Chapter 1 Introduction

Eighteen geological excursions and guides to popular walks are described in this book and, with the exception of some outcrops on the road traverse, all the localities described lie within the boundaries of the recently published Harlech (135) 1:50 000 Geological Sheet (Figure 1). Most of the area is in the Snowdonia National Park. Apart from the coastal strip from Talsarnau to Barmouth it is sparsely populated and used mainly for upland grazing and forestry. The principal topographical features, rising to heights of over 700 m, are the Rhinogs, which form an imposing spinal ridge, and Rhobell Fawr to the east.

Whilst every effort has been made to ensure that the routes are public rights of way, the footpaths may be changed from time to time. Ask permission from the land owners before leaving footpaths, refrain from climbing over dry stone walls and fences and always observe the Code of Conduct for Geology, published by the Geologists' Association. Special care should be taken at old mine workings some of which may be in a dangerous condition. You are strongly advised not to enter them.

Several people have helped us in the preparation of this book. Among them we should like to thank Ian F. Smith, Shirley Jackson and M. F. Howells for their help in the field and with the manuscript. Dr A. W. A. Rushton provided the palaeontological notes.

Stratigraphy

The exposed rocks in the area covered by this book are Cambrian and Ordovician in age. Rocks of Precambrian age have been encountered only in a borehole drilled through the lowermost Cambrian (Allen and Jackson, 1978) and are nowhere likely to be exposed. On the coast, however, under a cover of unconsolidated Pleistocene and Recent sediments, a thick succession of Tertiary, Jurassic and Triassic sediments was penetrated by the Mochras Borehole (Woodland, 1971). The complete sequence of rocks known in the area is illustrated in (Figure 2).

Since the publication of the classic work on the area by Matley and Wilson (1946) this part of Western Merioneth has been called the Harlech dome. The 'dome' specifically refers to the structure of the Cambrian succession which is exposed in an almost circular area bounded on the west by Tertiary sediments against the Mochras Fault and elsewhere by Ordovician rocks.

The Cambrian and Ordovician rocks are divided, in ascending order, into the Harlech Grits, Mawddach, Rhobell Volcanic and Aran Volcanic groups. This classification is used on the Harlech (135) Geological Sheet, and is the result of the progressive refinement of Sedgwick's (1852) original scheme by Lapworth (in Andrew, 1910), Wells (1925), Matley and Wilson (1946), Ridgway (1975), Kokelaar (1979), and Allen, Jackson and Rushton (1981).

The succession of Cambrian sedimentary rocks, some 5 km thick, is represented by the Harlech Grits and Mawddach groups which are divided into ten distinctive formations (Figure 3). On the south-eastern part of the Harlech dome the two uppermost formations of the Mawddach Group are overstepped by basaltic volcanic rocks of the Rhobell Volcanic Group. According to Kokelaar (1979) the group represents the remnants of a volcanic pile erupted during the late Tremadoc epoch and was originally at least 3.9 km thick.

Both the Mawddach and Rhobell Volcanic groups are unconformably overlain by about 1.2 km of volcanic and intercalated sedimentary rocks of Ordovician age named the Aran Volcanic Group by Ridgway (1975). The group crops out as a continuous belt of volcanic rocks around the southern, eastern and north-eastern sides of the Harlech dome. On the northern side of the dome Ordovician rocks younger than the Aran Volcanic Group are thrust over the Cambrian. The stratigraphical classification (Figure 5) of the group is based broadly on the divisions recognised by Fearnsides (1905) and Cox and Wells (1927). All formations except the Allt L■yd are defined by their volcanic character. The intercalated sedimentary units have not been named because of the difficulty of recognising them when the volcanic formations are missing.

Geological history

The oldest rocks known in the area are andesitic lavas and volcaniclastic sedimentary rocks of presumed late Precambrian age encountered only in the Bryn-teg Borehole (Allen and Jackson, 1978) beneath the Harlech Grits Group. The base of this group is also nowhere exposed but, in the borehole, about 40 m of conglomerate and pebbly sandstone appear to overlie the volcanic rocks unconformably and pass upwards into a deltaic succession, the upper parts of which are exposed at surface. These lower Cambrian rocks, attributed to the Dolwen Formation, mark the establishment of a sedimentary basin that covered all of Wales, much of England, parts of Ireland and extended into Belgium. The basin was situated on the edge of a continental mass which lay to the south-east, with the Iapetus ocean on the northwest.

Above the Dolwen Formation the Harlech Grits Group consists of grey, green or purple siltstone interbedded with thick units of coarse-grained, locally pebbly, sandstone of greywacke or quartz wacke composition that display the characteristics of turbidites (Figure 4). Such rocks, derived from sediment deposited from turbidity flows, were first identified in this area by Ph.H. Kuenen, the pioneer Dutch sedimentologist. The discovery that coarse-grained sediment may be carried into deep sea basins by turbidity flows was one of the most important made in sedimentology this century. Two major invasions of turbidity flows into the gradually subsiding basin are represented by the Rhinog and Barmouth formations (Figure 3). Palaeocurrent analysis for the Rhinog Formation (Crimes, 1970), indicates that current flow was from the north with a subsidiary easterly source, whereas in the Barmouth and Gamlan formations current flow was from the south or south-east. Both the Hafotty and Gamlan formations, which overlie the two turbidite formations, are manganiferous, and it has been suggested by Mohr (1964) and Glasby (1974) from geochemical studies of the manganese ore-bed at the base of the Hafotty Formation that these rocks were deposited in an enclosed, or partly enclosed, shallow marine basin. Such conditions, however, must have been short-lived and local. In the Gamlan Formation individual manganiferous beds rarely exceed a centimetre thick, and they are associated with thin tuffaceous beds which represent the first evidence of volcanism in the Cambrian of this area.

At the top of the Harlech Grits Group two major changes in sedimentary patterns are recorded; the Clogau Formation at the base of the overlying Mawddach Group (Allen, Jackson and Rushton, 1981) contains the lowest black, carbonaceous mudstone in the succession; locally, within the uppermost few metres of the underlying Gamlan Formation there is a marked change in the arenaceous component from coarse-grained sandstone, which is dominant in the Harlech Grits Group, to fine sandstone or coarse quartzose siltstone. The two predominant lithologies of the Mawddach Group are dark grey or black silty mudstone and white or grey coarse quartzose siltstone or fine sandstone. The latter rock type is rare in the Clogau Formation. The base of the overlying Maentwrog Formation is defined by the first appearance of fine-grained turbidites. A faunal hiatus at the top of the Clogau Formation suggests that there may have been a period of non-deposition at this time. Throughout the Maentwrog Formation, the turbidites, which diminish in abundance upwards, are closely associated with beds of coarse quartzose siltstone showing sedimentary characteristics similar to those in deep ocean contourites. Thus, though coarse material was periodically being introduced into the basin by turbidity flows, there was constant reworking of the material by sea bottom currents.

The basin became shallower during the later stages of deposition of the Maentwrog Formation, and the Ffestiniog Flag Formation was deposited largely in a shallow, tidal or alluvial/estuarine environment. The overlying Cwmhesgen Formation contains black carbonaceous mudstone, a rich fauna and thin tuffaceous beds. In it there are indications of several short pauses in deposition before the final uplift and emergence at the end of the Tremadoc. Although much of North Wales was emergent at this time, Lynas (1973) showed that locally in the Migneint, just north of this area, there was no break in sedimentation through the Tremadoc into the Arenig epoch. He attributed this to the strong influence of contemporaneous north–south block faulting on patterns of sedimentation.

At the end of the Tremadoc epoch the subaerial Rhobell Fawr volcano erupted in the south-eastern part of the area. According to Kokelaar (1979), eruption took place along north–south fissures marked by the complex of intersecting dykes on the west side of Rhobell Fawr. The preserved extrusive rocks related to this episode are predominantly basaltic in composition, but the co-magmatic intrusive rocks, which form numerous sills and laccoliths in the Cambrian on the east and south sides of the Harlech dome, include microtonalite and microdiorite in addition to the dolerite. A swarm of mainly NW-trending basic dykes which crosses the Cambrian rocks of the Harlech dome is possibly a product of this magmatic episode.

During the marine transgression at the beginning of the Ordovician period, the eroded and collapsed Rhobell Fawr volcano was submerged and clastic sediments were deposited in a shallow sea. These sediments comprise the basal part of the Aran Volcanic Group (Figure 5). They are overlain by epiclastic volcanic sediments, probably derived by reworking of contemporaneous volcanic rocks to the south and east, and they mark the renewal of volcanism during the Ordovician after only a short break. The overlying volcanic sequence includes rocks of acid, intermediate and basic composition, in deposits which consist of ash-flow tuffs, crystal-rich tuffs, agglomeratic mudflows, acid and basic lavas and hyaloclastites. Most of the volcanic formations thicken towards the south-east suggesting that the main eruptive centre was in this direction. The marked thickness variation of the Melau Formation, however, indicates a number of local and separate cones, each erupting basaltic tuff and lava into a shallow sea. The presence of intercalated siltstone throughout the Aran Volcanic Group suggests that the area was submerged, though there is evidence of some local emergence. Among the volcanic rocks, and apparently contemporaneous with them, are numerous dolerite sills.

Geological structure

All the lower Palaeozoic rocks in the area have been folded, faulted, locally cleaved, and regionally metamorphosed to low greenschist facies. The main structure of the Cambrian rocks is not a simple dome. It consists of the N-trending Dolwen pericline flanked on the west by two major parallel plunging synclines, the Caerdeon syncline which plunges south, and the faulted Mod Goedog syncline which plunges north (Figure 1). East of the pericline, though there are many large folds, the dip is predominantly eastwards. The structures are most likely the result of folding during the climax of the Caledonian orogeny at the end of the Silurian period (Figure 2), but recent mapping has identified local north–south folding both before and immediately after the Rhobell volcanism. Major faults, trending roughly northwards, were initiated in the late Cambrian, and continuing movement along them exercised some control on sedimentation. In the south-east of the area the NE-trending Bala Fault is the dominant structural feature. The N-trending Mochras Fault brings Tertiary sediments into juxtaposition with Lower Palaeozoic rocks in the coastal area.

Mineralisation

The Harlech dome has long been known as a mineral province. Ore deposits of four distinct types have been profitably mined in the area. About 44 000 tons of manganese ore were mined prior to 1928 from the bedded deposit of Cambrian age near the base of the Hafotty Formation. This sedimentary ore consists mainly of spessartine (manganese garnet), rhodochrosite and quartz.

In the area around Capel Hermon, Riofinex Ltd proved (but did not work) a low-grade, disseminated copper deposit of the porphyry type (Rice and Sharp, 1976). Subsequent work by Allen, Cooper, Fuge and Rea (1976) has shown that this mineralisation is genetically related to the late Tremadoc Rhobell Volcanic Group magmatism. A copper deposit at Glasdir, worked until 1914, is within a breccia pipe (Allen and Easterbrook, 1978) formed during this same mineralisation episode.

The Dolgellau gold-belt (Andrew, 1910) lies entirely within this area. A large number of quartz veins within it have been worked for copper, lead, zinc, silver and gold at least since the 18th century. Base metal production was never great, but two of the mines, Clogau and Gwynfynydd, produced about 120 000 oz gold. K/Ar age measurements on mica taken from these veins give a mean value of 405 ± 15 Ma (C. Rundle, personal communication), which dates the veins as end Silurian or early Devonian.

The youngest ore deposit worked in this area is at the Turf copper mine where peat, impregnated with copper minerals deposited from copper-rich waters draining the porphyry copper deposit at Capel Hermon, was dug in the early 19th century (Hall, 1975).

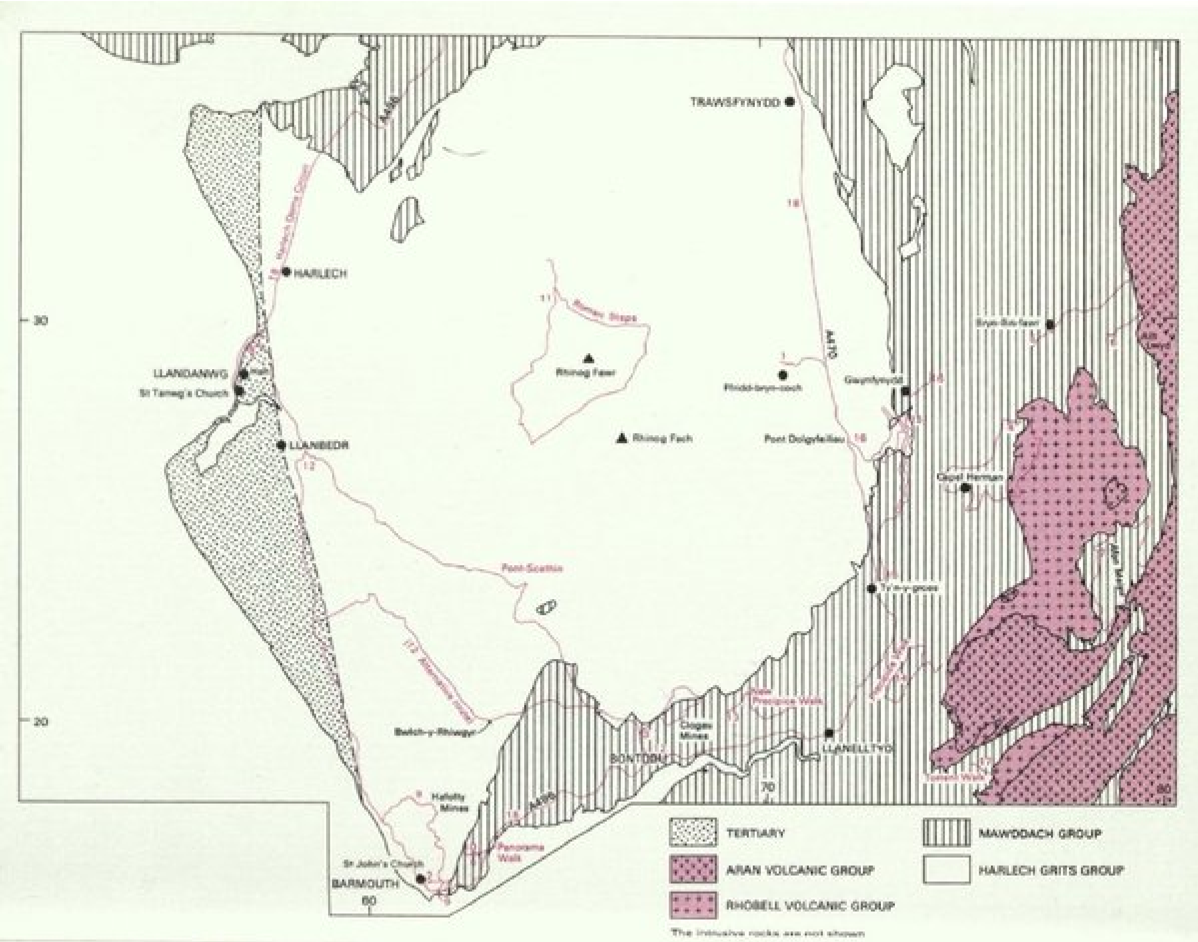
Quaternary

Superficial or drift deposits mask much of the solid geology in this area. Most of these deposits are the result of glacial or periglacial activity. At the climax of the last (late Devensian) glaciation about 17 000 years ago, the Merioneth ice cap, radiating from the Arenig to Rhobell Fawr axis (Foster, 1968), extended across the Rhinogs creating ice-scoured pavements in its passage. As the climate improved, the ice sheet gave way to valley glaciers which themselves eventually disappeared. The present-day landscape owes much to this period of intense glacial and periglacial erosion. The dominant features include U-shaped valleys, dry valleys, corries, rock basin and till-dammed lakes, as well as altiplanation terraces and stone stripes on the higher ground. Depositional features include drumlins and moraines, but there is a distinct paucity of fluvio-glacial gravels.

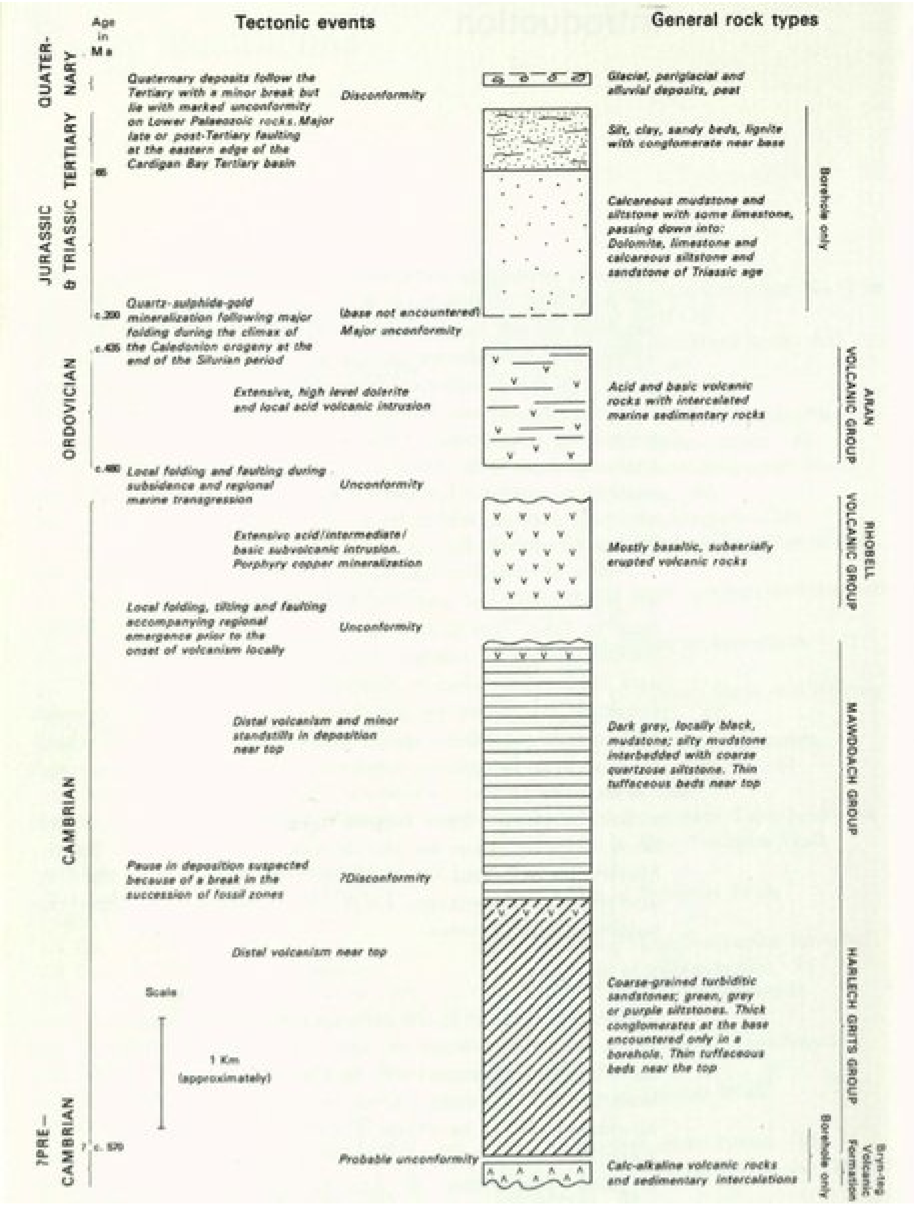
Along the coast, both the Traeth Bach and Mawddach estuary are drowned river valleys with thick accumulations of alluvium. The intervening coast, however, shows signs of accretion, with sand, silt, laminated clay and layers of peat beneath the blown sand. Peat is extensive in upland areas and along the coast, where marine erosion of the deposits, in places, has left full sized tree trunks stranded on the shore.

(Figure 44) Simple grading.

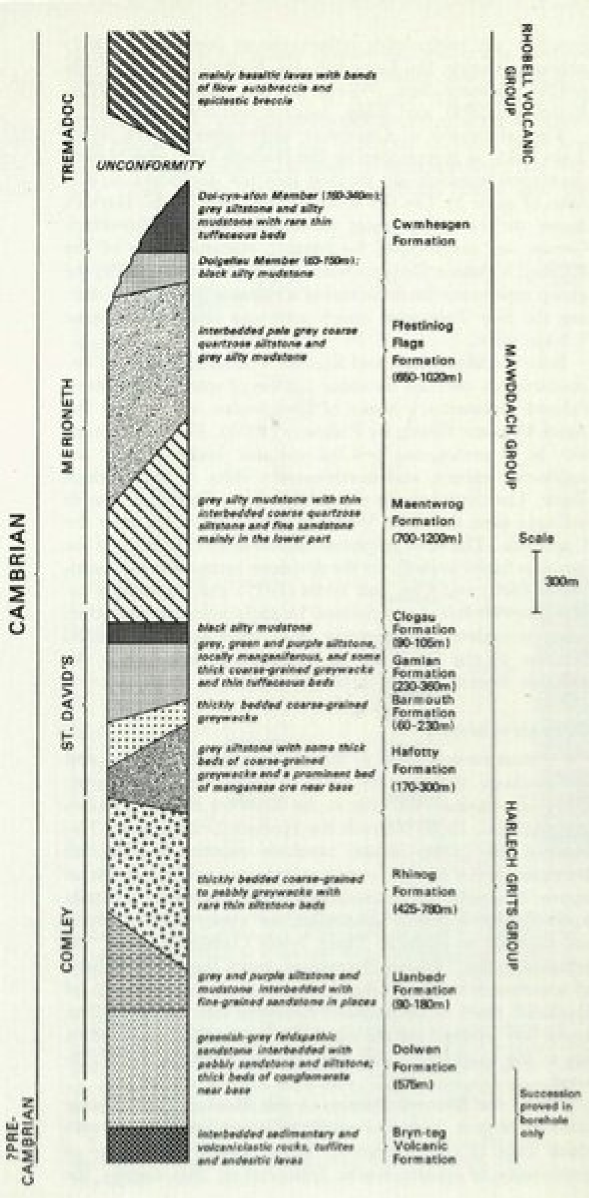
References



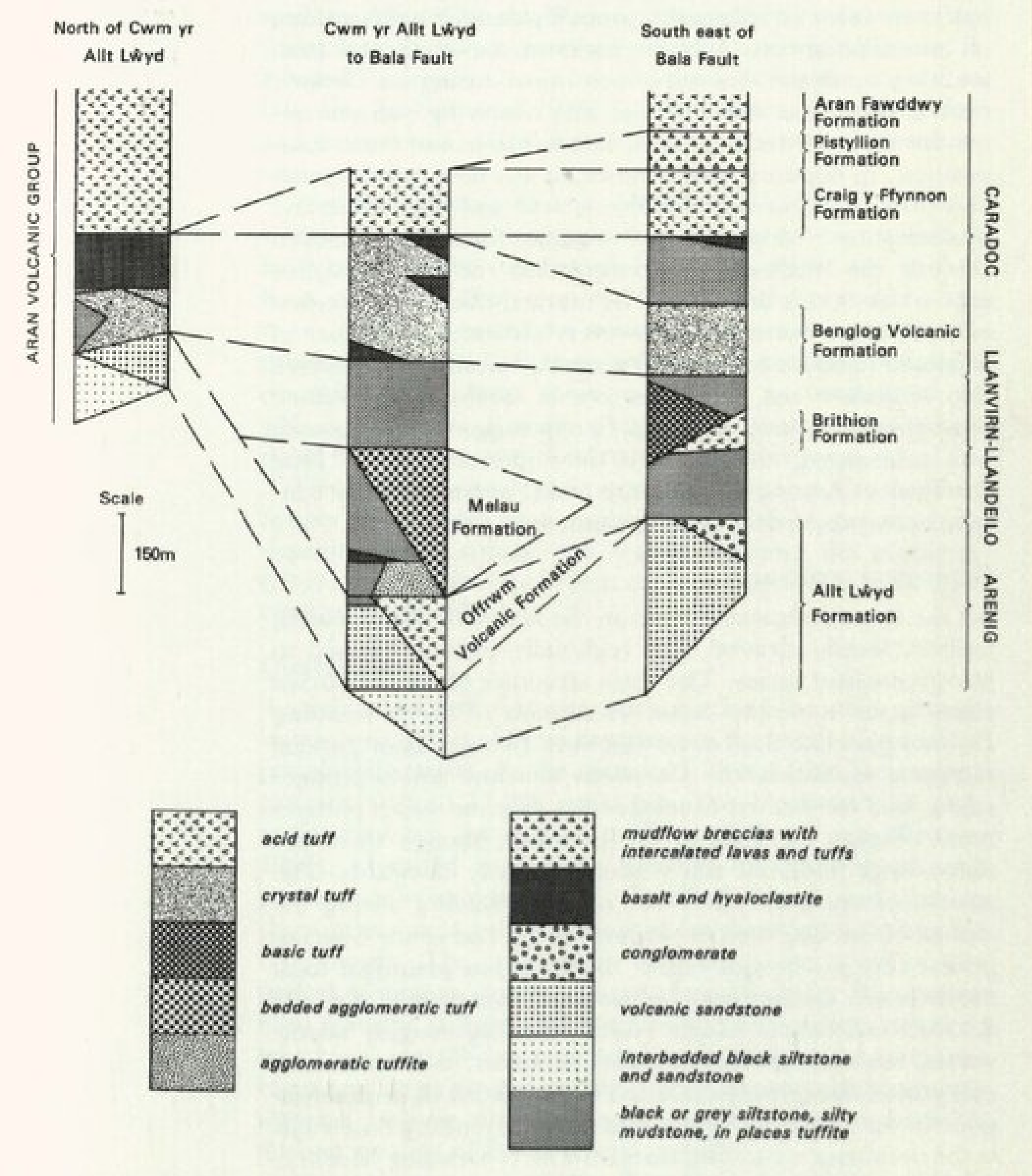
(Figure 1) Simplified geology of the Harlech (135) geological sheet showing excursion and foot path routes .



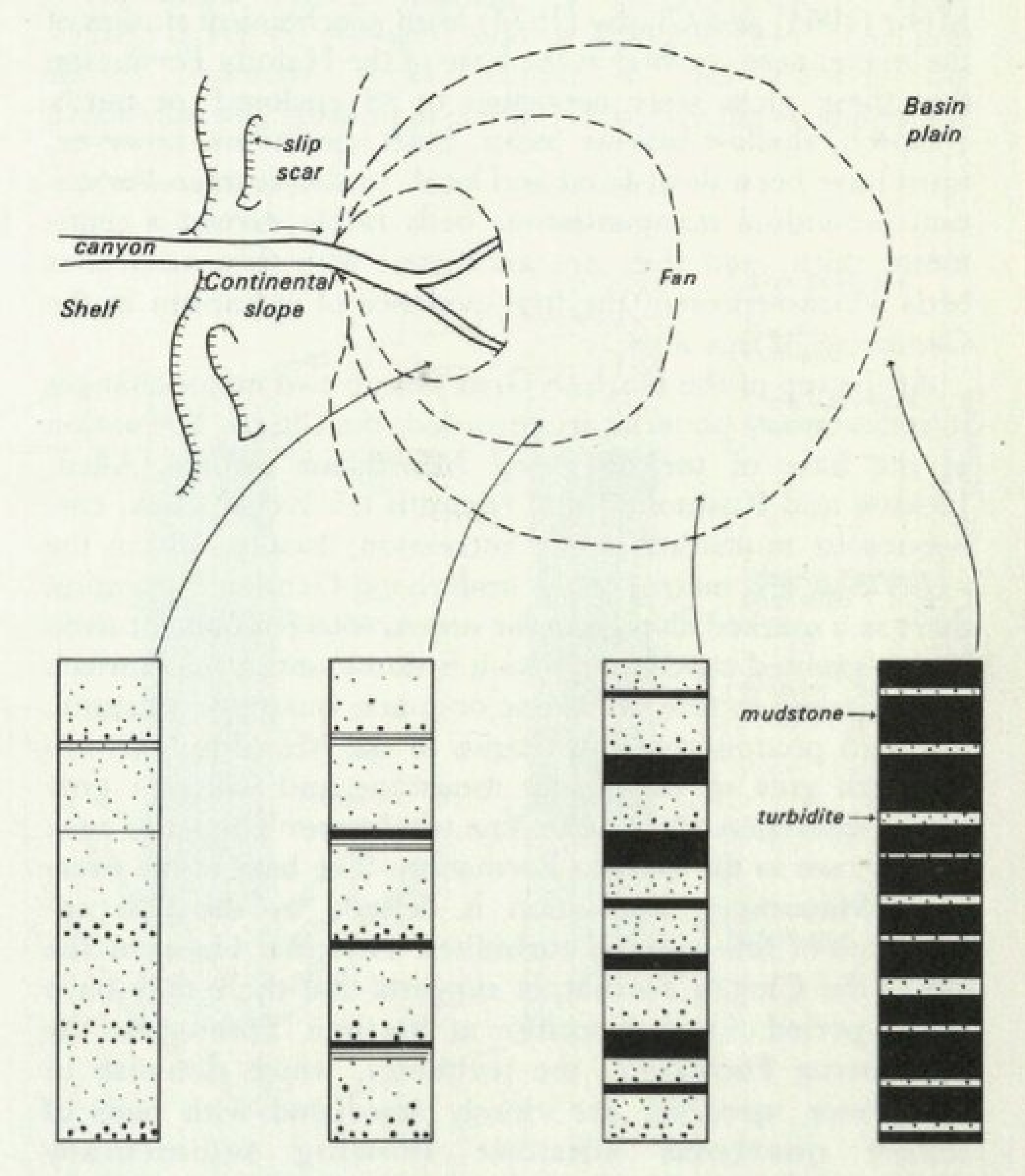
(Figure 2) Generalised stratigraphy and tectonic evolution.



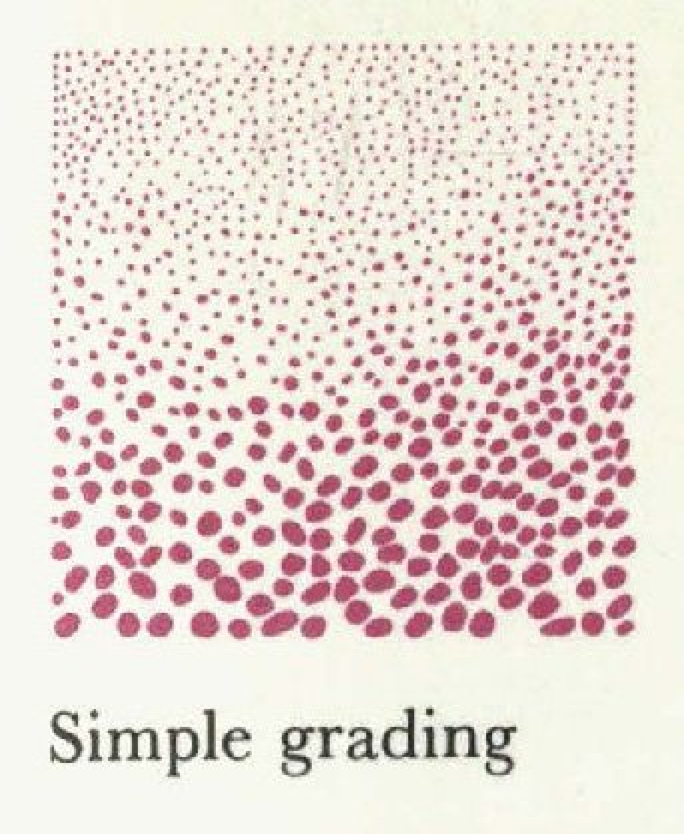
(Figure 3) Stratigraphy of the Cambrian and Precambrian.



(Figure 5) Variations in stratigraphy of the Aran Volcanic Group.



(Figure 4) Turbidite facies model. Turbidites form in deep sea fans, many kilometres in diameter, at the mouths of canyons on the edge of the continential shelf. The sedimentological characteristics in a turbidite sequence change away from the source. The sediments near the canyon mouth are generally coarse and show little internal segregation. The sediments of the mid-fan show grading and internal segregation (intervals a to e, see (Figure 9)). Interbedded mudstones and siltstones are progressively more abundant towards the edge of the fan where base-absence sequences predominate (cde) and the sediments pass imperceptibly into the abyssal plain. Near the canyon mouth the inner fan is cut by major distributary channels, whereas the outer fan is mainly an area of accretion cut only by shallow channels not more than 1 to 2 m deep. S. Dzulynski and E. K. Walton (1965) provide a comprehensive description of turbidites in 'Sedimentary features of flysch and greywackes'. Other sources are Ricci-Lucci (1975) and Walker (1965).



(Figure 44) Simple grading.