Carreg Llwyd Rhoscolyn North RIGS

NRW RIGS no. 239 [SH 26126 77209]

GeoMôn Global Geopark original webpage

RIGS Statement of Interest:

Carreg Llwyd Rhoscolyn North RIGS site is key for showing relationships between Precambrian igneous sections and a major Palaeozioc dyke. The contact relations between weakly foliated Precambrian serpentinised gabbroic rock, and green mica schists of the New Harbour Group can be seen at several locations on the site. This is the only known inland site on Anglesey where Palaeozoic dyke outcrops can be traced for any distance. Both the mica schists and serpentinised gabbroic rock are cut by a Palaeozoic dyke. The dyke shows an apparent strike-slip offset to the right of about 30 metres However, the dyke shows a chilled contact at the termination the dyke against the offset. This proves that the dyke was not displaced after intrusion by a dextral strike slip, rather, the dyke simply “side-stepped” to the right during intrusion to follow a different plane of weakness. Where the Palaeozoic dyke is relatively broad, the northeastern side shows well-developed chilling and development of a relatively fine-grained margin up to a metre thick. Farther within the dyke, the crystals become much coarser, with felsic segregations in some places. The rock is much more severely altered where it is more coarsely crystalline. Topographically, the Palaeozoic dyke is a positive feature where it is fine to medium crystalline and crosses the serpentinised gabbro, and is a negative feature, where coarsely crystalline and crosses the New Harbour Group.

Geological setting/context: The Precambrian basement rocks of Anglesey and south-west Ll■n can be divided into several discrete groups, all of which were juxtaposed along a series of steep, brittle and/or ductile faults and shear zones (e.g. Dinorwic and Aber-Dinlle faults; Berw, Central Anglesey and Ll■n shear zones) collectively referred to as the Menai Strait Fault System (MSFS). First, the Monian Supergroup consists of a thick sequence of polydeformed metasediments and meta-igneous rocks, comprising the South Stack, New Harbour and Gwna groups, the latter representing the type example of a large-scale submarine debris flow or mélange said by some researchers to be of Lower Cambrian age. Ongoing research, however, may suggest a much older date for the Gwna Group with possible Cambrian ages being put forward for the South Stack metasediments. Second, the Coedana Complex of central Anglesey comprises high-grade metasediments, amphibolites and gneisses, and low-grade, thermally metamorphosed hornfelses adjacent to a granite (Coedana Granite), which has recently yielded a late Precambrian zircon age of 614 ± 4Ma. Third, a belt of schists and metabasites displaying blueschist facies grade of metamorphism lies within the MSFS. The metabasites have yielded ages of 580–590Ma. Fourth, the Sarn Complex in Ll■n comprises metagabbros and granite rocks which occur to the south-east of the Ll■n Shear Zone (LSZ), a continuation of the MSFS, which separates these igneous rocks from low-grade Monian mélange to the north-west. A late Precambrian zircon magmatic age of 615 ± 2Ma has been obtained from a metagabbro of the LSZ. Fifth, on the mainland of north-west Wales, the Arfon Group comprises a thick sequence of tuffs and volcaniclastic rocks, dated at 614 ± 2Ma, which are conformably overlain by late Lower Cambrian siltstones. Correlatives of the Arfon Group may occur as isolated outliers on Anglesey and, if proven, would provide an important potential lithostratigraphical link across the MSFS. The stratigraphical correlation between the various units has proved highly controversial. The recent recognition of mylonitic rocks, for example in the LSZ, emphasises the presence of tectonic contacts and indicates that each component may represent a so-called ‘suspect terrane’ which was transported laterally into position along the major faults and shear zones. Ongoing unpublished research suggests, that Anglesey’s Precambrian rocks accumulated in accretionary prisms, providing a tectonic sequence rather than a stratigraphic sequence which was formerly accepted. This Precambrian basement later formed the north-west margin of the Lower Palaeozoic Basin, the initiation of which was contemporaneous with Arfon basement terranes and was completed at least by early Ordovician times since an unconformable Arenig overstep sequence has been identified at several localities such as Wig Bach, Parwyd and Mountain Cottage Quarry. The Arenig sequence of Anglesey and Ll■n is considerably less deformed and metamorphosed than the underlying basement, although this distinction is not everywhere obvious.

The confirmed Palaeozoic sequences on Anglesey include parts of the Ordovician, Silurian and Carboniferous. The Carboniferous sediments rest with marked angular unconformity on folded Ordovician to Silurian sediments, and on older strata. In addition, it has been traditional to assign red beds beneath the Carboniferous limestones at Lligwy Bay to the Devonian. However, there is no biostratigraphic confirmation of Devonian age, and red beds beneath the Carboniferous along the Menai Straits are demonstrably Carboniferous in age. The youngest of the deformed sediments that unconformably underlie the Ordovician on Anglesey may be Cambrian in age. On the basis of new outcrop work for RIGS, it is considered possible that the Church Bay Tuffs post-date the Gwna Melange, and thus could be the youngest part of this contentious late Precambrian or Cambrian succession. However, until this proposition can be confirmed, the Church Bay Tuffs will continue to be considered for RIGS purposes to be part of the Precambrian Igneous Section. Consequently, the oldest Palaeozoic igneous activity known on Anglesey is represented by felsic igneous rocks which were erupted on the sea floor in the vicinity of Parys Mountain during deposition of the Ordovician sediments. The igneous rocks near Carmel Head that were termed the Fydlyn Felsitic Beds and assigned to the Mona Complex by Greenley could, on the basis of outcrop characteristics, also be representatives of the Ordovician felsitic suite, as has been suggested by Barber and Max. Discrimination of Palaeozoic mafic dykes from Tertiary mafic dykes is a recurrent problem on Anglesey. Igneous intrusions that cross-cut parts of the Ordovican but have suffered significant deformation can be assigned to the Palaeozoic. The deformation is usually expressed by numerous tectonic joint sets that cross-cut the original igneous cooling joints, whereas joint sets in the Tertiary dykes are almost entirely due to igneous cooling. The Palaeozoic intrusive mafic rocks on freshly broken surfaces sometimes show small patches of pyrite – these have not been seen in Tertiary mafic intrusive rocks. The Palaeozoic intrusive mafic rocks in thin section typically show alteration to a range of minerals but in particular to extensive well-crystallised chlorite. These alteration product minerals are more resistant to weathering than the olivine and pyroxene in the Tertiary igneous rocks. Consequently, despite being much older, the Palaeozoic mafic intrusions commonly look much harder and “fresher” at outcrop than the Tertiary intrusions. Igneous rocks on Anglesey classified as Palaeozoic on the basis of these contact relations and lithological characteristics may span a wide range of ages. For example, in NE Anglesey NE of Parys Mountain, felsic igneous magmas extruded onto the ocean floor and/or into wet sediments in Ordovician times. These felsites have been strongly affected by folding and faulting associated with compressional movements in the Carmel Head thrust complex. Doleritic sills and dykes in the same area have likewise been strongly affected by these compressional movements. In contrast, hornblende picrite intrusions in that area appear not to have been affected by these compressional stresses. All Palaeozoic igneous rocks in this area do however appear to pre-date some steep normal or strike-slip faults. In terms of igneous magma composition, hornblende picrite is an unlikely associate with felsic and doleritic igneous activity, hence supporting the outcrop-based observations of evidence for at least two different Palaeozoic magmatic events. Similarly, in SW Anglesey SW of Aberfraw, dolerite dykes and lamprophyre dykes of very different orientations occur within 500m of each other. Contacts between the two dyke sets have not been found, but again in terms of magma chemistry it is unlikely that the two intrusion sets are part of the same phase of igneous activity. In view of the enormous volumes of doleritic and felsic igneous activity in Snowdonia of mid-late Ordovician age, it is presumed that the bulk of the Palaeozoic felsic and doleritic igneous activity on Anglesey is of similar age, since this is compatible with the contact relations. However, lamprophyre dykes and hornblende picrites are not part of the classic Snowdonia Ordovician igneous association. Interestingly, later Palaeozoic minor lamprophyre dykes and hornblende-rich intrusives, dated at circa 430–390 Ma, have been found across parts of Scotland, Ireland and northern England. They are often associated with major NE–SW strike-slip fault systems, such as the Great Glen Fault in Scotland. The lamprophyre and hornblende picrite intrusives of Anglesey might well be of similar age, and part of a NE–SW strike-slip fault system association, but insufficient research has been undertaken to establish this proposition. The dyke swarms of Anglesey have played a key role in the history of geology. This was one of the first places in the world where the nature of igneous intrusions, and their thermal effect on surrounding rocks, was documented. This work was undertaken in 1822 by John Stevens Henslow as part of a little-known but remarkably insightful piece of geological mapping. Henslow was the Cambridge mentor for the young Charles Darwin. Geological fieldwork in North Wales introduced Charles Darwin to new geological concepts, including the enormity of geological time, which helped Darwin develop the theory of evolution. Anglesey again set a world class standard for geological mapping in 1919, when the British Geological Survey published a detailed geological map by Greenly, which continues to be used to the present day. Greenly noted that many of the dykes mapped by Henslow were not visible, having been quarried out or buried by land-fill in the intervening hundred years. It was only in 1996, when airborne magnetic surveys conducted for oil and gas exploration were published, that the existence of some of Henslow’s missing dykes could be confirmed. This illustrates the particular sensitivity of dyke sites to loss, and emphasises the need to preserve those key sites that remain.

The dykes of Anglesey are now known to include two main groups. One group is associated with the Caledonian Orogeny that gave much of the folding and faulting seen in Snowdonia. It seems likely that this interval, some 350–500 million years old, encompasses several discrete phases of dyke injection, but insufficient scientific work has yet been done to clearly define these separate events. The second set, some 40–60 million years old, was caused by the plate tectonic stresses and igneous activity associated with the onset of rifting and continental drift which led to formation of the North Atlantic Ocean. This younger set is part of the same phase of igneous activity that formed the columnar basalt “Giants Causeway” of Ireland. The dykes of Anglesey represent a potentially rich source of geological data that is not available elsewhere in Wales and England. The dykes can be dated radiometrically, and the orientation of the dykes and the nature of the intrusive displacements can be measured. From these observations the state of stress in the Earth’s crust during intrusion can be deduced. The temperatures in the Earth’s interior can be inferred from the dyke rock chemistry and mineralogy. This in turn means that data from the Anglesey dykes will enhance our knowledge of the Plate Tectonic evolution of western Britain. The regional heating associated with the younger dyke swarm may have “cooked” organic-rich sediments to yield the oil and gas now exploited off North Wales, and may have helped formed some mineral deposits such as the copper at the Great Orme. The associated changes deep beneath the Earth’s crust, and the tectonic stresses associated with rifting and continental drift, contributed to the crustal uplift which has created the mountains of Snowdonia. The underlying mechanisms that trigger the modern earthquakes in North Wales are poorly understood. The geometries of the younger dykes suggest that the magma was intruded up NW–SE fissures in the Earth’s crust, which dilated in response to NW–SE compression. Analysis of earthquakes shows that North Wales continues to be affected by NW–SE compressive stresses – so study of the dykes may help shed some light on our modern earthquakes. In summary, the dyke swarms of Anglesey need to be preserved for their significance in the historical development of geology, as educational localities, and for continued research of both academic and economic significance.

Network context of this site: To select RIGS to demonstrate the Precambrian evolution of Anglesey and Ll■n, four separate networks were devised. These are: 1. Precambrian stratigraphy and structures. This network includes two sub-sets: a) Precambrian sedimentary structures; and b) tectonic structures, such as folds and faults, which may have occurred during a tectonic event in Precambrian times or later, for example, during the Caledonian Orogeny; 2. Precambrian palaeontology which includes any life-form and trace fossil, such as stromatolites, sponge spicules, worm burrows and bioturbated metasediments. Some current research suggests that some of these fossils may be Cambrian or even Ordovician in age,although other geologists dispute this. As these life-forms were previously held to be Precambrian in age, they have been included in this category; and 3. Precambrian reference sections. These aim to represent all important Precambrian rock types found in Anglesey and Ll■n. They include the major mapped units of Greenly (1920). The aim is to provide the best and most accessible exposure of the rock type. These can be considered as RIGS ‘type sections’. Where there is a relevant mineralogical, sedimentary, structural or other change across an outcrop, several representative sites have been chosen. 4. Precambrian igneous sections. This network includes four main subsets: a) mafic rocks that were erupted during deposition of Precambrian sediments, as volcanic ashes or as lava flows, b) mafic and ultramafic rocks that were intruded whilst these sediments were wet, c) the products of alteration of these mafic and ultramafic igneous rocks as the surrounding wet sediments were buried, intensely deformed, and dewatered by metamorphism, and d) felsic to intermediate rocks that were erupted as volcanic ashes or formed major to minor intrusions, following regional deformation and metamorphism. Precambrian rocks may also have suffered later phases of deformation, along major shear or thrust zones. To select RIGS to demonstrate the Palaeozoic igneous characteristic of Anglesey, three separate networks were devised. These are: 1. Extrusive and intrusive Ordovician felsic igneous rocks; 2. Intrusive doleritic igneous rocks; 3. Intrusive igneous rocks of the lamprophyre-hornblende picrite association. Careg-lwyd includes elements of Precambrian Network 4. Precambrian igneous sections, but is principally a site for Palaeolzoic Igneous Network 2, Intrusive doleritic igneous rocks.

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Site geometry: Site boundary