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Unravelling a Precambrian rift and passive margin sequence: pitfalls and challenges

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The broad tectonic principle behind the formation of rift and passive margins basins is relatively simple. Nevertheless, the detailed sedimentology and architecture of rift/passive margin basins shows a huge diversity, caused by differences in - amongst several factors - amount and duration of extension, sediment supply from the hinterland, magmatic activity, and climate with its implications for carbonate production.

Modern passive margin basins can be studied only by seismic methods and drilling, with clear limits on resolution. Ancient rift and especially passive margin basins can only be studied in outcrop after uplift following orogenesis, e.g. after closure of the ocean that created the passive margin in the first place. Such basins are thus deformed, metamorphosed and partially eroded, creating problems in restoration and interpretation. Therefore, to reach a complete understanding of rift / passive margin basins, the challenge is to compare two strands of evidence, each with its own limitations. Additional problems concern particular structures that can be formed either by sedimentary or by orogenic processes, or that can be reactivated during orogenesis.

The Scottish sector of the Neoproterozoic to Cambrian Laurentian margin, as exposed in the poly-deformed and medium-to-high grade metamorphosed Dalradian Supergroup, is a good example illustrating the challenges at hand. This sequence consists of a lowermost sand-dominated sequence (Grampian Group); succeeded by a varied, thin-bedded group of limestone, mudstone, sandstone and quartzite (Appin Group); to a varied group of quartzites and black shales, a first turbidite series and a basin-wide limestone (Argyll Group) and finally a second turbiditic sequence (Southern Highland Group).

A particular problem of interpretation concerns ‘missing’ Dalradian stratigraphy. In places, large sections of stratigraphy are absent, with high-level Argyll Group rocks juxtaposed against Grampian Group rocks. Traditionally, the horizon of missing stratigraphy was termed the ‘Boundary Slide’, interpreted as an orogenic peak-metamorphic ‘D2’ shear zone. Alternatively, this stratigraphic ‘omission’ might be caused by: i) late/post orogenic extension; ii) syn-basin extension; iii) a non-deposition / intrabasinal unconformity.

The strata overlying the omission comprise a lower sequence of deep-water ?turbiditic rocks (Crinan Subgroup) and are laterally continuous over 200 km strike-length and we prefer an interpretation as an overstepping, intrabasinal unconformity. This unconformity is akin to the rift-to-drift unconformities imaged in seismic profiles of modern passive margins. The occurrence of ultramafic pods (?originally serpentinite bodies) just below and within the lower turbidite sequence supports this notion. However, the lower turbidite sequence is followed by laterally continuous carbonate deposition and c. 600 Ma MORB volcanics, the latter generally interpreted as heralding the opening of the Iapetus. This was followed by more uniform turbidite deposition. It thus appears that the ‘geometric’ rift-drift transition unconformity was not coeval with the magmatic signature of ocean opening. Rather, the unconformity may link to an earlier phase of crustal thinning and mantle exhumation, only followed later by ocean opening.