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How did the Archean crust evolve? Insights from the structure and petrology of the Lewisian of Scotland

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High-grade Archean gneiss terranes expose mid to lower crustal rocks and are generally dominated by tonalite-trondhjemite-granodiorite (TTG) gneisses. Occurrences of mafic-ultramafic bodies and garnet-bearing felsic gneisses within these environments have been interpreted as supracrustal or near-surface rocks requiring a tectonic process involving mass transfer from the near-surface to the mid-crust. However, there is significant uncertainty regarding the nature of this mass transfer, with suggestions including a range of uniformitarian and non-uniformitarian scenarios. One non-uniformitarian scenario, 'sagduction', has been proposed as a possible mechanism (Johnson *et al.,* 2016, and references therein), although the dynamics of sagduction are still relatively unexplored.

This study focuses on mafic, ultramafic and garnet-bearing felsic gneiss bodies in the central region in the Lewisian Gneiss Complex of northwest Scotland as test cases to investigate the behaviour of possibly supracrustal rocks in a mid-crustal environment. Existing datasets of TTGs (Johnson *et al.,* 2016), mafic gneisses (Feisel *et al.,* 2018) and ultramafic gneisses (Guice *et al.,* 2018) from across the central region were utilised in addition to felsic and mafic gneiss samples obtained in this study from the ~10 km^2 Cnoc an t-Sidhean (CAS) suite. The CAS suite is the largest reported supracrustal in the Lewisian, and dominantly comprises garnet-biotite felsic gneiss assemblages and an associated two-pyroxene mafic gneiss. Field mapping was undertaken to collect samples representative of the observed heterogeneity of the suite, and to assess field associations between possible supracrustals and surrounding TTGs. Phase equilibria modelling was conducted on all lithologies to ascertain peak pressure-temperature (*P-T*) conditions, and to calculate the density of the modelled rocks at peak conditions.

The results obtained in this study indicate peak metamorphic conditions of 950 ± 50 °C and 9 ± 1 kbar for the CAS suite, consistent with the central region of the Lewisian Complex (Feisel *et al.,* 2018). Density contrasts at mid-crustal conditions of 0.12–0.56 gcm^{-3} were calculated between TTGs and the other lithologies and used to estimate the buoyancy force that drives density-driven segregation. This allowed us to investigate the rates of vertical motion that result from density contrasts, as a function of the effective viscosity during metamorphism. Independent viscosity estimates were attained using mineral flow-laws and our estimated *P-T* conditions, and from examination of modern-day regions of crustal flow. We were therefore able to estimate the conditions under which sagduction could have been a viable mechanism for crustal evolution in

the Lewisian and similar high-grade metamorphic terranes. We conclude that sagduction was unlikely to have operated in the Lewisian under the dry conditions implied by preserved mineral assemblages.

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