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Non-lithostatic eclogitization in exhuming continental crust

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During collisional orogeny, the lower continental plate is typically subjected to pressures no greater than 3 GPa (~100 km). Locally, however, ultrahigh-pressures (UHP) in excess of 5 GPa have been recorded, most commonly in included metamorphosed mafic-ultramafic rocks. Such pressures would suggest burial of continental crust to mantle depths; however, continental subduction to such depths is not observed in active orogens as it is hindered by the positive buoyancy of sialic crust relative to the mantle. An alternative explanation for extreme pressures recorded in continental crust is that they reflect non-lithostatic conditions, an idea that has been limited to modelling experiments and thus its applicability to natural systems is highly debated. Specifically, it was proposed that mechanical heterogeneities could explain extreme non-lithostatic pressures of c. 5.5 GPa obtained in enstatite eclogite veins cross-cutting a peridotite hosted in the archetypal subducted continental terrane, the Western Gneiss Complex (WGC) in Norway. Here, we use thermobarometry and Lu-Hf garnet geochronology to determine at what conditions and at what point in the burial cycle the enstatite eclogite assemblages actually equilibrated. The results show that the enstatite eclogites equilibrated at pressures of 4-5.5 GPa and at c. 393 Ma; these conditions are greater than those typical of 'normal' eclogites in the WGC and the age represents a time when the terrane had already exhumed to crustal depths (<2.5 GPa). Finite element modeling of mechanical pressure distribution can explain the seemingly spurious conditions recorded in these unusual rocks and demonstrates that these late extreme pressure excursions are feasible for the given rock system. Although the occurrence of non-lithostatic UHP conditions in deeply buried continental crust may, indeed, be unusual, it allows crucial simplification of models for continental subduction and validates the importance of integrating rock thermo-mechanics with geochronology and thermobarometry in interpreting observations from collision zones.