

A Soil Trail?—A Case Study from Anglesey, Wales, UK

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Received: 18 July 2009 / Accepted: 10 March 2010 / Published online: 11 April 2010
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Abstract Geodiversity includes not just rocks and major geological features, it also embraces soft sediments and landscape features. This paper demonstrates how soil profiles can be promoted within geoheritage as an important feature of the aesthetics of the landscape as well as being vital to support biodiversity and many environmental functions including pollution abatement, climate change and food production. Their importance is recognised increasingly by scientists and policy makers but there is great diversity of soil types that often goes unrecognised, and hence soils are not always used appropriately. Whilst writing a guide to the coastal footpath around Anglesey, it became obvious that there are numerous opportunities to view the soil exposed on cliff edges and this prompted the idea of a trail leaflet for walkers and the interested public. This paper summarises the range of soils on view and how they support different land uses and form the underlying reason for the diversity of the landscape.

Keywords Anglesey · Geodiversity · Soil Trail

Geodiversity of Anglesey

Subsequent to the production of the first geological map of Anglesey by Darwin's tutor, Prof John Henslow (Henslow 1822), Anglesey has attracted much attention due to its amazing diversity of rock types and the arguments over the age and origin of the large area of Precambrian metamorphic rocks. It was remapped a century later in considerable

detail by Greenly (1919). Many authors have subsequently re-examined the rocks, the structures and Greenly's interpretation; the latest publication (Treagus 2009) is an excellent field excursion guide detailing the geodiversity from Precambrian to Carboniferous, with a wide range of metamorphic, igneous and sedimentary rocks, overlain by an interesting mix of glacial and post-glacial deposits, as well as recent alluvium and blown sand due to sea level changes.

The landscape is also very varied, a low platform carved into the solid rock with a number of isolated hills, rocky coasts, extensive sand dunes, mudflats and drumlin swarms. Landscape owes its character to both geodiversity and soils, in that the latter influences natural biodiversity and human land use (Countryside Commission 1996).

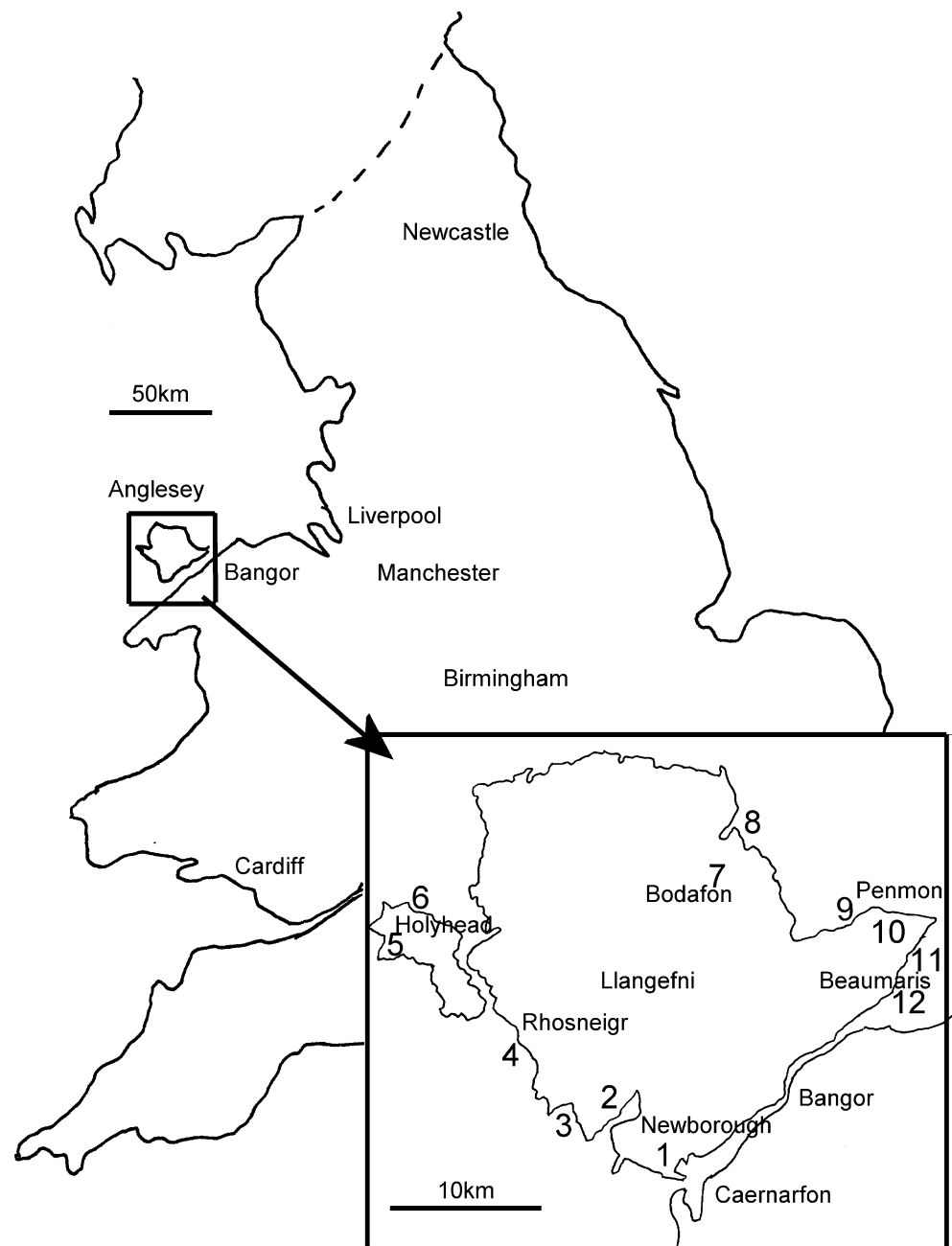
The Anglesey Coastal Footpath

Anglesey (or Môn in Welsh) is an island located off the north coast of Wales, of approximately 720 km² with 201 km of coastline (Fig. 1). The coastal area was designated by the UK government in 1967 as an Area of Outstanding Natural Beauty (AONB—a statutory designation under the Countryside and Rights of Way Act 2000) in order to protect the aesthetic appeal and the variety of the island's coastal landscapes and habitats from inappropriate development. The AONB covers about a third of the island, the coastal zone and prominent areas of Holyhead Mountain, Mynydd Bodafon and other land that forms the backdrop to the coast.

A long-distance footpath was created more recently (Anglesey County Council 2009) by linking existing footpaths and rights of way together with new sections to provide a comprehensive route around the coastline. The

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Fig. 1 Location map, (*inset*)
Anglesey soil trail locations



potential usage is hard to measure but County Council data suggest 282,000 visitors each year to the AONB, almost all of whom come for some form of experience of the coastline.

The footpath is strongly promoted to tourists as the best way to enjoy the varied landscape; it involves mainly fairly low level, gentle walking, generally crossing a plateau with isolated hills, fault-controlled valleys and a varied coastline. The most challenging sections, but also the most scenic, include Holyhead Mountain, the north coast from Porth Swtan to Porth Wen, the section south of Point Lynas and the rise to Bwrdd Arthur from Red Wharf Bay. The western coast is characterised by a series of rocky headlands with

intervening sandy bays and extensive sand dunes that enclose shallow marshes. Impressive sea cliffs dominate the northern coastline, while on the eastern side of Anglesey, more modest limestone cliffs and wide sandy beaches provide an interesting contrast. Two tidal straits—the Menai Strait and the Inland Sea—provide more sheltered coastal landscapes. The mountains of Snowdonia and Llyn dominate the view along the south and west coast, whilst there are views along the north coast of mainland Wales from the east coast of the island.

Although much of the interior has been converted to agricultural use, around the coast there are still many areas of natural or semi-natural landscape. Continuous marine

erosion refreshes exposures of solid geology, Quaternary sediments and soils along the cliffs and shorelines. A guide for the general public (Conway 2010) explains how the geology relates to the scenery along the coastal footpath; the aim of this “walkers guide” is to encourage casual walkers to appreciate not just the natural beauty or the specific features they came to view [such as birds, archaeology, wild flowers], but also to appreciate the underlying reasons for the diversity of the landscape.

Anyone walking the coastal footpath is quite likely to be looking at both landscape and the natural vegetation. There is quite a wide diversity of vegetation communities including saltmarsh, sand dune, grassland (acid and calcareous) and natural woodland. In historic times Anglesey was known as the ‘mother of Wales’ a reference to the fact that the soils grew such rich crops of grain. In these days of large machinery, arable farming is restricted by the frequent rocky outcrops in most fields and agriculture is overwhelmingly grassland and forage for livestock.

Soil Diversity

The classic view (Jenny 1941) is that soil is formed by the interaction of factors such as parent material, climate, natural vegetation, topography and time. Parent material includes both solid rocks and superficial sediments; climate and natural vegetation are environmental factors that generate weathering and other processes that change parent material into recognisable soil types. Topography, i.e. location in the landscape, slope and altitude affects hydrology and position relative to the water table, and also interacts with climate and vegetation. Time, in the context of Anglesey, relates to the last 14,000 years or so since the ice melted during which weathering has progressed on the limestones and Quaternary sediments. New soils have developed in emerging locations such as raised beaches and tracts of wind-blown sand.

The diversity of the underlying geological materials means that Anglesey provides a greater range of soil types than might at first be expected in such a relatively small area. Additionally, the combination of other factors involved in soil formation can generate several soil types from the same parent material. Mobile sediments [such as the extensive blown sand] can bury existing soils, leading to profiles superimposed above each other.

Anglesey was one of the first places in England and Wales to be surveyed (Roberts 1958) with a map published at a scale of 1:63,360 showing the different soil series (defined as a combination of soil type and parent material). Many soil series, therefore, have Welsh names which add a historical dimension to this project.

Soil Trails—Communicating Soil Information

Farmers and gardeners are familiar with the concepts of adding lime and nutrients and carrying out various forms of cultivation, whilst naturalists are aware of the relationship between plant species and specific soil conditions. However, communicating soil information to the general public is a difficult task; soils are generally below ground and most people are unaware that differences might exist. Several papers at EUROSIL (Blum et al. 2008), as at many soil conferences, address the difficulty of this task, but as yet most suggestions relate to different methods of publication, websites or multimedia which do not address the issue of the public actually seeing real soils in the field.

The importance of understanding soil processes and valuing the ecosystem services they provide is increasingly being recognised by policy makers. The proposed EU Soils Directive (CEC 2006) is not popular in England, but the UK government’s Department for Environment, Food and Rural Affairs (DEFRA 2009) has produced its own strategy for soil protection, as has the Scottish Government (2009), the Welsh Assembly (consultation paper in 2008) and England’s statutory agency for nature conservation (Natural England 2009). DEFRA focuses on agricultural management of soils but Natural England believes that soils are an essential component of most landscapes, i.e. are the link between landscape and the historic environment and play a vital role in ecosystem services, including biodiversity.

The role of soil in ameliorating climate change, moderating water quality and supporting biodiversity is increasingly mentioned in the news media. It is timely, therefore, for an initiative like the Anglesey Soil Trail to provide the public with a visual and very real engagement with soil characteristics.

Soil sites and trails have been used before, the British Forestry Commission established a trail through Delamere Forest in Cheshire [north-west England] using timber revetted pits cut into the hillside, but erosion of the face and health and safety concerns forced the closure of the trail. Conway (2006) produced a field guide to exposed soils in North Wales, utilising a variety of sites that could reasonably be expected to remain open, such as low quarry faces, roadside cuttings, eroding river banks and coastal locations, but these are isolated sites across a wide area and not a connected network. This guide was produced under sponsorship from a government agency to enable local schools to undertake geography fieldwork by providing safe locations with full information but without the need to dig pits. All the sites detailed in that publication have been notified as Regionally Important Geoheritage Sites (RIGS)

Prinz (2008) describes an initiative to encourage visitors to vineyards to view the soil by constructing roofed structures with a visible soil face and explanatory posters,

sponsored by the Bavarian government as part of its soil protection policy. Herzberger et al. (2008) describe a newly opened 5-km trail through the Austrian forest at Salkammergut illustrating seven soil profiles, accompanied by a “virtual” trail on DVD. Conway (2008a) was invited to present the concept of the Anglesey soil trail to the 3rd UNESCO Geopark conference, whilst this paper expands the outline presented by invitation at the ProGeo conference in Drenthe in 2009 to emphasise the range of soil types, and its relevance to the educational aims of geoconservation.

The Anglesey Soil Trail

The final publication format of the Trail leaflet has yet to be agreed with potential sponsors, but it will list the soil sites in a clockwise direction around the coast following the coastal footpath (the main geological footpath guide includes many more opportunities to see soils exposed). The Soil Trail is designed to promote examples of the main soil types in safe and easily accessible locations with directions to each site. This paper is intended to present the concept, and an abstract of the sites which will be included but is not the full trail leaflet.

Criteria for Selecting Sites

There are examples along the coastline of most of the ten major soil groups recognised in England and Wales (Avery 1980), including terrestrial raw soil and raw gley soil, lithomorphic, brown soils, podsol and surface water and ground water gley. The component sites of this trail have been selected for a range of criteria:

1. Linking to important features or sites of the geology/geoheritage of Anglesey—most of these sites are best exposures of geology features causing the soil types
2. Illustrating as wide a range of typical soils as possible to bring diversity to the attention of the public
3. Easily accessible and safe locations—most sites are within areas already well used by the public for other purposes, who are encouraged to notice the geoheritage of their surroundings
4. Suitability for group demonstration purposes—we hope that school and other groups will adopt some of these sites for educational purposes.

These are detailed in Table 1. The majority of the sites included in this trail have been notified as RIGS (Regional Important Geoheritage Sites), a grassroots geoconservation concept which has nevertheless been recognised in local government planning and which requires consideration before any development that would damage or destroy the

site is approved (ODPM 2005). The vulnerability of sites is also listed in Table 1; most coastal sites benefit from being refreshed by gentle erosion but are also vulnerable to damage by continued major erosion which also poses the threat of coastal protection schemes which have already obscured many sites which were valuable for demonstration of geoheritage features. Increased tourist usage of the two country parks, South Stack and Breakwater Quarry will create pressure for erosion control and footpath construction but the designation of these sites as RIGS should afford a measure of protection by consultation with the geoconservation bodies. Publication of the sites in the coastal guide (Conway 2010), the Soil Trail, and this journal will strengthen the case.

Trail Sites

1. Newborough Warren

This is an extensive area of recent blown sand in the extreme SW corner of Anglesey. It has been designated as a Special Area of Conservation for its wide range of dune habitats (embryonic, mobile and fixed dunes, dry dune heaths, humid dune slacks and dune woodlands). Within the more mobile dune areas and where erosion has cut into the other dune habitats, there are many exposures of a range of soil types from terrestrial raw soil (well-drained material with no development of soil features) on sand dunes (Fig. 2) through to raw gley soil (saturated material with no development of soil features) in wet depressions between the dunes. There are many well-exposed examples of multiple organic layers created by shifting sand burying existing soils. The importance of organic matter in creating a topsoil horizon and stabilising the sand is clear demonstrable. This is an excellent area to demonstrate the fragility of sandy soils and the extreme risk of wind erosion should the tenuous vegetation cover be disrupted. In fact, the current mobile nature of the sand is one reason for the SAC designation, namely that processes are as important as features. Part of the area has been planted with Corsican pine which not only provides some stability for the sand but shows the very early stages of podsolisation (the downward movement of iron catalysed by organic acids which leaves a bleached upper layer creating an iron enriched subsoil layer) if examined carefully. This is too slight to refer the general public to in a leaflet but can be demonstrated to a group.

2. Malltraeth

This is one of two sites included to demonstrate that soils have been in existence since the plants first colonised the land, and soils can be preserved in the geological

Table 1 Site selection criteria

Site	Location	Relevance to geology/ geoheritage	Soil type(s)	Access	Suitable for demonstration	Vulnerability (natural)	Vulnerability (man)	Public use
1	Newborough	Largest area of mobile sand dunes and flats on Anglesey, recognised as Special area of Conservation	Raw soil Raw gley Brown earth	Coastal path, beach	Open access	Risk from coastal erosion		Ecologists, birdwatchers, walkers and beach users
2	Malltraeth	Only example of upper Carboniferous palaeosol in Anglesey		Coastal walk	Open access on shore			Geologists
3	Porth Cwyfan	Low cliffs in local boulder clay displays a variety of periglacial features and best groundwater table features on Anglesey	Brown earth, Stagnogley, Groundwater gley	Coastal path	Open access	Risk from coastal erosion	Risk from coastal protection	Birdwatchers, walkers and beach users
4	Rhosneigr	Mobile sand demonstrates the accumulation of Holocene sediment and unconformity with Quaternary deposits	Raw soil Brown earth, Stagnogley	Beach	Open access	Risk from coastal erosion	Risk from coastal protection	Ecologists, birdwatchers, walkers and beach users
5	South Stack	Most easily accessible view of the South Stack beds (green schist) and various forms of weathering	Podsol	Country park	Open access	Risk from overgrowing vegetation	Risk from building works	Tourist "honey pot" - Ecologists, birdwatchers, walkers, archaeologists, rock climbers
6	Breakwater Park	Country park established in former quarry in Holyhead	A wide range of soils are on view	Country park	Open access in country park		Risk from construction of walls & footpaths	Tourist "honey pot"— as above
7	Bodafton Mountain	Quartzite and South Stack schists, with glacial deposits	Podsol	Country walk	Open access but only suitable for small group	Risk from overgrowing vegetation		Walkers
8	Lligwy	Small quarry exposes clearest example of post-glacial scree	Arid zone soils	Beach, limited by tides	Open access on beach			Birdwatchers, walkers and beach users
9	Penmon	Classic Devonian palaeosols	Rendzina	Country walk	Open access but only suitable for small group	Risk of overgrowing vegetation		Walkers
10	Llêmïog	A disused limestone quarry in farmland affords a lengthy exposure that is unlikely to be disturbed	Brown earth, Stagnogley	Coastal path limited by tides	Open access on shore	Risk from coastal erosion	Risk from coastal protection	Birdwatchers, walkers and beach users



Fig. 2 Trail Location 1. Example of an exposure of the terrestrial raw soil typical of this area of mobile sand dunes, Newborough Warren

record, known as palaeosols. At this location, root channels and other pedogenic features, together with fragments of stigmata in Carboniferous (Namurian) sandstones provide hints of soil formation which can be linked to the coal seams mined close by. This site is unique in the Carboniferous sequence on Anglesey. A site interpretation board is being designed for installation early in 2010 with a reference to the palaeosols.

3. Porth Cwyfan

This site demonstrates very clearly the lateral variations in soil that can occur when the ground surface is cut through a sequence of sediments and the water table is at variable depth. The cliffs are in Quaternary till, head and recent wind-blown sand at the head of a small bay; the till and head have weathered into brown soils (soils without any special features beyond oxidation and weathering of the parent material) which in places may show evidence of impeded drainage. Approaching the stream, a variety of features of varying redox conditions are visible, most notable is a layer of unusually large iron–manganese nodules (Fig. 3) which often form above a relatively stable water table in gley soils (where the shortage of oxygen leads to reducing conditions affecting the colour of iron)

While some of these features are indicators of complex soil chemistry, the site does illustrate very clearly, even to

the layman, just how variable soil conditions can be, how they are related to changes in parent material and microtopography. These soils are typical of many around the island, but this is a very important site because it demonstrates this variety in a small area popular with tourists without the need to disturb the soil.

The agricultural land adjacent to the shore provides an opportunity to explore the risks of soil degradation and environmental pollution [e.g. leaching] under both cultivation and grazing management.

4. Rhosneigr

The Rhosneigr site is included because it is a very popular tourist spot for its sandy beaches, rocky coves, shelter for small boats and increasingly for kite surfing and there are a number of soil features easily visible. The sand dune area presents a similar range of soils to those seen at Newborough but in a more easily accessible location. The small cliff at southern end of the beach presents soils similar to those at Porth Cwyfan, but between the two areas here, one can see a stagnogley profile in the till buried beneath a gley soil developed in the overlying recent blown sand (Fig. 4).

The development of small raised beaches gradually being colonised with salt tolerant and drought tolerant plants which accumulate organic matter illustrate some principles of soil formation. This process can be seen in a number of places around the coast but this is one of the most easily accessible, as well as being a popular tourist location. This site challenges people to consider the concept that soils are dynamic, not static features, and that changes in the environment, or in land management, will in fact cause changes in the soil.

Although lacking the extensive ‘natural’ ecosystem present at Newborough, this area is of conservation value and we hope to add some details of the soils visible in this area to the revised nature notice board.



Fig. 3 Trail location 3. Detail of iron–manganese nodules/pan at water table in gleyed soil on local till, Porth Cwyfan



Fig. 4 Trail location 4. Brown earth profile in sand accumulated over and burying gley profile in till, Rhosneigr

5. South Stack

This is an area which is very popular with visitors; in fact, it is one of the iconic landscapes of Anglesey, with spectacular views from a high sheer cliff down over the lighthouse. The vegetation here is maritime heathland, quite a rare habitat in North Wales, consisting of two species of gorse and three species of heather, making it a riot of colour, yellow, maroon and purple throughout spring and summer. It is also an area very popular with climbers on the cliffs below and with birdwatchers as many seabird species nest on the cliffs and peregrines, ravens and choughs are a common sight. Its high popularity with a wide range of visitors made it important to include this area within the Soil Trail and it has been published as a geotrail within the AONB/Coastal footpath magazine (Conway 2008b).

The only public toilets are situated in a small disused quarry where there is a very good exposure of the shattered rock and scree that forms the parent material for the Cybi

series podsol (Fig. 5). Visitors can clearly see the peat layer, the grey horizon from which iron has been leached and the dark pan which has resulted from the deposition of the iron leached from the grey layer above. The exposure clearly links the soil to the heathland vegetation which is the cause of the organic acids causing the podsolisation (iron leaching) process.

The accumulation of organic matter (carbon) in podsol and peat soils, and the potential loss due to erosion or degradation is an important topic in relationship to climate change which is highlighted at this site. It is relevant to similar soils at sites 6 and 7 and also to areas where soils are being cultivated.

Nearby, however, there are grazing fields of reasonable quality which are on brown soils formed over pockets of well-drained superficial deposits. These can often be seen in road cuttings. These more productive soils are closely associated with the nearby Neolithic hut circles and explain the food economy of the ancient site.

6. Breakwater Country Park

Breakwater Country Park is located in the disused quarry which provided stone for the Holyhead harbour breakwater. It is managed by the County Council as a recreation and tourist facility and has a network of footpaths along the coast, across the grass and heathland and links to the coastal footpath.

There are several habitats, maritime heathland over podsol, glaciated rock surfaces with humic rankers, glacial sediments with brown soils or stagnogleys and small areas of peat. Not all of these are exposed, but it is possible to direct visitors to good podsol exposures in deeply eroded gullies, to stagnogley exposures on eroding glacial material along the coastline, whilst the rankers and peat are easily visible on the bare rock.



Fig. 5 Trail location 5. Exposure of Cybi series podsol developed in shattered Precambrian schists, South Stack

The value of this area lies partly in the diversity of soils in a small area, but mainly in the opportunity to link soil types to individual geological materials already published in a geological trail, and referred to in a series of information panels about the local geology and landscape erected by the Country Park wardens. Discussions are ongoing about a further information board about soils, but certainly the trail leaflet will be available from the information office and café.

This type of site presents a valuable opportunity to interest the local people who frequently use the area for exercising their dogs or fishing off the rocks. It is important to make use of opportunities to reach both local people and visitors and to emphasise the valuable role that soils play in determining the vegetation and therefore the appearance of the landscape.

7. Bodafon Mountain

This hill on the eastern side of the island has been chosen because it presents a 360° panorama of Anglesey and is a superb location for relating geology, soils and topography to each other, and recognising how these affect land use. Looking south, there are strips of high quality agricultural land on the calcareous soils on the Devonian rocks and Carboniferous limestone on the valley sides, wet and dry heath on the coarse sandstones and conglomerates in the valley bottom and areas of conifer plantations. Bodafon Mountain itself is a hard quartzite with shattered post-glacial scree on its sides which has led to podsol formation which can be seen in the small disused quarry on the side of the footpath.

8. Lligwy

This is the second palaeosol site; along the coast are extensive exposures of Devonian rocks, a sequence of sandstones, mudstones and occasional limestones, but the real interest is the environmental interpretation (Allen 1986) who believes that together they represent a river floodplain in an arid landscape with seasonal floods and temporary lakes. In both the mudstones and the sandstones, there are palaeosols, contemporary soils, which must rank as some of the oldest soils on the planet as they are contemporary with the major colonisation of the land by plants, some 390 million years ago. Soil features include biogenic channels, carbonate nodules and clay redistribution features.

This site is an excellent example of where geoconservation protects an important piece of evidence for the evolution of soil types. Devonian palaeosols are not rare (Marriot and Wright 2006) but this small area is unique in North Wales.

9. Penmon

The east coast of Anglesey from Traeth Bychan to Penmon is characterised by cliffs in Carboniferous limestone and occasionally sandstone but much of the area is

overlain by the Irish Sea till leading to examples of karst or solution weathering features typical of limestone pavement, which is a key habitat in the UK biodiversity action plan.

This is another very popular area with tourists from Liverpool and Manchester (evidenced by the high number of caravans and campsite).

Typical rendzina soils (Fig. 6) are very shallow and highly calcareous soils in residual deposits left by solution weathering of the carboniferous limestone found in areas not mantled by drift. Although such soils are extensive in southern England [for example on the Chalk Downs or the Jurassic limestones of the Cotswolds), they are rare on Anglesey. Roberts (1958) refers to them as “too small to show on the map”. This example is important and forms part of a 100-m exposure.

10. Lleiniog

The section of coastline from here to Beaumaris provides a long exposure of the Irish Sea Till which varies from a clay rich till to a stony, sandier textured deposit, with glaciofluvial and lacustrine deposits in places. A complex set of soils, ranging from Salop Series gleys (Fig. 7) to well-drained brown soils of the Flint Series (Fig. 8) has developed on these varying parent materials. Both profiles



Fig. 6 Trail location 9. Marian Series rendzina developed over Carboniferous limestone, Penmon

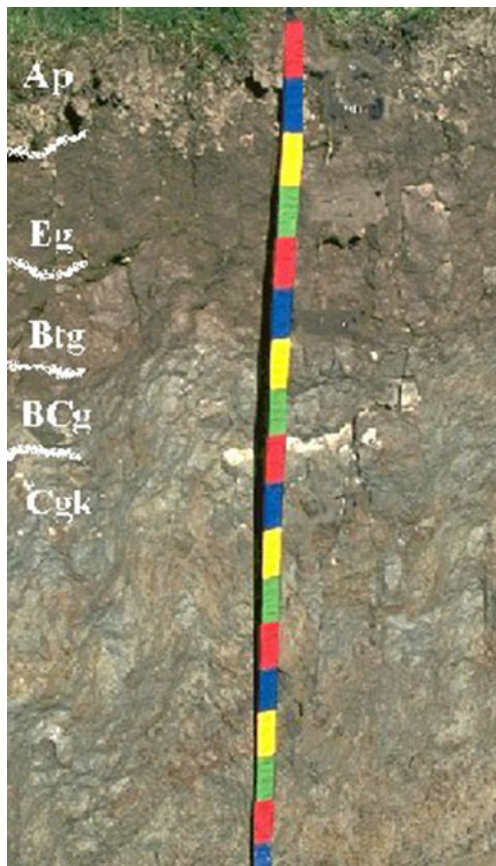


Fig. 7 Trail location 11. Profile of Salop Series, typical stagnogley on Irish Sea till, Lleiniog, near Beaumaris

are refreshed by coastal erosion and are best seen here despite occurring along much of the east coast of Anglesey.

Inland, the gley soils are utilised as grassland due to their wetness and risk of compaction, whilst the brown earths provide some of the best quality soils on Anglesey and are always in arable cultivation leading to island’s historic reputation as the bread basket of Wales. The varying character of the two soils can easily be seen in profile, and the variations in land use related to poor drainage, coarse blocky structure and plasticity of the gley.

Perhaps the most exciting of all these soils is a post-glacial palaeosol which is now submerged but contains tree stumps dated to around 8,000 BP still in situ. The scientific story is post-glacial sea level rise drowning the coastal woodlands, but the more romantic story is that of the “Cantref y Gwaelod”, a tale from Celtic mythology which tells of the extensive network of roads, farms and villages drowned in a terrible storm. Although this is taking geoconservation into the realms of fantasy, the reference to local culture and folklore and certainly stimulates some animated discussions when showing groups around the site and thus helps arouse interest.

Developing and Publishing the Trail

All the information and illustrations are prepared, we are currently negotiating for funds to publish the trail leaflet as a self guided walk, and developing an online ‘virtual’ trail (to complement the online version of the North Wales guide http://www.rac.ac.uk/?_id=3717) with downloadable teacher’s notes, data and further references. All the sites are publicly accessible from the Coastal Footpath, and we encourage viewing of natural exposures without digging or disturbing the sites to minimise any impact on the environment.

Conclusions

This paper has described how a project initially designed to engage walkers and tourists with concepts of geology and landscape developed into a more specific project focussing on the importance of soil as a crucial element expanding the concept of geoheritage/geoconservation and linking to

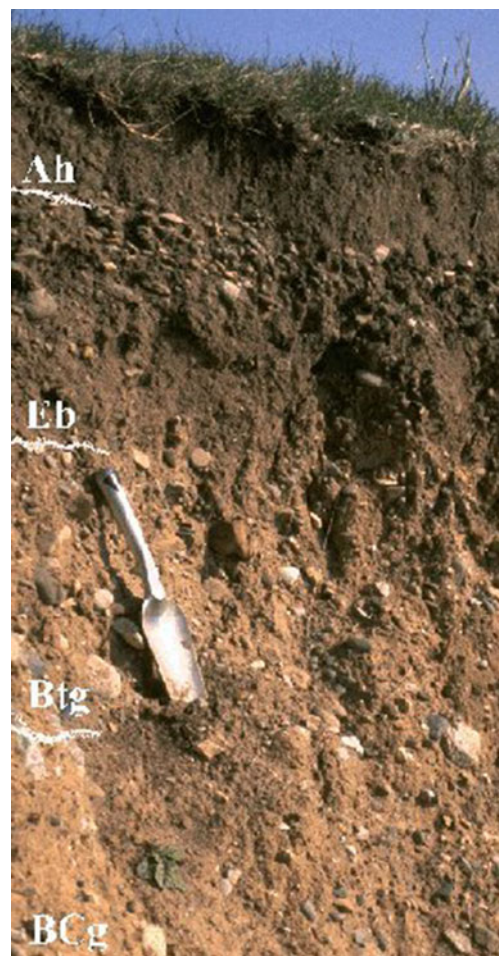


Fig. 8 Trail location 12. Profile of Flint Series, typical brown soil on stony drift, Beaumaris

biodiversity/land use. The project has identified an opportunity to engage the public through their other interests such as nature, birds and archaeology to recognise the role of soil in their special interest and then relate the soil to the underlying geology. It offers an introduction to some of current environmental issues, such as soil erosion and carbon storage. A range of locations together with photographs and data have been accumulated, some have already been used in training courses, but the format of the final publication is dependent on securing funding.

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This was originally presented as an invited conference paper at the 3rd UNESCO Global Geopark conference, Osnabruck, June 2008 and developed into an invited paper presented at the ProGeo conference in Drenthe, Holland in April 2009.