Changing exhumation potential of (U)HP eclogite through geological time

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Ultrahigh-pressure (UHP) metamorphism is defined by achieving P–T conditions sufficient to transform quartz to coesite (~26–28 kbar at ~500–900 °C), which occurs at ~90-100 km depth within the Earth under lithostatic conditions. Thus, the occurrence of UHP metamorphism is often taken as being a diagnostic indicator of subduction having operated in the geological record, and hence plate tectonics. Yet, the oldest such coesite-bearing rocks belong to the Pan-African belt in northern Mali, and formed at 620 Ma, although there exist multiple lines of evidence to show that a global network of subduction had been operative on Earth for billions of years beforehand. Why, then, are these key geodynamic indicators missing from the majority of the rock record? Here, I show how secular cooling of the Earth’s mantle since the Mesoarchean (c. 3.2 Ga) has affected the exhumation potential of UHP (and HP) eclogite through time due to time-dependent compositional variation of both oceanic and continental crust. Petrological modeling of density changes during metamorphism of Archean, Proterozoic, and Phanerozoic composite continental terranes shows that more mafic Archean crust reaches a point-of-no-return during transport into the mantle at shallower depths than less MgO-rich modern-day crust, regardless of whether this occurs via subduction of stagnant lid-like vertical ‘drip’ tectonics. Thus, while Alpine- and Himalayan-type (U)HP orogenic eclogites represented by metamorphosed mafic intrusions into continental crust may readily have formed during the Precambrian, they would have lacked the buoyancy required for exhumation and preservation in the geological record.