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## Newborough & Llanddwyn RIGS Site

NRW RIGS no. 322 [SH 39495 64190]

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### RIGS Statement of Interest:

Newborough & Llanddwyn RIGS Site exposes red jaspers in the pillow lavas associated with stromatolitic limestones in the Gwna Mélange.

Newborough & Llanddwyn RIGS Site exposes spectacular red jaspers in the pillow lavas at Newborough appear to be associated with the stromatolitic limestones of the Cemaes Bay area, both of which are included in the Gwna Mélange. The mélange is a mud-rich sediment containing rounded boulders of varying size which accumulated on the sea floor adjacent to a land mass. Large. The jaspers are reported to contain the 'ghosts' of calcite rhombs (Muir et al.) and also include filaments and rounded bodies, though these are less well preserved than those at Cemaes. Wood and Nicholls writing about Cemaes Bay, described the layers as stromatolites and the spheroidal bodies as Vesicularites (algal floating or rolling bodies) which may represent bacterial forms. They were described by Wood and Nicholls as Precambrian in age but later workers thought they could be Cambrian or even Ordovician fossils. However, new isotope dates have shown them to be between 650 and 700 million years old. This information has a huge bearing on the so-called sedimentary succession described by Greenly and Shackleton and makes the Gwna the oldest sedimentary formation in North Wales. These rocks are now considered to be part of a tectonic, rather than a stratigraphic sequence and they provide important evidence about the nature of the sea floor and rare life forms from a time prior to the 'explosion' seen of life forms during Early Cambrian times. The presence of both types of fossil in this area and Cemaes begs the question as to whether the jaspers were originally calcareous.

**Geological setting/context:** The Precambrian basement rocks of Anglesey and south-west LI■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 LI■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  $614 \pm 4\text{Ma}$ . 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■n comprises metagabbros and granite rocks which occur to the south-east of the LI■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  $615 \pm 2\text{Ma}$  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:** Newborough and Llanddwyn RIGS provides a critical component of a network of 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 spilites and associated jaspers are in regional, unconformable or tectonic contact with the Gwna Group Mélange and are interpreted as having belonged to a Precambrian accretionary prism. 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 jasper (deep-sea chert) is thought to have been deposited as an iron-rich carbonate ooze which was replaced by an iron-rich silica in deep water, on or near to a constructive plate margin (oceanic ridge). It is unclear when this replacement took place and whether the fossils were present before or after it was silicified. Siderite (Iron-rich carbonate) is known to exist alongside stromatolitic limestone at Cemaes Bay, in rocks dated between 650 and 700 million years old. This suggests that silicification of the jasper could post date the Cemaes Bay deposits. This ties in with dates of Vendian to Cambrian ages put forward by Muir et. al. However, the presence of drop stones in the jasper indicates either a glacial period when they were formed or a time during 'Snowball Earth'. In either case it suggests that the jaspers are Precambrian and not Cambrian.

**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. Apart from the jasper, cherts and spilite (pillow lava) in the forest and some appearing from beneath the dunes on the foreshore, other exposures on the margins of Llanddwyn Island are included in a GCR site, Llanddwyn Island (Greenly's Gwna Group). 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. Firstly, Llanbadrig at Gadlys Quarry is important for the stromatolitic limestones (Gwna Group) on the north Anglesey. These are formed in shallow water or intertidal conditions and have been dated as the oldest fossils in Anglesey. 2. A small quarry on Llanbadrig Point to the south-west of Llanbadrig Church is important for 'pseudo-oolitic' (Vesiculites) fossils and could be the same age as 2. 3. Associated with the limestones is an unusual outcrop of siderite which may yield other bacterial forms. 4. Wylfa Head contains various stromatolitic forms and an all important condensed sequence in a narrow band of black limestone (current research). On Holy Island, two fossiliferous beds occur in the South Stack Group. 5. The worm casts in the cliffs to the west of Holyhead Breakwater and 6. The bioturbated rocks west of the lighthouse on South Stack.

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, Newborough and Llanddwyn RIGS belongs to Network 2 (RIGS Precambrian palaeontology; see above) and has been chosen to demonstrate important characteristics and variations of filament and spheroidal microfossils in jasper associated with spilitic pillow lavas. They indicate an environment where deep sediments comprising iron rich cherts (replaced iron-rich or a complete ice-covering of the Earth 'Snowball Earth' have been found in the jaspers carbonate ooze) were located near an oceanic ridge where pillow lavas were being extruded. This was somewhere in the southern hemisphere as part of the super continent Pangaea. The age is probably from late Riphaen to Vendian times (up to 590 million years ago) because drop stones originating from an ice sheet, although Muir et. al., think they are Vendian to early Cambrian in age.

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**Site geometry:** Site boundary