Geo Factsheet

Number 99

Glaciation in the Berwyn Mountains

During the last ice age, North Wales was subject to several glacial episodes which resulted in substantial modification of the existing landscape. The effects of glacial erosion, such as flat-floored glacial troughs and corries dominate the Berwyn Mountains, but additional evidence of deglaciation and periglaciation can be found in the form of various depositional features. An examination of the Nant-y-Llyn valley in the S.E of the Berwyn Mountains provides a good framework to study landscape within the recent geological past. The Berwyn mountains are located in Powys in the Welsh Borderland area.

Understanding the last 'ice-age'

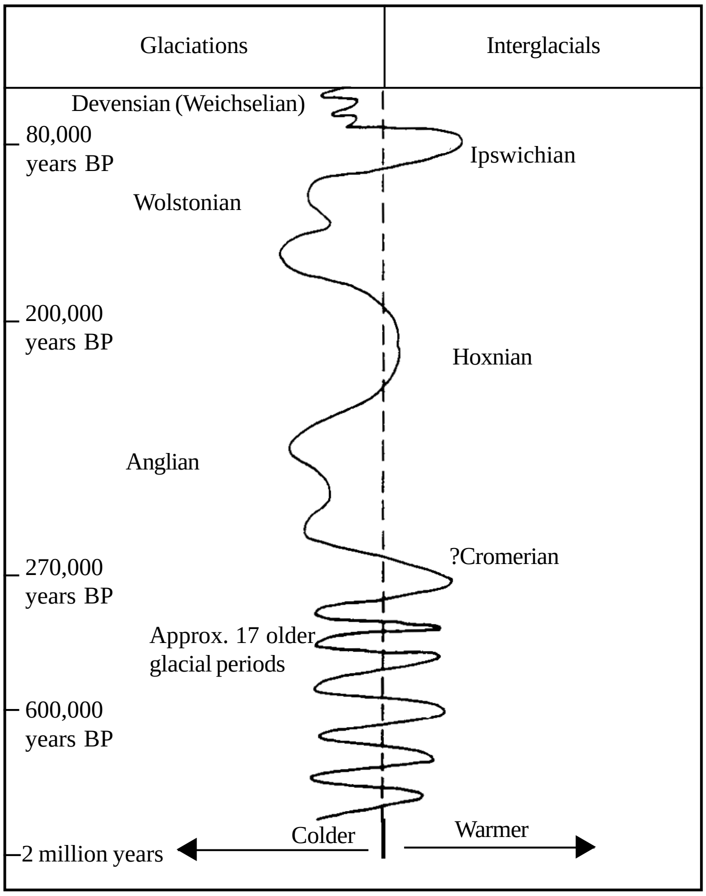
The idea that the last ice-age (the **Pleistocene**) was one of freezing climates is a commonly held belief. In fact the Pleistocene lasted about 3-4 million years and was made up of cold and warm periods of climatic activity: **glacials** and **interglacials** (see Fig. 1 a & 1b).

Fig 1a. Glacials and Interglacials of the Pleistocene

Stages In Britain		Climate
Holocene	Flandrian (Post Glacial)	Temperate
Pleistocene	Loch Lomond 10kyBP Devensian 80kyBP	Mt. Glacial? Cold Glacial
	Ipswichian	**Interglacial**
	120kyBP Wolstonian 200kyBP	Cold Glacial
	Hoxnian	**Interglacial**
	Anglian 270k BP	Cold Glacial
	Cromerian	**Temperate**
	Beestonian	Periglacial and Glacial
	Pastonian 0.6-1.6 million BP	**Temperate**
	Baventian	Cold
	Antian	**Temperate**
	Thurnian	Cold
	Ludhamian 2 - 2.5 million BP	**Temperate**
	Waltonian	**Temperate**

Interglacial Epoch in bold
(warmer period between colder glacials)

Fig 1b. Temperature fluctuations in the Pleistocene



But evidence of the earliest climatic fluctuations within the Pleistocene becomes increasingly unreliable due to the progressive reworking and modification of the existing landscape.

The post-glacial period, i.e. the last 10,000 years before present (B.P.) is known as the **Holocene**. This period witnessed massive deglaciation across Northern Europe and further modification of the existing landscape. Evidence for this is often based on analysis of the vegetation history by means of pollen remains preserved in peat bogs and archaeological evidence. Even today the causes of climatic change leading to the switching between warmer and colder periods of atmospheric conditions are not fully understood. It is likely that a number of factors are responsible, examples include:

1. Distance of the earth from the sun, i.e. the amount of solar energy received by the Earth (the Earth has a cyclical elliptical orbit around the sun)
2. Changes in the amount of carbon dioxide in the atmosphere. This can be linked to volcanic eruptions and more recently pollution from power stations and vehicles etc.

3. Tectonic activity and periods of mountain building leading to changes in the Earth's **albedo** or reflectivity, due to the formation of high, snow covered mountain peaks.

Unravelling the Past in the Berwyn Mountains

Whatever the causes of climatic change, there is clear evidence in the Nant-y-Llyn valley that it has been extensively modified by glacial processes. Indeed, the bulk of the landscape features in the Berwyns are **relic**, largely inherited from processes operating in cooler conditions of the Ice Ages. It is likely the **Devensian** ice advance has significantly influenced the region in recent geological history (Fig. 1a and 1b). This glacial reached its maximum extent about 30,000 B.P., when much of Wales was covered with a considerable thickness of ice. More recently the **Loch Lomond Readvance** (c.11,000 B.P) over-deepened many Welsh valleys in upland areas, including the Berwyns. During this final part of the Pleistocene, **periglacial** conditions dominated by **permafrost** (frozen ground) affected all areas of Wales. **Solifluction lobes** are also are common in upland areas, being produced by the gradual oozing of unsorted rock debris down slopes during periods of summer thawing.

The Loch Lomond glacial was short-lived and by 10,000 B.P. temperatures began to steadily rise. This period of climate **amelioration** marked the start of the Holocene and the return of climate to more temperate conditions, similar to those which are experienced today. During the early part of the Holocene, there was a high energy, **fluvio-glacial** meltwater stream occupying the Nant-y-Llyn valley produced as a result of thawing ice. This has left a variety of semi-sorted deposits on the valley floor.
There is also plentiful evidence within the valley for the effect of contemporary processes such as, **gullying**, which have tended to modify the glacial features, since the last glaciation.

Geological Background of the Berwyn Mountains

Geologically, most of Wales consists of rocks which are over 300 million years old. Generally, older rocks tend to be harder and form areas for higher relief, whilst younger rocks are usually softer and provide flatter, more rounded topography. The South and East of England for instance, are mostly made up of rocks which are less than 200 million years old.

The Berwyn Mountains originate from Ordovician strata which are about 450 million years old. The rocks forming the sides of the Nant-y-Llyn valley were originally sediments, including sandstones, siltstones and shales. Pressure and heat has caused many of these soft sediments to become baked and compressed into harder slates. This **pressure metamorphism** also produced quartz veins within the slates which are apparent in the backwall of the corries.

The presence of a micro-granite sill, up to 30 m thick in places, forms an important intrusive, horizontal layer within the valley. This can be seen forming prominent crags around the valley and the hard cap rock of the waterfall (Pistol Rhaeader).
It is thought that a fault line runs down the line of the valley having been first exploited by fluvial activity and eventually by periods of glaciation, as a line of weakness. (Shatter zone).

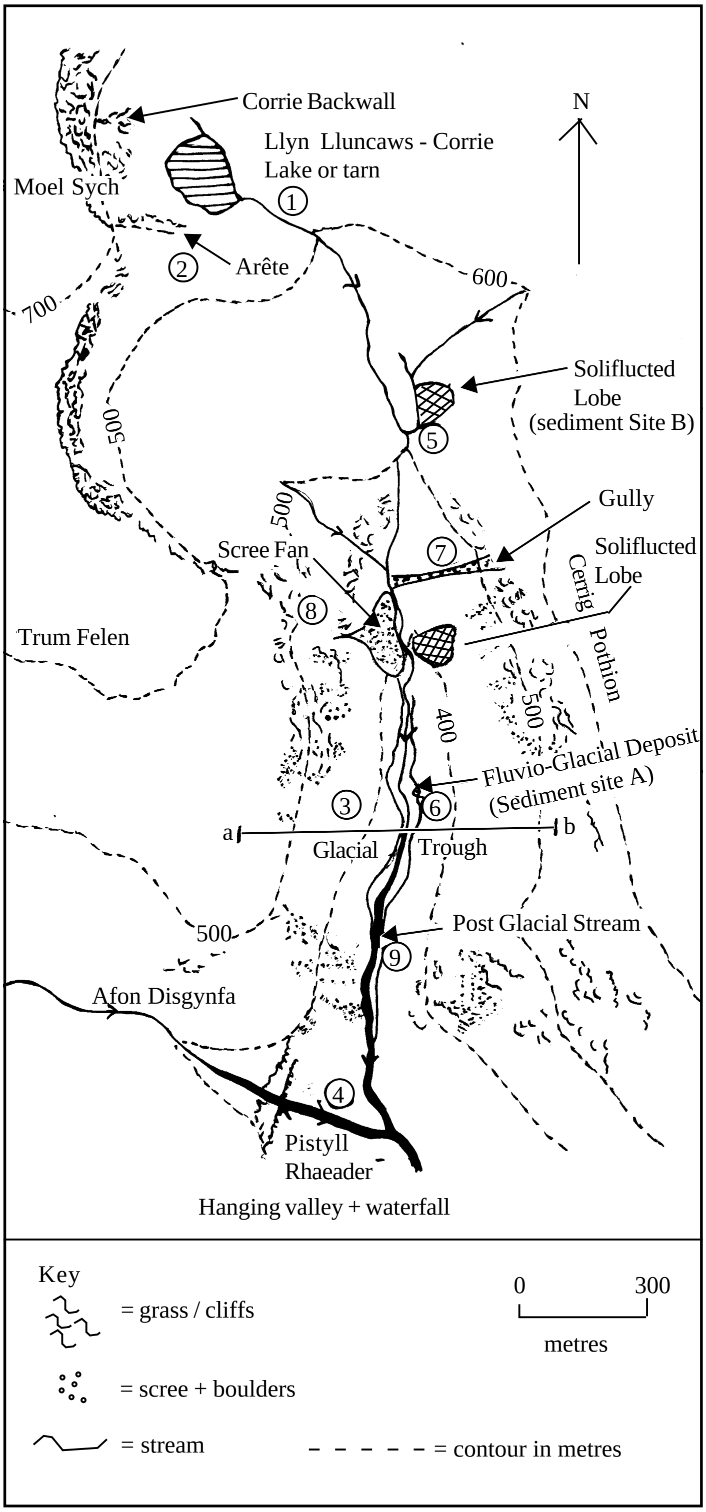
Features in the Nant-y-Llyn valley

The Welsh translation of Nant-y-Llyn means 'Valley of the Lake'. Using Fig. 2 as reference, the valley runs approximately North-South for 3000 m and has an obvious glacial lake or **tarn** at its northern end. The summit tops are 827 m above sea level. Three main categories of features are identified for ease of reference:

- Erosional
- Depositional (including till fabric analysis)
- Post-glacial and recent

Each feature / point of reference is numbered and labelled on Fig 2.

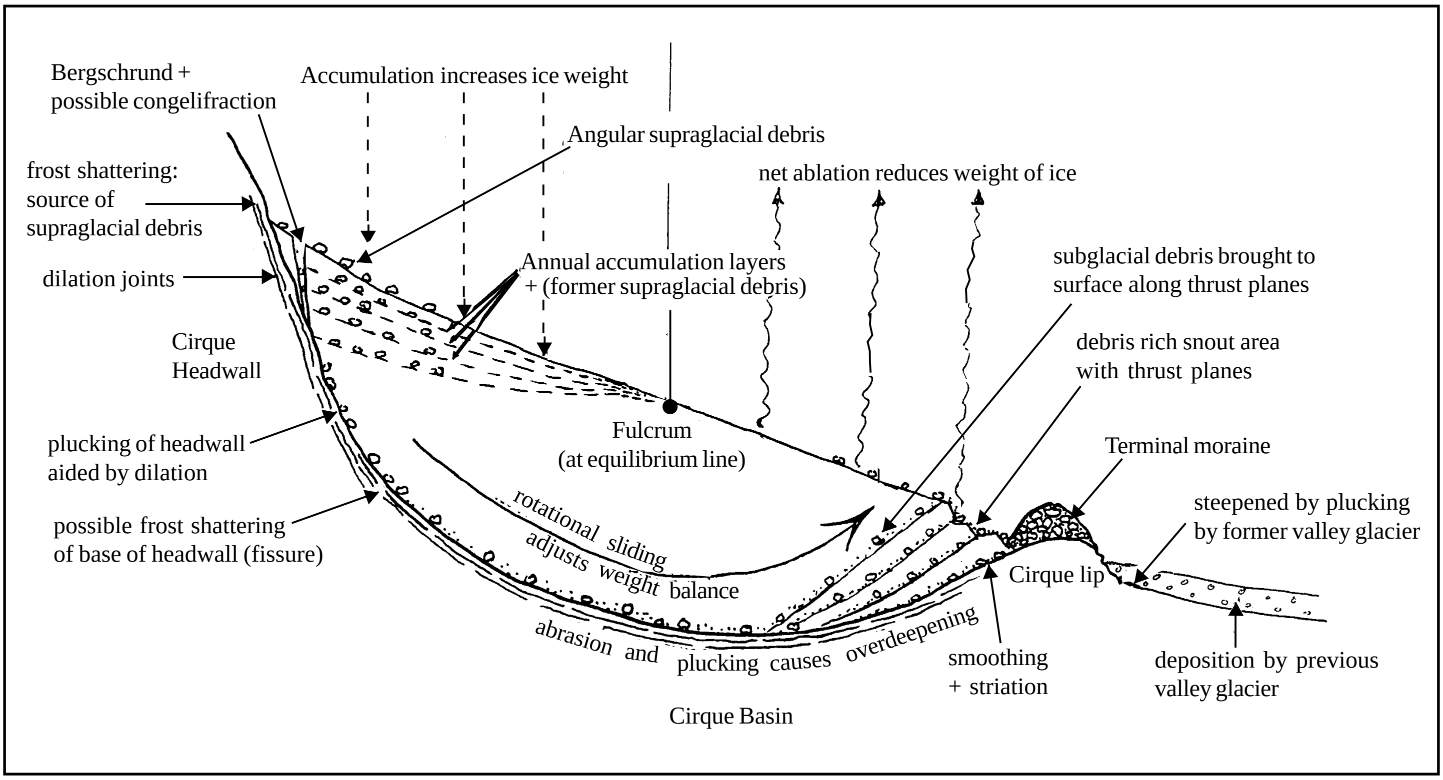
Fig 2. Geomorphological map of the Nant-y-Llyn Valley



Erosional features:

Llyn Lluncaws (1) This is the glacial tarn surrounded by an armchair shaped depression. Fig 3a (overleaf) is a long section of this glacial **corrie** or **cirque** which shows the characteristic processes during formation. Llyn Lluncaws acted as the collecting ground or source for the ice which moved S.E and then southwards down the Nant-y-Llyn valley following the previous river valley.

Fig 3a. A Glacial Cirque (long section) Llyn Lluncaws Cirque

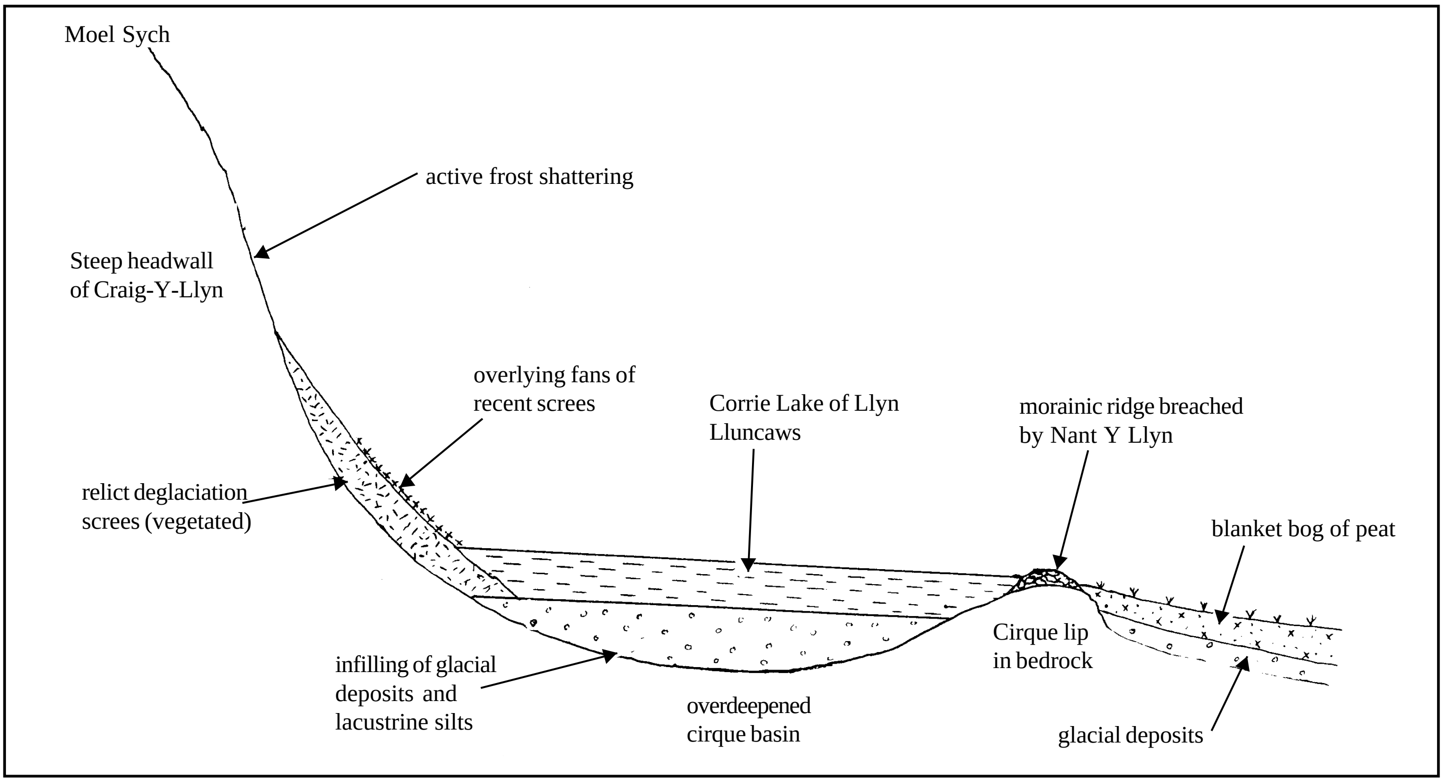


Corries originate with the accumulation of snow in a hollow and through **nivation** the snow is gradually compacted into ice. This process causes deepening of the hollow, and when the ice reaches sufficient mass, it begins to flow away from the backwall and eventually down the valley under response to gravity. Note the unusual **aspect** of this corrie – S.E. Most corries in England and Wales have a N. or N.E. aspect, their development being linked with low temperatures allowing more rapid snow accumulation. However SE is a relatively sheltered aspect from the prevailing westerlies, which allows for maximum accumulation of snow.

Fig 3b. shows a current field sketch of the corrie and post-glacial lake.

The round tarn is often referred to as the 'Lake of Cheese' which is a translation of 'Llyn Lluncaws'. During the late summer, floating plants on the lake flower and this gives rise to the appearance of a 'round cheese' when the lake is viewed from above.

Fig 3b. Postglacial cirque: Llyn Lluncaws Berwyn Mountains



Arête (2) Corries are rarely isolated features, and using Fig. 2, note that there is another corrie to the south of Llyn Lluncaws. Where two corries cut back into a ridge against each other, the intervening apex or spur may be sharpened into an arête. The arête shown in Fig. 2 is not a knife-edged ridge, but is a well defined linear feature about 50 m wide at its narrowest point.

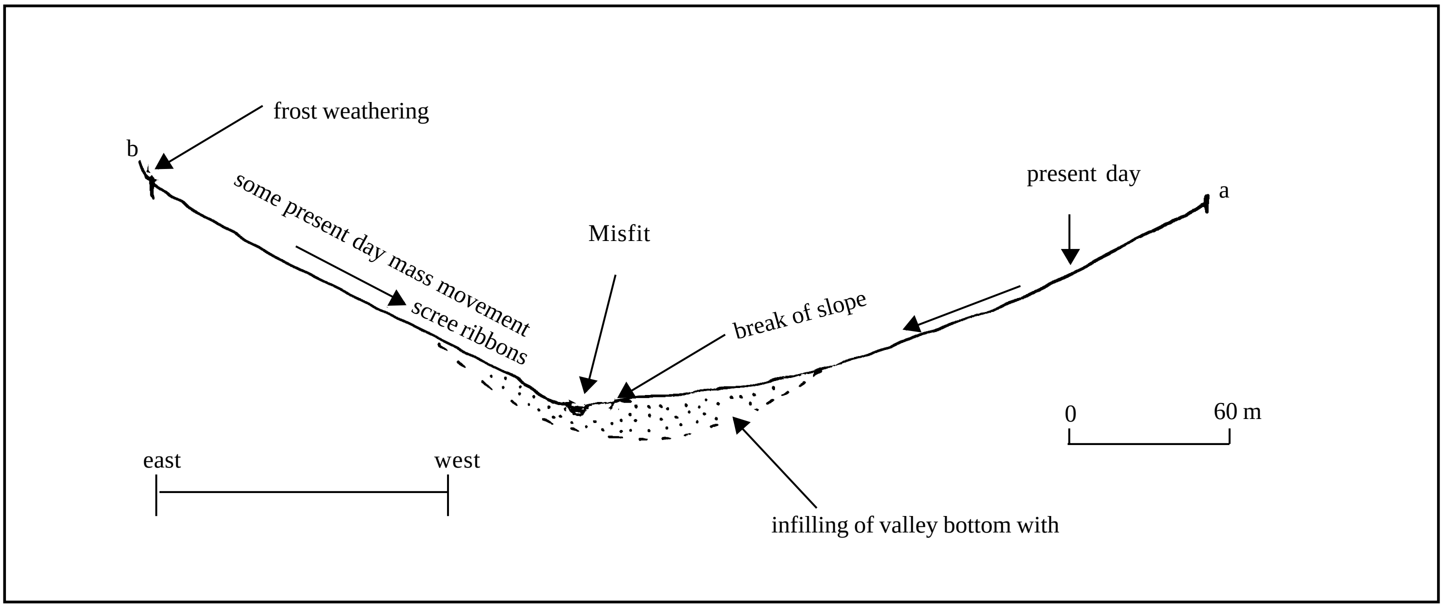
Glacial Trough (3) The Nant-y-Llyn valley is an example of a glaciated valley, with a characteristic parabolic cross-section. The idea that all glaciated valleys are 'U' shaped is a simplification as there are many diverse forms of **glacial troughs**. Another important feature of the valley is the occurrence of **breaks in slope** and the presence of a step **incised** by stream action.
Fig. 4 shows a cross-section of the valley through point a-b on Fig 2.

This profile is determined by the energy of the ice movement in relation to the structural geology at this point. The long profile of the Nant-y-Llyn is characterised by pronounced **headward steepening**.

Pistyll Rhaeadr (4). The Afon Disgynfa forms a tributary valley to the main Nant-y-Llyn. There is now an impressive **waterfall** feature at the junction between the two valleys, with the smaller Disgynfa left '**hanging**' above the larger Nant-y-Llyn. Differences in the erosive energies of the two glaciers accounts for the height difference which is over 70 m (the drop on the waterfall).

The waterfall is capped by the harder micro-granite sill, underlain by the softer shales and slate. The waterfall is also an important **honey-pot site** attraction and is recognised as one of the 'Seven Wonders of Wales'. Various facilities are provided for tourists: café, toilets, car park and interpretation boards.

Fig 4. Valley cross profile - valley morphology



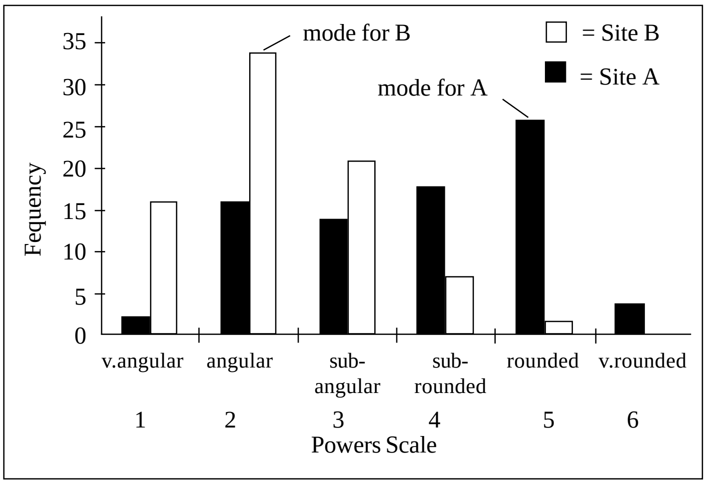
Depositional features:
Table 1 can be used to assist with interpretation of some depositional features.

Table 1. Deposit and depositional features

DEPOSIT	Position in Valley	Orientation	Shape	Degree of Sorting
Fluvial	Bottom	Downstream / valley	Rounded	Well sorted
Fluvio-glacial	Bottom	Some downstream	Variable, some rounded	Some sorting
Moraine / Till	Bottom & Side	No orientation apparent in this location	Angular	No sorting apparent
Soliflucted 'Head'	Valley sides	Downslope	Angular	Poor sorting

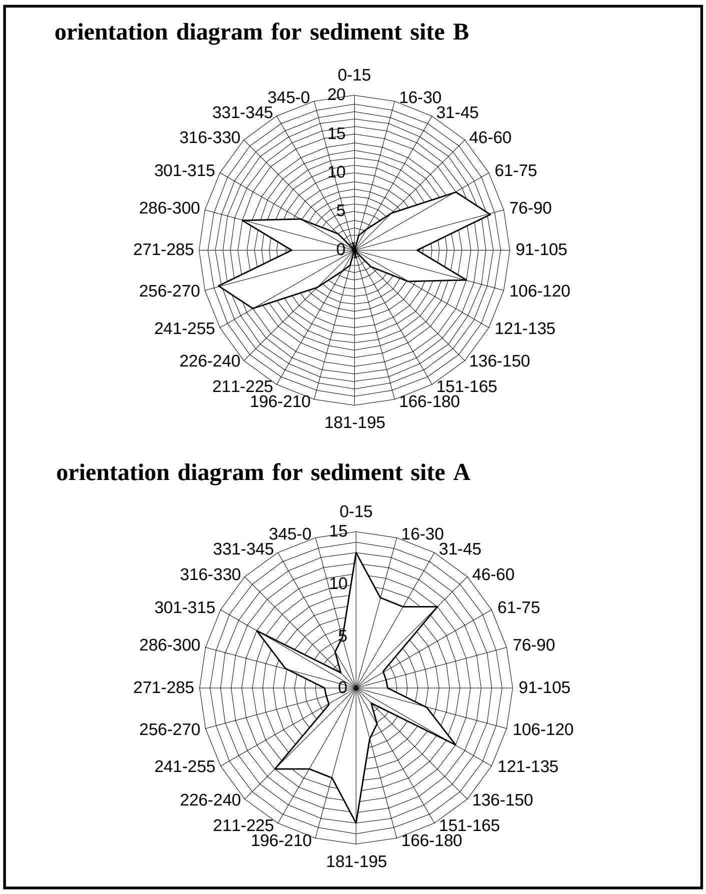
Fig 5. Shows field based sediment fabric results for site A and B (see Fig 2.)

Fig 5. Powers Shape Index



The Powers index is a measure of the shape of a sediment, 1 being 'very angular' and 6 very rounded'. Note how data for site A has a **mode** which is rounded and there are relatively for angular stones, whereas for site B the mode is angular. The measures of shape could be further backed up by index of wear/roundness measurements (Cailleux) or the use of Zing's index if the a, b, c axis, and radius of curvature of each stone in the sample was measured. (See Fig 6.)

Fig 6. Comparison of orientation of stones at the two sites



Soliflucted lobe/ Sediment Site B (5) This deposit is positioned on the eastern valley side above a tributary to the main Nant– y – Llyn River. The stones in the solifluction lobe at Site B (5) in Fig 2. can be seen to have marked E-W orientation in Fig 6. suggesting down slope gravity movement down the sides of the North – South glaciated valley. The Power's index results in Fig 5. confirm a wide range of shape but largely sub angular and angular. This is indicative of frost weathering as you would expect in periglaciated conditions. The deposit is therefore a **head** deposit.

Fluvio-glacial / Sediment Site A (6) This site is located adjacent to the present river and is part of an exposure or **river cliff**, where sediment samples have been taken. The sediments at this site show a strong preferred orientation NNE-SSW, although a certain amount of bi-modal trend is apparent (Fig 6) in the NW-SE axis. The Powers data indicates variability in sediment shape, but has a 'Rounded' modal class (Fig 5). Evidence, therefore, points to this deposit being **fluvio-glacial in origin**. The bi-modal trend from the orientation data can be linked to a dynamic braided system on the valley floor during deglaciation, with the river regularly changing direction and course.

Post Glacial And Recent Features / Processes

Although the Nant-y-Llyn valley has been extensively modified by ice, a number of more recent processes have influenced valley morphology (Fig 4.)

Infilling of Glacial Trough. The Nant-y-Llyn valley has been infilled by deposition from the fluvio-glacial stream, **moraine**, and solifluction from the valley sides.

Weathering and mass movement (7, 8) Freeze-thaw action on exposed rock outcrops and crags is the dominant weathering process in this harsh upland environment delivering large quantities of angular material to the base of slopes. It has contributed to the development of various **scree fans** and **scree ribbons** on the valley sides. In addition to these there are a number of **gullies** which act as conduits, allowing passage of weathered debris to move down slope under response to gravity.

Post glacial stream (9) The present Nant-y-Llyn river is a misfit stream. The river forms a **sinuous** channel pattern located along the eastern part of the valley bottom. However, evidence of the former course of the river is apparent in the form of the **river terraces**, caused by erosion (fluvial incision) of the relic fluvio-glacial deposits laid down at the start of the Holocene. Effectively there is a valley within a valley – the post glacial stream identifiable by is V-shaped cross section cutting into the fluvio-glacial deposits, but contained within the much larger, principal Nant-y-Llyn trough.

A final reminder…….

Most glacial landforms are **polygenetic**, i.e. they are the product of several episodes of glaciation, and have also been modified under periglacial and interglacial conditions, as well as post glacial conditions. In summary

- At different times in geological history, the Nant-y-Llyn valley has been occupied by ice and rivers of greatly varying dimensions.
- The most recent deglaciation led to big increases in meltwater activity and energy, thus modifying the associated glacial erosional and depositional features.
- During interglacial periods, the valley sides have experienced **sub-aerial** processes (in the absence of ice and snow), as well as frost shattering and other periglacial processes.
- With the onset of milder climatic conditions during the Holocene, the Nant-y-Llyn valley has been subject to modern fluvial and hillslope processes.

Practice Questions

1 (a) With reference to a glaciated upland region
  (i) Draw an annotated sketch map to show the features formed by galciation. (Hint- learn your own simple version of Fig 2.) (10 marks)
  (ii) To what extent have the glaciated features been modified by post glacial processes. (A simple section such as Fig4 . would be ideal here- include details of weathering, mass movement and fluvial activity (7 marks)

Acknowledgements;
This Geo Factsheet was researched and written by David Holmes Geography advisor for the Field Studies Council.
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