REPORT ON PEMBROKESHIRE FIELD WEEKEND SEPTEMBER 2000

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This field weekend was organised as part of our Millennium celebrations. It was led by Sid Howells and accommodation was provided by Tyr-y-Felin Hotel in St. David's. Sid met us on Friday evening and waited to give us an introductory talk while we finished an enormous, delicious dinner and chose our packed lunches for the next day. The bar was open and we knew already that it was going to be a good weekend!

Geological background and setting

Precambrian

There are three main areas of outcrop of Precambrian rocks in Pembrokeshire and both extrusive and intrusive igneous rocks occur

- in the St David's area

- ***extrusive*** - Pebidian. These volcanic rocks are predominantly of acid type (rhyolitic tuffs and lavas) but intermediate and basic types also occur. An estimated thickness of 1400m of volcanic rocks occurs in the fault-bounded core of the St David's Anticline.

- ***intrusive*** - Dimetian. The main intrusive mass is the St David's Granophyre (a microgranite displaying graphic texture).

Between the formation of the Precambrian rocks and the marine trangression which heralded the deposition of the Cambrian sedimentary sequence, the Precambrian rocks were folded, basic dykes were intruded and there was a significant amount of terrestrial weathering and erosion, to the extent that the St David's Granophyre was uncovered. There is clear evidence of unconformity in the St David's area. Between the Caerbwdy Valley and St Non's bay (a distance of 850m) the basal Cambrian conglomerate was deposited across (oversteps) c.330m of the Precambrian sequence on the eroded south-eastern limb of a gentle anticline. At Porth Clais the conglomerate rests on a weathered surface of the St David's Granophyre.

Cambrian

The outcrop of Cambrian sedimentary rocks on the south side of the St David's Peninsula is on the southern limb of a fault-bounded anticlinal structure, the axis of which is aligned WSW-ENE. Although the Cambrian beds generally dip southwards, there are a number of tight folds, creating a wide outcrop on the plateau surface at 60m a.s.l.

The Cambrian rocks are also affected by a number of faults, particularly dextral wrench faults. These structures were formed during the Caledonian Orogeny, although the folding was intensified and faults reactivated during the later Variscan Orogeny. The faults bounding the block of Precambrian rocks to the north of the Cambrian outcrop may be related to much older deep-seated structures. The Cambrian rocks were penetrated by numerous igneous intrusions during the Ordovician.

At several localities, notably St Non's and Porth Clais, the Cambrian beds are seen to rest unconformably on weathered Precambrian intrusive and extrusive rocks. The Lower Cambrian sedimentary rocks (Caerfai Group) provide a good example of a fining-upwards sequence (conglomerate - sandstone - shale), produced as the Precambrian land surface was inundated by the sea and the shoreline migrated south-eastwards (marine transgression). Comparison of Cambrian sequences in Pembrokeshire and elsewhere suggests that deposition occurred on the south-east shelf of the Welsh Basin (an area of deep water separated from the main expanse of the

Iapetus Ocean by the Irish Sea horst complex. The shales in the Caerfai Group contain thin layers of ash indicating that there was some contemporaneous volcanic activity during the Lower Cambrian.

The earliest Middle Cambrian (Solva Group) rocks are sandstones, suggesting shallowing of coastal waters or uplift and erosion on the adjacent land surface, whereas the mudstones that follow (Menevian Group) suggest lower energy, deeper water conditions or a decrease in sediment input. The upper part of the Menevian Group consists of sandstones (including coarse 'grits') with the brachiopod *Bilingsella (Orthis) hicksii.*

The Upper Cambrian Lingula Flags contain fossils such as the inarticulate brachiopod *Lingulella,* and sedimentary structures such as flaser bedding, that are characteristic of intertidal areas, but in some parts display features that suggest that they were deposited by sub-marine sediment flows (turbidity currents). These features can be reconciled if there was relatively rapid subsidence of fault blocks leading to instability of unconsolidated sediment.

The earliest examples of easily recognised fossils with shells or other hard parts in the Cambrian sequence of Pembrokeshire are found in the Lower Cambrian Caerfai Bay Shales. Later sedimentary rocks are more fossiliferous and trilobites in particular have been useful in determining the stratigraphy of these rocks and facilitate correlation with Cambrian rocks in other areas.

Ordovician
In South Wales, Ordovician rocks cover most of north Pembrokeshire. Rocks of Arenig-Llanvirn age are particularly well exposed along the northern coast between St David's Head and Fishguard and on Ramsey Island. Sedimentary rocks of Arenig age can be seen to rest unconformably on Upper Cambrian 'Lingula Flags' at several locations.

The lowest Ordovician (Tremadoc) rocks are missing, and the unconformity and fining-upwards sequence of Arenig-Llanvirn rocks, indicates that a period of uplift and erosion during the Tremadoc was followed by a marine transgression.

Most recent palaeogeographic reconstructions indicate that the Ordovician rocks of Wales were originally located somewhere between latitudes of 30 - 60^0S, just off the northern margin of a large continent (Gondwana). Deposition occurred on the southern margin of Iapetus in a partially enclosed marine basin (Welsh Basin) which lay between the shoreline of a microcontinent (Avalonia) and a shallow area (Irish Sea Platform) of the seabed that separated the basin from the open ocean.

Within the confines of the Welsh Basin there was considerable lateral and temporal variation in water depth, reflecting movements of fault-bounded blocks. The typical sediments of the deep water areas were fine grained and rich in organic detritus, leading to the development of anoxic conditions. The rocks formed from these sediments are black shales (later metamorphosed to slate), often rich in iron- sulphide.

The fossils found in these rocks tend to be pelagic, e.g. graptolites, or specially adapted bottom-dwelling organisms e.g. trilobites with no eyes. The deeper water deposits constitute a 'graptolitic' facies.

Earthquakes caused by fault movements caused underwater landslides, dense suspensions of sediment or turbidity currents, which swept material off the flanks of the uplifted areas into deep water.

The shallower areas of the seabed, particularly near to coastlines, supported a diverse fauna and were characterised by slightly coarser or carbonate-rich sediments. The shallower water deposits

constitute a 'shelly' facies with a more diverse fauna including trilobites, graptolites, gastropods, hyolithids, conulariids and rare echinoderms.

Volcanic activity, concentrated along deep-seated faults, was widespread in the Welsh Basin during the Ordovician Period. In Pembrokeshire there are thick accumulations of volcanic rocks of Arenig-Llanvirn age in several areas. Thinner sequences are present at several other locations. Generally the eruptions of acid-basic lavas and tuffs occurred in relatively deep water, but there is occasional evidence that there were some islands in adjacent areas, including the presence of well-rounded clasts in poorly sorted tuffaceous sediment. The clasts were produced by attrition of eroded blocks in an intertidal environment and were subsequently carried into deeper water by gravity slides. There are locally developed, minor unconformities in several places and a more widespread unconformity marks the base of the overlying Llandeilo sequence.

The Strumble Head Volcanic Formation, exposed to the south and east of Strumble Head, consists mainly of basalt lavas. The lower part of the formation displays excellent examples of pillow lavas. The basalts in the upper part of the formation interleave with the predominantly rhyolitic volcanics of the overlying Goodwick Formation. It has been concluded that the lavas and associated pyroclastic rocks were derived from the fractionation of a tholeiitic magma which was also the source of the many high-level contemporaneous intrusions which are principally of dolerite/gabbro, but also include diorites, microtonalites and microgranites.

Cretaceous/Tertiary
The scenery is dominated by a marine erosion surface which formed at the end of the Cretaceous and was uplifted in the Tertiary.

Quaternary
There is a significant thickness of boulder clay over Pembrokeshire.

All this information was accompanied by excellent slides and a very good, enthusiastic interpretation by Sid. We hoped that after a good night's sleep, it would be clear in our minds in the morning (?).

Day 1 Porthllisky to Caerfai Bay

Site 1 Porthllisky - SM 731237
Here we were occupied with the tremendous variety of pebbles on the beach. They are mostly Precambrian tuffs (Pebidian volcanics) dated at about 640 Ma, (million years ago). They contain pyroclastic particles which are angular clasts that do not touch and show no sorting. Most are of andesitic type though some have basalt clasts within them. The clasts are quite large so the source must have been nearby.
We also saw much evidence of microgranite here (also Precambrian - Dimetian intrusions) from the nearby intrusion on the headland to the east. In the bay there is evidence of much hydrothermal alteration caused by fluids associated with this intrusion. We also found flow-banded rhyolite. All this variety indicates that there were several different sources of the magma over a huge area.

2 - 3m of boulder clay is evident at the back of the beach with clasts aligned by solifluction.

Site 2 Headland to east - SM 730234
The headland is composed of a Precambrian microgranite intrusion. Between here and the back of the bay at Site 1 is a fault which brings the microgranite against the tuffs. The microgranite here is a granophyre (granophyric texture with quartz and orthoclase feldspar crystallising out together at the eutectic point). The biotite in this rock is altered to chlorite. From here we could see columnar jointing of a dolerite sill on the west side of the bay.

Intrepid members of the Bath G.S. on the headland east of Porthllisky Bay (photograph by John Parkins)

Just inland from the headland is a large ultrabasic erratic. It is very coarse grained with large ferromagnesian crystals and is picrite from the Lleyn Peninsula in north Wales. Sid offered a prize to the first person to spot 'something unusual'. I have rarely seen the student members of our group move so fast but two of them did win the prize.

Site 3 - SM735235
From the site the Cambrian Solva beds can be seen; vertical beds of green sandstone. There is a faulted contact here between the Precambrian microgranite and the Cambrian Solva beds. Here the lower part of the Cambrian sequence has been faulted out and erosion has occurred along the fault.

Site 4 - SM738237
A natural arch can be seen on the coastline here. It is an igneous rock, possibly dolerite from the basic intrusion. We could not get near enough to it to confirm this.

Site 5 Ogof Golchfa - SM741237
There is a very obvious dolerite intrusion here into the Cambrian Solva beds. Very good chilled and baked margins are visible.

There is also a remarkable Pleistocene sequence in the cliff at this site. It shows the following:-
• c.1m of raised beach deposit on a wavecut platform - formed in the Ipswichian interglacial c. 125000 years ago. It is cemented by iron and manganese compounds.
• above this about 3m of solifluction deposit with aligned clasts (Cambrian flags - thinly bedded sandstones). This deposit indicates that the climate was getting colder.
• above this c. 2m of random, angular, poorly sorted material - boulder clay representing the Devensian glacial. It contains all sorts of rock types.
• c1m of another solifluction deposit - similar to the one below but made of smaller aligned material indicating that conditions were warming again - 16500 - 14000 years ago
• this is followed by about 1m of windblown sand - loess - presumably blown from the coastal plain which is now underwater. Tundra conditions probably existed now.

Site 6 Porth Clais - SM742237
The Cambrian sequence seen on the opposite side of the inlet show the beds dipping to the south and represents the south side of the St. David's anticline. The Solva beds are on the headland with the older purple Caerbwdy Sandstones inland. This purple sandstone is used locally for building. The distinctive red Caerfai Bay Shales occur between here and the back of Porth Clais inlet.

Site 7 Lime Kilns at Porth Clais - SM741242
The River Alun flows out here; its original route to the sea to the east of here was blocked by ice. The valley was much deepened by meltwater and then drowned with the rise of sea level at the end of the last glacial - it is a ria. Sea level was c. 40m lower than today.
Since the onset of agriculture, the river has become silted. It was once possible to go into St. David's by boat along this river.

Site 8 St. Non's - SM750242
The lower part of the Cambrian sequence has been overturned here and appears to be dipping to the north.
St. Non's Sandstone - oldest
Caerfai Bay Shales
Carebwdy Sandstone
The Precambrian tuffs occur at the back of the bay. They are rhyolitic tuffs and may have been waterlain.

Site 9 - SM751241
It is possible here to descend the cliff and see the unconformity between the Precambrian and the Cambrian basal conglomerate which has huge clasts with lots of quartz. The unconformity represents c.40 million years time gap. Both have been overturned and there is a difference of about 5° in their dip inland. Very convincing way-up structures can be seen in the basal conglomerate.

At the base of the cliff is a quartz porphyry sill intrusion. Several metres to the east, this can be seen again but now in the cliff - it is a transgressive sill.

Site 10 West side of Caerfai Bay - SM 757242
From here the following Cambrian sequence can be seen in the cliffs opposite - dipping south so younging out to sea -
St. Non's Sandstone
Caerfai Bay Shales
Caerbwdy Sandstone
Solva Beds
Menevian Mudstones
A dolerite sill protects the headland from erosion.

Site 11 Caerfai Bay - SM762244
At the back of the bay is the St. Non's Sandstone but showing signs of hydrothermal alteration. Two roughly north-south faults run into the bay from the sea. One has offset the beds by about 50m. The junction between the St. Non's Sandstone and the Caerfai Bay Shales can be traced across to a central fault. It is a dextral strike slip tear fault.

Ash bands occur in the Caerfai Bay Shales (which are really mudstones) and bioturbations can be seen between the upper surfaces of these bands and the mudstones. There are also some load casts - flame structures - at the base of the ash bands where it slumped into the mudstones.

As can be imagined we were rather tired when we finally returned to Tyr-y-Felin after an extremely good day in the field. The students agreed they had learned more in one day than they would in a month's worth of lessons in school. We were treated to the most magnificent pork roast (with all the trimmings) that evening and as we had enjoyed the best-ever packed lunches that day, we were agreed that this hotel was the place to stay in St. David's. We also agreed that Sid Howells is the person you need if you want to know anything about the geology of Pembrokeshire. More was to come -

Day 2 Whitesands
Abereiddy
Porth Gain

Site 1 - Trwynhwrddyn Head - SM732273
Here we investigated the Upper Cambrian Lingula Flags, a laminated green sandstone - estuarine, sub-tidal in origin. Lingula is an inarticulate burrowing brachiopod.
There was evidence here of flaser bedding where discontinuous curved lenses of mud or silt were deposited in troughs or draped over ripples in cross laminated sands.

The cliffs here are made of the lower part of the Ordovician sequence (Arenig) - Ogof Hen Formation. There is an angular unconformity between the Cambrian and the Ordovician which represents a period of uplift, tilting and erosion. The Ogof Hen beds are formed from the erosion of the Lingula Flags and only differ from them in that there are only broken remains of Lingula.
The cliffs to the north side of Trwynhwrddyn Headland are made of Penmaen Dewi (St. David's) Formation, also Arenig, Ordovician. These are black slates with cream layers caused by ash/tuff deposits. They are very fossiliferous with graptolites and trilobites (esp. Trinucleids).
Just north of the headland is a stack made of igneous material. It is siliceous and very hard. There is much controversy as to whether it is a tuff or an intrusion.
From here St. David's Head can be seen to the north - formed from a gabbro intrusion.
All the rocks in this area have suffered regional metamorphism in the Caledonian orogeny, when the mudstones were metamorphosed to slates. Slaty cleavage is well developed.

Site 2 Penlledwen Headland - SM727276
This is made of dolerite (part of the huge layered Ordovician (Llanvirn) gabbro intrusion). On the north side of the headland it is possible to see the contact between the gabbro and the Penmaen Dewi rocks. The intrusion has created hornfels (contact metamorphism) in these rocks. All the rocks were then later folded and regionally metamorphosed in the Caledonian orogeny.

Summary sequence: Arenig (Lower Ordovician) muds were deposited
Llanvirn intrusion with contact metamorphism of muds to hornfels
Folding and regional metamorphism in Caledonian orogeny

Site 3 Porth Melgan - SM728278
Here there are a variety of dolerite/gabbro pebbles on the beach. Many are egg-shaped from marine erosion and are called Porth Melgan eggs and really do look like birds' eggs. Sid did say something about having put some perfect ones into a model bird's nest in a museum display and nobody noticed. He didn't say whether or not they are still there. . . . . Again there is boulder clay at the back of the beach.

Site 4 Abereiddy - SM795314
The Llanvirn beds represent deposition in the bottom of the Welsh Basin and are low energy clays. They formed in anaerobic conditions and contain sulphide deposits and many well preserved graptolites. These mudstones suffered low grade regional metamorphism to slates in the Caledonian orogeny. Lots and lots of of graptolites were found. We also found gypsum 'flowers' (calcium sulphate) on some of the cleavage planes in the slates.

On the north side of Abereiddy Bay is St. Bride's slate quarry, now flooded by the sea and called the Blue Lagoon. There are the remains of slate miners' cottages which were destroyed by storm waves at the end of the 1930s. Slate mining was a flourishing business at the end of the 19th century.

Site 5 Porth Gain - SM813326
Porth Gain used to be a busy industrial port with a brick works and stone crushing plant. There is a slate quarry on west side of port and on the southern side of this quarry is a scree slope of clay. Somewhere here is the contact between the microdiorite and the slate. Hydrothermal fluids have altered the feldspars in the microdiorite to clays which were used in the brick making industry. Porth Gain bricks are well known and were exported.
There is a cutting between this quarry and the Pen Clegyr microdiorite quarry to the west. The quarries are linked by Jerusalem Road along which ran a complicated railway system for moving the rock. Microdiorite was hauled from this quarry to the slate quarry where it was crushed and fed into hoppers which sent the blocks down to the harbourside and so into waiting ships. Porth Gain now is an attractive tourist honey-pot with a very good pub.

As you can tell from this short account, the whole weekend was very enjoyable and geologically extremely interesting. We hope to ask Sid to take us to some of the other many good sites in Pembrokshire next time.

REPORT ON THE MEETING OF LOCAL GROUPS AND AFFILIATES OF THE GEOLOGISTS' ASSOCIATION

Bath Geological Society is affiliated to the Geologists' Association. Part of the report which was published following the meeting in November 2000 is reproduced here.

The 'Annual Meeting '
Interest was expressed by representatives in GA plans for the future of the Reunion as an 'annual meeting' of the Association, choice of future venues and relationship to 'Festivals of Geology' following the success of Earth Alert, Brighton 2000.

Reunion
The future of the Reunion was discussed in the context of the planned Liverpool event (2001). The purpose and scope of the Liverpool event were outlined, drawing attention to the range of planned activities, intended to attract both the geological community and the general public. Activities are expected to include a Geology Department Open Day, the Discovery Room and an exhibition with stands representing environmental groups, Rockwatch, NHM, Local Groups, Affiliates, and dealers There will also be a programme of lectures and field meetings, aimed primarily at members of the GA, its Local Groups and Affiliates. The importance of retaining the spirit of the traditional Reunion was recognised even if the headline name of the event is changed - e.g. to Festival of Geology.

Scarborough 2002
The purpose and scope of the Scarborough event were discussed. An event intermediate in scale between Earth Alert (Brighton 2000) and the Liverpool meeting (2001) is envisaged, with local societies and museums playing an important part, with industrial participation, active promotion by Scarborough Borough Council, and free admission to the general public, alongside a programme of lectures and field meetings for the geological community.

The GA will provide advice on accommodation for both Liverpool and Scarborough, and the Curry Fund will be approached to consider making small grants available to Local Groups and Affiliates to encourage participation in both events.