The Garbh Eileach Formation, SW Scotland: A strengthened case for the Tonian–Cryogenian GSSP

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Abstract

The boundary between the Tonian and Cryogenian periods (c. 720 Ma) represents a transition into one of Earth's longest and most extensive ice ages, the Sturtian glaciation. Owing to major global glacioeustatic sea level fall and the action of glacial erosion, the sedimentary record of this transition has commonly been erased. Missing strata at such a key juncture presents a significant challenge to both stratigraphic correlation of pre-glacial successions, and the establishment of a formal Global Stratotype Section and Point (GSSP) for the basal Cryogenian.

The Garbh Eileach Formation (GEF) is a > 75 m succession of Tonian carbonates that directly underlies the 1.1 km thick glaciogenic Port Askaig Formation of Sturtian affinity. Fairchild et al. (2018) argued for a possibly unique transitional contact between Tonian and Cryogenian sediments on the largest of the Garvellach islands (Garbh Eileach) where the formation is best exposed. Amongst several lithostratigraphic observations for the gradual onset of ice (e.g. ice rafted sediment, gypsum pseudomorphs), their argument is poised on the preservation of the Garvellach carbon isotope anomaly and associated values of clasts in the overlying diamictite. The carbonate carbon isotope values defining the 'Garvellach anomaly' in the GEF, descend from -4‰ to -7‰, before recovering to +1‰ immediately beneath the overlying glaciogenic Port Askaig Formation. The GEF hosts the most complete known record of this global signal, where it is somewhat anchored chronologically by late Tonian 87Sr/86Sr signatures of 0.7066–0.7069 (Sawaki et al., 2010); however, the Garvellach anomaly is evidenced in at least two further global sections (Lamothe et al., 2019). In the absence of a reliable biostratigraphic framework for the Tonian, the point at which the carbon isotope values of the Garvellach anomaly become positive, 4 m below the first evidence for ice-rafted sediment, may offer a chronostratigraphic horizon suitable for the basal Cryogenian GSSP (Fairchild et al., 2018).

In 2013, Garbh Eileach was visited by the Cryogenian Subcommission to review its suitability for the placement of the basal Cryogenian GSSP within the GEF. The Scottish succession

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boasts a relatively thick and complete record of Sturtian glaciation as well as 100% exposure across the proposed Tonian-Cryogenian transition (Ali et al., 2018). Furthermore, the island of Garbh Eileach is relatively accessible and open to further research, all of which address criteria set out by the International Commission on Stratigraphy for future GSSPs. Although Garbh Eileach is considered to be a highly promising GSSP candidate due to its suitability as a chemostratigraphic type section, the lack of a direct radiometric age constraint still needs to be addressed (Shields et al., 2018). For this reason, we are focussing our attention on producing a more robust geochronological constraint for the GEF, while increasing the resolution of the Garvellach anomaly.

Here we present preliminary attempts at deriving a radiometric age constraint for the GEF by directly dating calcite using the U-Pb geochronometer. In-situ U-Pb carbonate geochronology has had recent success for Tonian carbonate successions to within 2.5% uncertainty (Lan et al., 2022) and it is hoped that further investigation will produce a meaningful age for this succession. These findings are coupled with a new high resolution carbon isotope curve ($>$ 200 data points) across the c. 75 m of exposed GEF on the island of Garbh Eileach. The new curve displays a similar form to that of Fairchild et al. (2018) and further refines the proposed chronostratigraphic horizon at which the GSSP could be placed.

Interrogating the links between coeval Earth system perturbations, climatic forcings, and the onset of the Sturtian glaciation, remains challenging. However, we consider that our high resolution, multiproxy study of the demonstrably transitional succession at Garbh Eileach will help to maximise the geological significance of any future Cryogenian GSSP, while shedding light on a remarkable episode in Earth's history.

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Keywords: Basal Cryogenian GSSP, Dalradian Supergroup, Garvellach anomaly, U Pb carbonate geochronology