



Fold structures in the Ordovician rock sequence in the cliffs north of Ceibwr Bay.

he rock sequence of Pembrokeshire in south Wales, from the Marloes Peninsula in the south to Strumble Head in the north, is a classical area of British geology, with its varied Lower Palaeozoic sedimentary and volcanic rocks. But to the east of Strumble Head, the rock sequence between the two main towns of Fishguard and Cardigan has remained largely unknown (see map, below). Until a few years ago, only a half dozen fossil-bearing localities were known from the 20 miles of coastline and inland exposures between Fishguard and Cardigan Island.

The coastal sections north of Fishguard, from Dinas Island to Cemaes Head, are spectacular, the cliffs rising to over 100 metres. This makes the bays below the cliff top largely inaccessible. It is the very inaccessibility of the coast that has

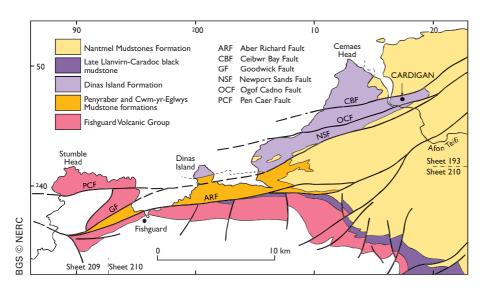
precluded detailed study of the sequence before now. Indeed, without the use of a boat, a detailed study of the rock sequence along the coastline would be virtually impossible.

During the summer months of 1998 to 2000, the BGS's central Wales mapping team made a detailed survey of the coastal sequence, chartering a boat out of New Quay harbour skippered by Steve Hartley. Steve's boat, equipped with the latest sonar apparatus, allowed the team to hop in and out of most of the bays and coves along the coastline, including those areas that are completely inaccessible from the cliff top. The whole sequence from Fishguard to Cemaes Head was photographed, documenting the spectacular fold structures exposed in the cliffs (see photograph, top left). The boat also facilitated the collection of

## Cardigan rock sequence revealed

## Graptolites are the key to reconstructing an area of complex Ordovician geology

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Geological map of the Fishguard and Cardigan region of south Wales.

fossils, with the result that over 60 graptolite-bearing horizons were identified, greatly enhancing our biostratigraphical knowledge of the sequence.

Graptolites were marine colonial organisms. The organic remains of their skeletons are fossilised in rocks from the Cambrian to the Carboniferous, but they are most common in the Ordovician and Silurian. The planktonic graptolites, which include well-known forms such as the Ordovician *Dicellograptus* and the Silurian *Monograptus*, may have dominated the biomass in certain marine environments. This is witnessed by their superabundance in the deep marine

## Modern geological mapping



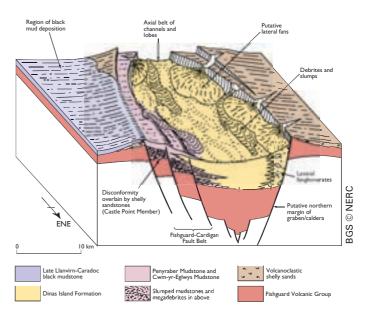
Lower Palaeozoic mudstones of central Wales, southern Scotland and the English Lake District.

Graptolites evolved rapidly, producing a huge variety of different morphologies that had limited time spans. As a result, they are highly useful for the relative dating and correlation of Ordovician and Silurian marine rocks. Indeed, in the Lower Palaeozoic these fossils are second to none for producing refined biostratigraphies. Many graptolite biozones have been calibrated with radiometric dates from volcanic tuffs, and can be used to indicate periods of time of a million years or less, while graptolite subzones can represent even shorter periods of time.

The new graptolite collections from the Cardigan coast have enabled the sequence to be dated and correlated with rock sequences of comparable age elsewhere in Wales — but there was a big surprise. Most of the sequence between Dinas Island and Cemaes Head, representing more than 1.3 kilometres of rock thickness, lies within one graptolite zone, the Upper Ordovician clingani Biozone. This means that this thick sequence of rocks was deposited during a relatively short period of time, between about 446 and 444 million years ago. Elsewhere in Wales, only a few tens of metres of black mudstone were deposited during the same time interval. Evidently, something was allowing huge volumes of turbidite sandstone and mudstone to be deposited in this part of the marine Welsh Basin.

It seems that the Cardigan area was subsiding very rapidly during the Late Ordovician, and the resulting marine trough became a locus for the deposition of over a kilometre of mudstones and sandstones (see reconstruction, top right). The formation of this trough was probably controlled by contemporaneous faulting, suggested by rapid thickness changes in the sedimentary sequence from Dinas Island northwards. These faults may also have been the focus for the eruption of the older (mid Ordovician) Fishguard Volcanic Group that lies to the south and includes the submarine extruded pillow basalts of Strumble Head.

The marine trough developed in the Cardigan area also influenced the ecology of the graptolites in the overlying water column. The local rocks



Reconstruction of Late Ordovician (Caradoc) palaeogeography for the Cardigan district.

preserve diverse graptolite faunas throughout the middle and upper Caradoc (455–445 million years ago). However, in the Whitland area, just 40 miles to the south-east, rocks deposited at the same time are characterised by impoverished fossil graptolite faunas which indicate shallower marine conditions on the adjoining marine shelf of the Welsh Basin.

Without graptolites, the regional context of the Ordovician rock sequence of the Cardigan area within the Lower Palaeozoic marine Welsh Basin would not have been fully appreciated. It would, for example, have been impossible to quantify just how much sediment was flooding into the basin during the mid and late Caradoc. It would also have been difficult to correlate the structurally complex and predominantly mud-dominated sequences between outcrops. Graptolites provide a powerful tool for delimiting the ancient architecture of Lower Palaeozoic marine basins, particularly deep marine turbidite systems. They are also critical to resolving the structure and lithostratigraphy of complex, Lower Palaeozoic sedimentary terranes.

The BGS's 1:50 000 scale Cardigan Sheet 193 (England & Wales) and accompanying sheet description are available through BGS Sales or through the BGS website. For further information on the use of graptolites in biostratigraphy, contact Philip Wilby.



P Shepherd, BGS © NERC

Graptolites from Ordovician marine
mudstones of Dinas Island. The
graptolites are flow-aligned, indicating
current motion on the seabed. Each
fossil represents a colony of several
cohabiting animals.

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