consist of an alternation of coarse and fine grained debris subsequently cemented by mineral precipitation or by the deposition of silty matrix have been variously described as congelifractates (Bryan, 1946), éboulis ordonées (Tricart, 1953), grèzes litées (Guillien, 1951), cemented screes (Prentice and Morris, 1959), and bedded screes.

In the Lleyn Peninsula such bedded screes showing an alternation of coarser and finer grained material, are present beneath the boulder clays of the first recorded glaciation at a number of localities (Fig. 3). In this area, the distribution of bedded screes are confined to localities immediately adjacent to outcrops of fine-grained, fissile rocks, particularly the outcrops of Ordovician shales. Adjacent outorops of more massive rocks such as rhyolitic, micro-granitic and doleritic rocks which doubtless experienced identical climatic conditions, were shattered to produce a more blocky head deposit.

Near Wig (23/187258) at the western end of Aberdaron Bay, some 10 to 15 metres of bedded scree interposes itself between the overlying northern, calcareous till and the underlying Arenig shales. The deposit has an apparent dip varying between 10° and 27° to the east and is composed of angular flakes and slivers of shale (up to 8 cms long in the coarser horizons) cemented in a brown silty matrix of smaller shale fragments. The horizons of shale fragments can be traced back to the adjacent parent outcrop at the surface of which the laminations of the shale show evidence of downslope creep. No lithological differences have been observed in the shale outcrop which might have been responsible for the stratification of the scree : hence it is concluded that external, environmental factors must be responsible for the alternation of the coarse and fine material.

Similar stratified screes developed upon Ordovician shale outcrops and underlying tills of the first recorded glaciation, are exposed in Porth Neigwl and Porth Ceiriad. In each case the stratified scree deposit is between 6 and 10 metres thick and displays a rapid alternation of coarser and finer grained layers giving way to predominantly fine-grained angular material in the upper half of the deposit. In the Porth Ceiriad deposit the fragments in the finer grained horizons average 2.5 cms in diameter and those in the coarser bands 10.0 cms.

The remaining example of a stratified scree is found mantling the slopes of the Nant Bodlas meltwater channel, near Inkerman Bridge, and thus post-dates the last recorded glacial maximum (Saunders, 1968). At this locality, vegetated stratified scree developed on Ordovician shales was exposed to a depth of 3.3 metres on the southward facing wall of the channel but is only thinly developed (0.6 to 1.0 metre) on the northward facing slope.

At Inkerman Bridge the Ordovician outcrop is intruded by a dyke of quartz--albite granophyre. At the margins of the granophyre outcrop the stratified scree grades into a coarse, blocky vegetated scree with no visible signs of stratification.

HEAD DEPOSITS

The head deposits of the peninsula vary considerably in lithology and occur at several distinct stratigraphical horizons. Beneath the lower of the two tills horizons outcrops of massive igneous rocks produced a coarse blocky, open-textured scree markedly contrasting with the predominantly stratified

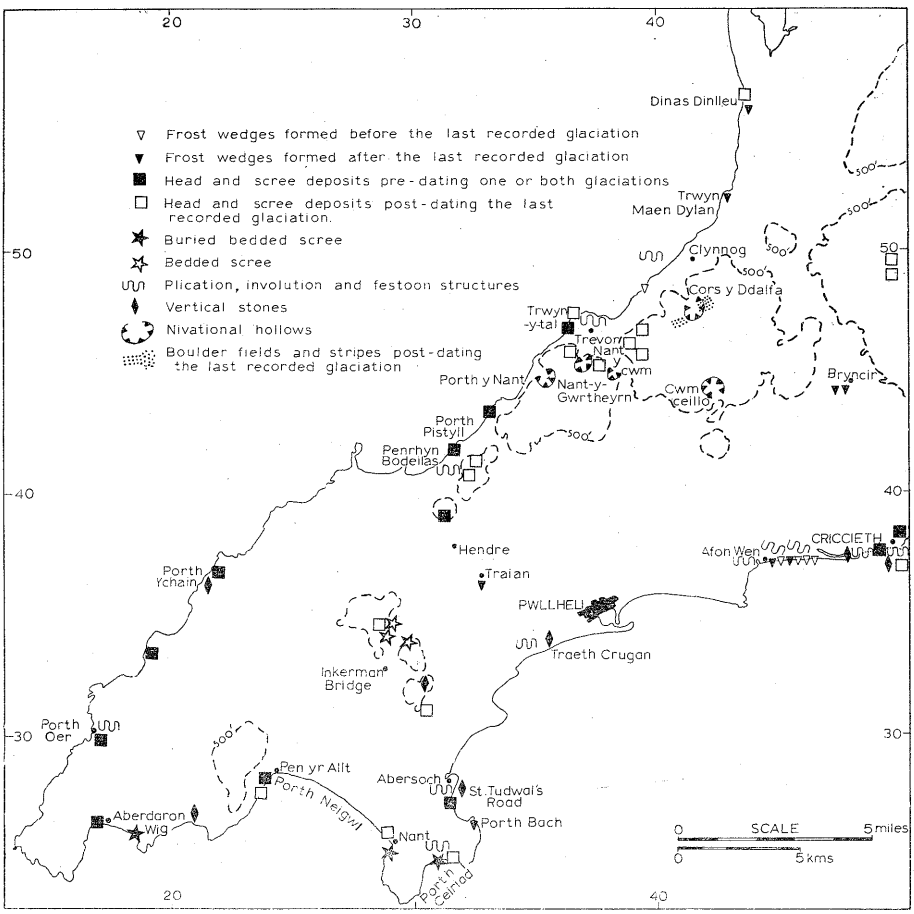


Fig. 3. Periglacial deposits, structures and landforms in south-west Caernarvonshire

screes of the same age developed on the shale outcrops. The distribution of this lower blocky head is shown on figure 3, but two localities deserve attention. On the southern side of Penrhyn-glas (23/332345) there is a development of some 10-12 metres of ‚granitic' head beneath the Northern calcareous till. This deposit is composed of large blocky, sharply angular fragments of granodiorite derived from the Yr Eifl mass. There is little interstitial material and no evidence of bedding. The deposit, however, does show the vertical gradation in particle size. The basal portion of the deposit is composed largely of blocks in excess of 30 cms in diameter, whereas the constituent fragments in the upper horizons have a mean diameter of some 20 cms. A similar differentiation between a coarse basal zone and a finer grained upper zone is displayed by a shale head on the northern flanks of Penrhyn Du.

This differentiation in the lower head deposits of a coarse basal zone and a finer-grained upper zone developed from rock outcrops of the same lithological characteristics suggests changing environmental conditions during its formation. Such a view is supported by the evidence of an interesting exposure (Plate 1) formerly visible on the eastern flanks of Criccieth Castle (23/301376). Here, a layer of frost heaved Welsh till (pre-dating the main advance of the first recorded glaciation) is inter-bedded between two layers of blocky, rhyolitic head. This tripartite division (head–local till–head) is overlain by some 10–15 cms of fine, silty loessic material.

The lithology of the ‚upper' head contrasts markedly with that of the lower head, and its distribution throughout the peninsula is more limited, being confined largely to areas in close proximity to outcrops or former outcrops of shale (Fig. 3). In the majority of exposures the upper head consists largely of fine angular flakes of shale in a matrix of soliflucted till. Such deposits are exposed at Trwyn-y-tal, Porth Ceiriad and Morannedd.

SOLIFLUCTION DEPOSITS

Away from the outcrops of Ordovician shales and in those parts of the peninsula where the surface is composed of glacial drifts, typical head deposits are replaced by horizons of soliflucted till in which there are few entrained frost-heaved fragments of local rocks. The fine flaky fragments which are to be found in the deposits have been largely produced by the disintergration of erratics of shaly material. Such solifluction deposits have been observed at two horizions in the drift section at Nant, at Porth Pistyll, and at Afon Wen. In the last mentioned locality, the solifluction deposits are assocated with a zone of weathering seperating the two main tills.

COLLUVIAL DEPOSITS

The uppermost member in many of the drift sections in the Lleyn Peninsula is a layer of fine-grained hill-wash or colluvial material often infilling cryoturbation structures in the underlying drifts. It is a predominantly silty deposit with proportions of sand and loessic material.

PERIGLACIAL STRUCTURES

Periglacial structures in south-west Caernarvonshire consist of frost wedge casts and involutions. The distrubution of these features is shown in figure 3. From this diagram it is apparent that the majority of these structures are located in the eastern half of the peninsula. The involutions vary considerable from simple symmetrical 'micro-folds' to complex undulations and 'overfolds' (Saunders, 1968). Although the involutions are more widespread throughout the peninsula than frost wedge casts, they are everywhere confined to the topmost horizons of the drift deposits and are generally located in the more gravelly tills of the second recorded glaciation. Only at Methlem (23/168301) have these structures been observed in the drift of the main Irish Sea glaciation. The thickness of the drift deposits affected by the involutions and associated cryoturbation features varies between 2.5 metres and 3.0 metres.

In contrast, frost wedge casts are found at two stratigraphical horizons. The surface of the blue-grey, argillaceous till of the first recorded glaciation is extensively cracked by frost wedge casts at Afon Wen (Fig. 4) and to a lesser extent at Morannedd. The wedges are infilled with the middle soliflucted deposits and, at Afon Wen their mouths are sealed by a band of finely laminated silts. These silts show wavy laminations. The morphology of the frost wedge casts varies considerably (Saunders, 1969), but their depth of penetration is between 0.6 metres and 1.7 metres.

Frost wedge casts of smaller dimensions have also been recorded in the gravelly northern till between Clynnog and Trwyn Maen Dylan (23/426522). These frost wedge casts extend to depths between 1.0 metres and 1.3 metres, but are associated with cryoturbation to a depth of 3.0 metres.

Frost wedge casts of considerably greater magnitude occur in the kame and kettle spread of outwash gravels, formed by the decay of the last ice-sheet in the peninsula, around Bryncir (23/480447). In this locality, numerous exposures display the existence of two generations of frost wedge casts (Plate 2). The lower, and generally smaller, of these casts are intra-formational and are unsually well preserved – even the up-arched 'lips' of the wedge are present, having escaped destruction during the subsequent deposition of the

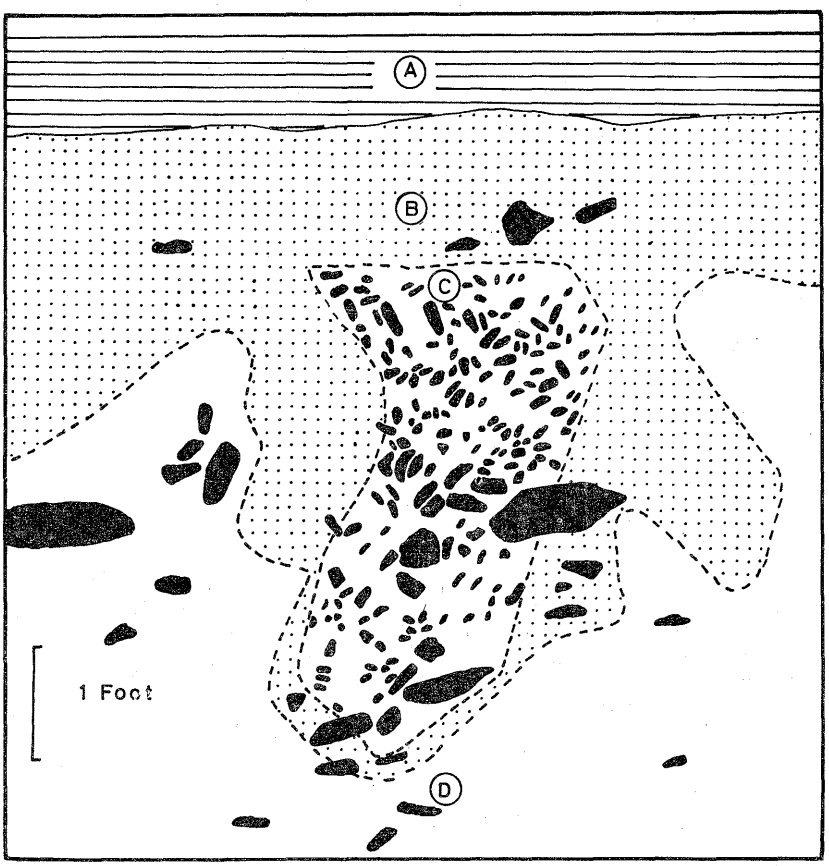
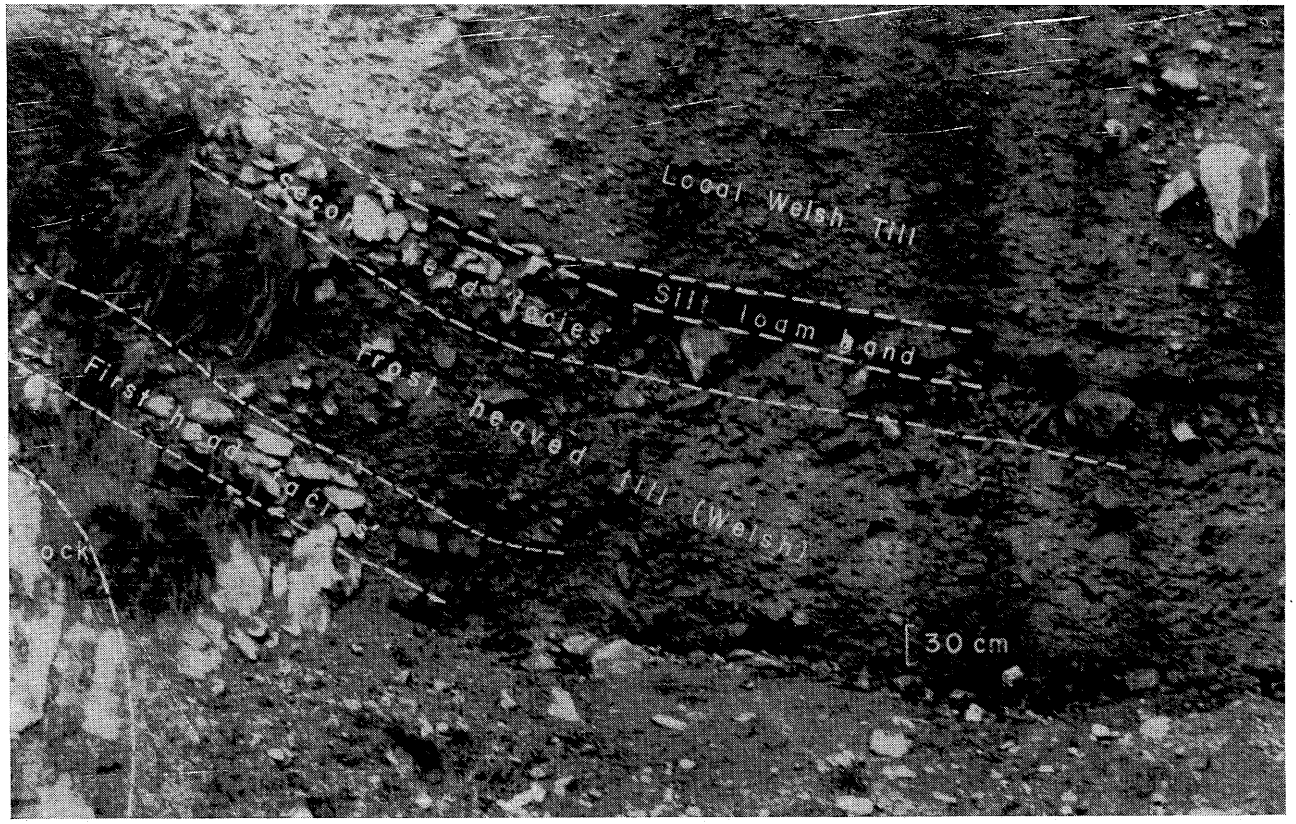


Fig. 4. Frost wedge developed in blue grey Welsh till at Afon Wen

A – laminated silts; B – weathered blue grey Welsh till; C – stones, largely vertical in silty matrix; D – fresh blue grey Welsh till. Stones are diagrammatic but largely to scale

overlying horizons of sands and gravels. There is no evidence of a stratigraphical break in the deposition of the outwash sands and gravels at the mouths of these intraformational frost wedges. Hence the conclusion would seem to be that they are syngenetic, having grown up through the accumulating gravels until the amelioration of climatic conditions terminated this phase of frost-wedge development. These intra-formational wedge casts are generally 1.9 metres wide at their mouths and penetre to depths of 2.0 metres to 2.5 metres.

The younger generation of frost wedge casts in the Bryncir gravels are only partially preserved. Their upper parts have been removed by erosion, and they now terminate at a clear stratigraphical break in the accumulation of the sands and gravels. In spite of truncation, however, these frost wedge



Pl. 1. The Criccieth Castle section. Note frost heaved till horizon, interbedded between two rhyolitic heads, and overlying silt loam band

Pl. 2. Two generations of frost wedge casts at Bryncir

casts are still considerably larger than the intra-formational casts both in terms of their width (1.0 to 1.2 metres) at their point of truncation and the depth of penetration (2.5 to 2.7 metres).

OTHER PERIGLACIAL PHENOMENA

The remaining cold climate phenomena are dominantly macro- and micro--landforms which are generally belived to post-date the last recorded glaciation of the area. The major landforms include numerous nivation cirques which are located on the Bwlch Mawr and Yr Eifl uplands (Fig. 3). Characteristic of these landforms are the nivation cirques of Corsyddalfa and Cwm Ceilio. Both cirques are relatively shallow features (*circa* 20 metres deep) with thick (over 15 metres) of solifluction deposits covering their floors. Small pro-talus moraines ridge the surface of the deposits and consist of either fine angular local rock fragments (as in Corsyddalfa) or blocky material in an argillaceous matrix (as in Cwm Ceilio). In all the nivation hollows the solifluction infill of the floor is overrun along its margins by later formed solifluction lobes. In the case of Corsyddalfa, the slopes of the adjacent upland areas show the development of stone stripes merging into block glides and finally spreading over the floor of the hollow as a block field of sub--anular boulders (*circa* 1.6 metres in diameter). Elsewhere, the slopes of the Northern Coastal Range and the Carn Fadron Hills are clothed by partially vegetated block glides.

DISCUSSION

PALAEO-CLIMATIC SIGNIFICANCE OF THE DEPOSITS AND STRUCTURES

Any attempt to reconstruct the nature of the periglacial environments of south-west Caernarvonshire during the Vistulian is dependent upon a knowledge both of the location of the periglacial phenomena within the chronostratigraphy of the local drift succession, and of the palaeo-climatic significance of the individual periglacial phenomena.

The periglacial structures and deposits of the Lleyn Peninsula clearly indicate that a cold, non-glacial climatic environment has prevailed on at least three separate occasions. The first phase of cold climatic conditions is witnessed by the formation of the buried bedded screes and the associated coarse and fine blocky heads which pre-date the deposition of the blue-grey, calcareous northern till of the first recorded glacial maximum. No periglacial structures have been observed in association with these 'lower' head deposits, a fact which suggests that the climatic environment was not conducive to

the formation of permafrost during this stage. The evidence of the 'lower' head, therefore, indicates only a prolonged phase of climatic conditions characterised by freeze–thaw cycles of unknown amplitude and frequency. The paleo-climatic significance of 'facies' changes in the buried bedded screes and the blocky heads is difficult to determine, beyond an indication of climatic fluctuations (not solely confined to temperature) during the cold climate phase.

The second phase of cold climatic conditions, indicated by the weathering horizon which overlies the tills and shelly outwash gravels, post-dates the first recorded glacial recession. The weathered and soliflucted till by itself provides little information concerning the prevailing climatic conditions, since sludging of the blue-grey calcareous till occurs readily after heavy rainfall under present climatic conditions. However, the weathering and soliflucted horizon is associated with the frost wedge casts at Afon Wen, Morannedd, and the cryoturbation structures at Dinas Dinlle and Clynnog. These structures would seem to indicate that the prevailing climatic conditions favoured the development of permafrost, and are indicative of more severe periglacial conditions than occurred during the accumulation of the 'lower' head (Péwé, 1963), with mean annual air temparatures of $-5°C$ to $-10°C$.

The third phase of cold, non-glacial climatic conditions, which is indicated by the marked development of involutions in the gravelly upper tills, the minor frost-wedging at Trwyn Maen Dylan and those at Bryncir, as well as the 'upper' head, is clearly associated with the recessional stage of the second recorded glaciation and the immediate post-glaciation period. At Bryncir the wedges would appear to indicate extreme periglacial conditions during the deposition of the lower horizons of the outwash grawels with wedge structures and permafrost keeping pace with the upward growth of the outwash sediments. These extreme environmental conditions temporarily ameliorated thus terminating the upward growth of the older, intra-formational frost wedge casts. Subsequent climatic deterioration resulted in the return of discontinuous or continuous permafrost conditions as indicated by the younger generation of frost wedge cast at Bryncir.

The paleo-climatic significance of the periglacial landforms and their position in the chronostratigraphy of the area is less certain. The nivation cirques probably owe their development to many periglacial phases, particularly during the latter stages of the Pleistocene. All that may be confidently concluded is that their development necessitated climatic conditions conducive to the existence of permanent snow patches, while a cold climate characterised by freeze–thaw cycles produced the stone stripes, block-glides and blockfields which post-date (albeit marginally) the formation of the nivation hollows.

Table I

A tentative Middle and Upper Pleistocene chronology for the Lleyn Peninsula

Thousands of years BP	North Europe chronology	C-14 dates in N Wales	C-14 dates in S Wales	C-14 dates in the Borderlands	Lleyn Peninsula terminology	Events in NW Wales
						Weathering and soil development
5	Holocene	Glanllynnau				
10	Zone III	Brynkir				Nivation cirques
	Zone II Alleröd				Upper Outwash	Blocky scree Weathering
15	Main Würm Glaciation	Porth Dinllaen	Tre-Ilys	Sandiway	Dinas–Trevor–Brynkir Moraine	Valley Glaciation Scottish Readvance
		Porth Neigwl	Mullock Bridge	·-? Four Ashes	Phase of weathering and frost wedging	Phase of weathering
20		Moel Tryfaen	Bano-y-Warren	New Marton	Shelly outwash	Retreat of Irish Sea Ice
			Cil-maenllwyd	Buildwas	Irish Sea Glaciation	Advance of Irish Sea Ice
25					Head and Scree	
30	Paudorf					Boreal / Arctic Climates
35	Middle Würm				Middle Würm Interstadial	
40	(Pleni-glacial A)					
45						
50	Early Würm				?	
55						
60	—Brörup—					
65	—Amersfoort—					
70						
75	Eemian Interglacial				Porth Oer Raised Beach	
80						
	Riss ?					

THE DATING OF THE PERIGLACIAL ENVIRONMENTS

Radio-carbon dates (Saunders, 1968c) for the blue-grey, calcareous northern till and its associated shelly outwash gravels of 29,000 ± 1,200 years and 31,800 $^{+\ 1,800}_{-\ 1,200}$ years B. P., indicate that the main glaciation in the Lleyn Peninsula should be ascribed to the Vistulian glacial maximum which occurred between 20,000 and 17,000 years B P. The younger re-advance glaciation seems to have occurred between 16,830 $^{+\ 970}_{-\ 860}$ years B.P. and 11,740 ± 170 years B.P.

In the light of these radio-carbon dates, it is clear that the earliest cold climate non-glacial environment was terminated by 20,000 to 17,000 years B.P. The duration of the cold climatic phase is, however, difficult to determine. The cold climatic conditions most probably related only to a very short time span immediately preceding the main Vistulian glaciation of the area, but it is possible that they may represent a more lengthy period extending back to the middle or even early Vistulian.

In contrast, the dating of the 'upper' and 'lower' tills of the peninsula provides relatively fixed time limits for the phase of intense permafrost conditions which separated the main Vistulian glaciation from the minor re-advance glaciation. Permafrost conditions thus existed in the lowlands of the Lleyn Peninsula between 18,000 years and 15,000 years B.P.

The final periglacial phase is quite clearly associated with the deglaciation of the late Vistulian re-advance glaciation and must have commenced somewhere between 13,000 years and 12,000 years B.P., and probably continued, to the close of Late glacial times, with minor fluctuations.

CONCLUSIONS

The lowlands of south-western Caernarvonshire have experienced three phases of cold climatic, non-glacial conditions. The earliest of these phases, pre-dating the Vistulian glacial maximum, indicates only the existence of a climate characterised by freeze—thaw cycles. The two remaining periglacial phases, both post-dating the Vistulian glacial maximum, show evidence of extreme periglacial conditions with mean annual air temperatures some 10° to 15°C lower than those of the present climatic environment. The major phases of periglacial activity in south-west Caernarvonshire is thus seen to post-date the main phase in Southern England, where the majority of workers have attributed the bulk of the periglacial erosion to the Vistulian glacial maximum.

ACKNOWLEDGMENTS

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