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## South Stack Fossils RIGS

### RIGS Statement of Interest:

South Stack Fossils RIGS consists of alternate bands of meta-sandstones and meta-pelites on South Stack Island belong to the lowest formation of the South Stack Group, described by Greenly (1919) as the youngest Precambrian rocks on Anglesey. Currently, there is much interest in these rocks, because they have been described by some authors as the oldest rocks on Anglesey. These same authors question their age as being Precambrian but suggest they could be Cambrian or even Ordovician in age. This research puts into question the relative ages of all the Precambrian Groups on the island and the relative sequence in which these formations were deposited. On-going research has indicated that Greenly was indeed correct that these are the youngest group of Precambrian rocks on Anglesey. Current research suggests that they most probably cross the Precambrian/Cambrian boundary. These researchers have also proved that they are not the oldest group of Precambrian rocks on the island. In the only accessible rocks around the lighthouse, there are possible traces of worm burrows and some bioturbated beds. However, as the particular beds show some slump features, it is difficult to prove their true origin. However, on the mainland, South Stack Moor and Soldiers Point Bay, there have been many sightings of worm casts and the presence of such features on the island should not be ruled out. In their favour, although the South Stack rocks are folded and re-folded, a vertical bed on an inlet on the seaward side of the island appears to contain good ripple marks down its entire length, showing that the sea conditions were shallow enough to allow worms to live in such sediments. A discrete boulder in the foundations of the lighthouse definitely contains ripple marks and in all probability is local in origin. Such crucial evidence of life on the Precambrian/Cambrian boundary is of vital importance in understanding ancient environments and determining the sequence of deposition in the Precambrian rocks of Anglesey, thus making this a very important RIGS for scientific and educational purposes.

**Geological setting/context:** The Precambrian basement rocks of Anglesey and south-west LI 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 LI 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  $614 \pm 4\text{Ma}$ . 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 LI comprises metagabbros and granite rocks which occur to the south-east of the LI 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  $615 \pm 2\text{Ma}$  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 volcanoclastic rocks, dated at  $614 \pm 2\text{Ma}$ , 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 Llŷn is considerably less deformed and metamorphosed than the underlying basement, although this distinction is not everywhere obvious.

**Network context of the site** South Stack 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 life forms in Precambrian strata in Greenly's Precambrian rocks in Anglesey. South Stack provides a critical component of a network of 7 RIGS which represent rare fossil evidence from a time before macrofossils had evolved and demonstrate key features of Greenly's Precambrian rocks in Anglesey. The seven chosen sites reflect three vital components in the evolutionary story, namely, the environment in which the life forms existed, the palaeogeography and climate where they evolved and their possible age. At this location, the meta-sandstone (quartzite) and meta-mudstone (micaceous pelite) host rock is part of the South Stack Formation, the lowest formation in the South Stack Group. It is an essential component of this fossiliferous network because worm casts have been reported by several authors in this location. In addition, there has been doubt cast on its Precambrian age and a possible Cambrian age has been mooted in recent years. It is possible that all Precambrian rocks in southern Britain were part of the same Avalonian subduction system as Nova Scotia, Newfoundland and Canada.

**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 Llyn, 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, Horak (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.

**South Stack RIGS** Apart from the bioturbated rocks west of the lighthouse on South Stack (South Stack RIGS). Six other 'Precambrian Palaeontology RIGS in Anglesey have been chosen because they show variations in their Palaeontological forms, environment of deposition or age in the Precambrian.

1. Gadlys Quarry RIGS, where biohermal stromatolites occur in abundance and from where the Conophyton fossil was obtained in 1970 which alerted scientists to the importance of the Precambrian fossiliferous rocks at this locality.
2. A small quarry on Llanbadrig Point (Ffynnon Badrig RIGS) to the south-west of Llanbadrig Church is important for 'pseudo-oolitic' (Vesiculites) fossils and could be the same age as 1.
3. Associated with the limestones is an unusual outcrop of siderite (Llanbadrig Point RIGS) which may yield other bacterial forms. On Holy Island, two fossiliferous beds occur in the South Stack Group.
4. The worm casts in the cliffs to the west of Holyhead Breakwater (Breakwater Bay RIGS) and
5. Wylfa Head RIGS where a condensed sequence of stromatolites have been found.
6. At the Llanddwyn and Newborough Forest RIGS, jasper, cherts and spilite (pillow lava) occur on the island, in the forest and from beneath the dunes on the foreshore (Greenly's Gwna Group).

To select RIGS to demonstrate the Precambrian evolution of Anglesey and Llŷn, 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 Llŷn. 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 RIGS belongs to Network 2 (RIGS Precambrian Palaeontology; see above).

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**Site geometry:** Site boundary