South Stack cliffs RIGS

RIGS Statement of Interest:

South Stack cliffs RIGS site is important for showing a range of structural and erosional features visible from the bridge between South Stack Moor, and Ynys Lawd, the small island that is the site of the lighthouse. The rocks consist of alternate bands of meta-sandstones and meta-pelites which belong to the lowest formation of the South Stack Group, described by Greenly (1919) as the youngest Precambrian rocks on Anglesey. The rocks are spectacular and great sweeps of folded rock in the cliffs are refolded with smaller folds along the limbs of the larger ones. The alternate beds of sandstone and mudstones (pelites) are sufficiently metamorphosed to convert the sandstone into a quartzite that has not been able to accommodate the folding stresses and has broken into separate chunks which are separated by the micaceous mud-rich rocks (boudins). The interleaved mud-rich rocks, which are an attractive greenish-blue, have stretched, rather like plasticine, and contain minor folds within the larger folds. At sea level these beds have eroded out to form, caves, stacks and arches. When looking back towards the mainland, a large fold to the north of the bridge is truncated and the beds are not continuous northwards. This is a large fault that runs eastwards into the cliff. Several other faults can be viewed from the steps leading down to the island. This combination of structural and erosional features makes this a prime site for teaching such features and can be seen easily by the many visitors to the island.

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 exhibit a strong mid-ocean ridge basalt signature and 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 new research would reverse the accepted stratigraphic order of the bedded succession, since the first (oldest) material to be accreted lies above later accreted material and thus reverses the age relationships for the South Stack Group, the New Harbour Group and the Gwna Group established for the island by Robert Shackleton. 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.

Network context of the site South Stack Moor RIGS lies on the landward side of South Stack Island and is in the Precambrian GCR site, South Stack (Precambrian of England and Wales). It provides a critical component of a network of 7 RIGS which demonstrate folding, faulting and other structures in Precambrian strata. They demonstrate key features of Greenly's Precambrian rocks in Anglesey. The seven chosen sites reflect three main vital components in Precambrian stratigraphy and structures, namely, the folding, faulting and subsequent erosion of the strata (including unconformities and sedimentary structures) which could have occurred during Precambrian times and/or during subsequent orogenies, in particular, during the Caledonian Orogeny some 450 million years ago. The erosion features displayed here are most likely to have been formed during recent times, i.e. after the Tertiary dyke intrusions were emplaced in the gully between the island and South Stack Moor and southwards towards Porth y Pwll.

The environment in which the life forms existed. During Precambrian times, oxygen levels in the Earth's atmosphere were less than 1%, the critical level for the start of evolution on a vast scale when macrofossils entered the equation. Thus, all types of life had to exist in the sea. By Cambrian times, this critical level had been reached and there was a burst of life and a great variety of organisms evolved. Precambrian fossils were, in the main, bacteria or algae and diverse forms reflected their location, such as deep sea, associated with underwater volcanic eruptions or shallow water and intertidal conditions. The organisms could either be attached to a substrate or free-floating.

The Palaeogeography and climate. During Precambrian times, proto- Anglesey would have been part of the super continent of Pangaea, located somewhere in the region of present day Australia. Later Pangaea split into Gondwanaland and Laurasia and proto Anglesey which was attached to the ancient rocks of western North America became part of the northward-moving continent of Laurasia. The climate in Precambrian times would have been relatively cool compared to the equatorial climate experienced around 300 million years ago which was preceded and succeeded by the tropical climate experienced 100 million years either side of the Carboniferous Period. On its journey northwards it would have experienced two orogenies and one prolonged period of regional metamorphism in late Precambrian times. In addition it would, have been affected by 'Snowball Earth', a prolonged time of freezing snow and ice cover from 750 million years ago to 600 million years, or at least a glacial episode in late Precambrian times. 'Global warming' , caused by volcanic eruptions and the build up of methane and carbon dioxide in the atmosphere finally released the Earth from its icy grasp at the end of Precambrian times and was, in no small part, responsible for the burst of life which heralded in the Cambrian, the first period of the Palaeozoic era.

The age of the Precambrian rocks The complexity of these rocks in Anglesey and Lleyn, both in their composition and tectonic history, has led to great discrepancies in age dating. Normally, rocks are dated by the fossil content or by geochemical analysis using radioactive decay methods. Precambrian fossils are rare and can give general comparative dates. It was not until the stromatolitic sequence at Cemaes Bay was first dated that this was possible in Anglesey. Later work has found other datable fossils in the cherts of Llanddwyn and the worm casts of South Stack but, much of the work has still to be verified because different workers have produced very different dates for the same rocks. Isotope analyses have produced more accurate dates and particularly Rb/Sr and U/Pb analyses from zircons have proved useful. Collins and Buchanan have found early Cambrian ages for the South Stack Group of rocks, thought originally by Shackleton and later workers to be the oldest of the Monian deposits in the sedimentary sequence. These workers had the South Stack Group as the oldest, succeeded by the New Harbour Group and the Gwna Group as the youngest on top. Most recently, Horák (pre-publication research) has dated the limestone olistoliths in the Gwna Melange as between 650 and 700 million years old, making the Gwna the oldest Group on Anglesey, as Greenly had said in 1919. This is in agreement with Windley et. al., (in the press) who have proposed a tectonic sequence, rather than sedimentary sequence as previously proposed. This involves ocean floor sediments and rocks descending into a subduction zone and becoming accreted onto the inner continental wall. These deposits were succeeded by rocks and sediments beneath the accreted 'prisms'. Thus, unlike a sedimentary sequence where rocks are laid on top of each other, tectonically accreted rocks young down the sequence. These hypotheses have implications as to the relative ages of the three groups of Precambrian strata but do not affect the depositional sequence of the formations within a particular group. Other unpublished work by Horák and co-workers has shown that the Anglesey gneisses are considerably older than the 614 million years old date given for the Coedana Granite in Anglesey. Until all these, so far, unpublished data are published and further research accomplished, it is difficult to ascertain true ages and sequences for the Precambrian rocks of Anglesey.

To select RIGS to demonstrate the Precambrian evolution of Anglesey and Ll■n, three 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, bacteria, 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 of the 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 metamorphic, mineralogical, sedimentary, structural or other change across an outcrop, several representative sites have been chosen. In this study, South Stack Moor RIGS belongs to Network 1b (RIGS Precambrian Folds and faults; see above).

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Site geometry: Site boundary