Accretionary processes and stratigraphic reconstruction of Neoproterozoic oceanic crust, North Wales, UK

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Introduction

The Mona Complex of Anglesey-Llŷn an assemblage of accreted units emplaced during the Neoproterozoic-Cambrian collision and subduction of Iapetus Oceanic Lithosphere against the microcontinent of Avalonia. It offers the opportunity to study the origin of emplacement of accretionary complexes from sub-greenschist to blueschist metamorphic conditions.

The Gwna Complex comprises a diverse, regional-scale subduction mélangé locally dominated by accreted ocean floor volcanic sequences. The concept of ‘mélangé’ was first described from the Gwna Complex [1].

Newborough is a small, well-exposed area of the Gwna Complex that is is dominated by volcanic sequences. Unlike elsewhere in the Gwna Complex, mélangé development in Newborough is limited, allowing ocean plate stratigraphy (OPS) to be reconstructed using field relations and whole rock geochemistry of igneous rocks.

From this idealised OPS, we look into internal disorder within units as a result of accretion, and examine structural links between Newborough and the rest of the mélangé-dominated Gwna Complex.
Newborough

All units in Newborough (right) are NE-SW trending and have been tilted subvertically SE. Cleavage ($S_1$), bedding orientations ($S_0$) and clast elongation are consistent with this trend. Kinematic indicators suggest a dip-slip shear sense upwards from SE.

Broadly repeating sequences are dominated by thick units of MORB-like pillow basalts and associated volcanics, overlain by various units of thin ocean floor sediments, which are preserved at sub-greenschist metamorphic conditions. Locality A preserves a possible petit-spot seamount sequence characterised by an OIB geochemical signature (below) and is not seen elsewhere in the study area.

Deformation is generally concentrated around unit interfaces and along weak planes. Thick pillow lavas, for example, are largely undeformed and macroscopic strain is confined along intermittent hyaloclastite layers.
Stratigraphic units

The stratigraphic columns (right) are taken from units across Newborough that show better coherence than found elsewhere in the Gwna Complex.

Units generally consist of a pillow lava-dominated volcanic sequence overlain by a sedimentary cover, usually of carbonates followed by cherts, sandstones and mudstones. Stratigraphic order of upper sediments is prone to being disrupted by internal slip between units, as seen in column F.

Column A is unique in Newborough and shows a possible petit-spot seamount stratigraphy of dolerite sills intruding sea floor sediments, with an extrusive hyaloclastite cap (shown by geochemical data, slide 3).

Hyaloclastites are most commonly found at basal interfaces of units where exposed. In units where pillow basalts are at the base, the pillows are locally deformed and elongated parallel to cleavage.

Sequences are also typically capped by a weak lithology (mud-rich beds, peperite or hyaloclastite). Column I is an exception to this, where chert layers of the siliceous mudstone have disaggregated within a weaker interbedded mudstone component.
Imbrication mechanisms

Broad repetition of stratigraphic sequences in a consistent orientation are bound by high-strain interfaces. This suggests that semi-coherent slabs of upper oceanic lithosphere have been imbricated against one another during accretion.

Hyaloclastites occur as intermittent planes within pillow lava sequences and act as a layer of weakness in an otherwise strong lithology. These hyaloclastites are often found at unit bases and likely accommodated detachment during subduction. Deep hyaloclastite layers within the lower plate may be responsible for the accretion of thick volcanic sequences in Newborough.

Slip is concentrated along unit interfaces and causes intense localised deformation. Interfaces are usually bound by weaker units, which easily deform to high strain, forming mélange.

Slip also occurs along lithological contacts due to differences in rheological competence. This is most likely responsible for the lack of stratigraphic coherence, particularly within sediments.
Mélange formation

Localised mélange zones have developed between stratigraphically more coherent units and typically consist of a mudstone matrix at the upper unit interface and of hyaloclastite at the basal interface.

Clasts in mélange zones originate from various lithologies in the Gwna Complex and are largely sourced from the nearest surrounding lithologies (most commonly sandstones and basalts with red jasper; see right). Clasts are typically elongated parallel to cleavage and have been found up to 2m in length.

The Gwna Complex elsewhere is dominated by much larger scale mélange that has developed from extensive sediment-dominated sequences with an abundance of thick mud-rich units (lower right).

Either through being starved of terrigenous sediment input or through little of this material being accreted, Newborough does not host thick layers of mud-rich sediment. This has hindered the development of mélange and may have influenced the accretion of thick volcanic sequences.
Field observations and whole rock geochemistry has allowed the reconstruction of OPS from Newborough (right). This study expands on previous work [5] by accounting for semi-coherence of OPS in imbricated units by considering internal structural controls, and by providing a link to the Gwna Complex as a whole through the recognition of localised mélange formation.

Variability in lithologies lead to localisation of strain along weaker units and has caused a partial loss of coherence within stratigraphic units through internal slip, particularly in seafloor sediments at the top of more coherent igneous lenses.

During accretion, shear concentrated along unit interfaces, leading to imbrication. Unit interfaces are typically hosted by weaker lithologies that are heavily deformed and can lead to the localised development of mélange zones.

Mélange formation is limited in Newborough due to a sediment-starved system, which means a lack of thick mud-rich sedimentary sequences capable of acting as a mélange matrix. Instead, relatively strong basalts, carbonates and cherts dominate, causing shear to be localised along relatively weak planes that tend to be thin and isolated.

References