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Basement-cover relationships in the Grampian Caledonides of Scotland - extensional strain preceding continental rupture and generation of the Laurentian ocean-continent transition zone

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Ancient rift and passive margin basins can frequently only be studied in outcrop after uplift following orogenesis. Such basins are thus deformed, metamorphosed and partially eroded as a consequence of closure of the oceanic system in which the passive margin was originally established. As a result there are significant challenges in restoration and interpretation of the original basin geometries and lithostratigraphical relationships.

The mid-Neoproterozoic to Cambrian Dalradian Supergroup of Scotland and Ireland was intensively deformed and metamorphosed by mid-Ordovician arc-accretion (c. 460 Ma) during the Caledonian Orogeny. Nevertheless, we can determine a history of stretching and break-up associated with rupture of the Neoproterozoic supercontinent of Rodinia and opening of Iapetus. Continental fragments apparently separated from the passive margin during rift-drift transition. The extensional structures bounding the various fragments subsequently exerted control on the collisional geometry and acted as nuclei for deformation structures during Caledonian orogenesis.

Reading the record of Neoproterozoic extension in the Scottish Caledonides is further complicated by the need to unravel the structural record at the boundary between the Dalradian Supergroup and underlying early-Neoproterozoic metamorphic basement. The depositional age of the Dalradian succession is not well constrained but the oldest strata could pre-date 800 Ma. If such should be the case, then the thick siliciclastic deposits characteristic of the lower Dalradian Grampian Group succession accumulated before 800 Ma during an early stretching phase (distributed high angle faulting) that led to crustal thinning (low-angle shearing). A major low-angle, regional-scale ductile shear zone in the upper levels of the underlying basement is arranged sub-parallel to the present structural base of the Dalradian. The high-temperature regional metamorphism in basement is c. 830 Ma old while the ductile shear zone is c. 800 Ma old.

Three major limestone – pelite – quartzite depositional cycles (Appin/Argyll groups) succeeded these earlier siliciclastic deposits, recording episodic transgression and regression in a largely marine, intracratonic setting. In this assessment, early-Dalradian sedimentation would overlap the proposed extensional deformation and consequent metamorphism in the basement, thus accommodating early rifting and extension on the Laurentian margin. This, and the parallelism of the ductile shear zone with the strata above and below, suggests that the shear zone was a mid-crustal extensional detachment that developed coeval with marine deposition at the top of the crust. The metamorphic basement can be regarded as a metamorphic core complex in a continental rift setting. The Neoproterozoic rift architecture is strongly reworked in the Caledonian Orogeny but elements of more modern extensional structures such as those preceding spreading in the modern Atlantic Ocean can still be seen.