Is extreme metamorphism the hallmark of plate tectonics?

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Assessing P-T conditions and tectonic settings of crustal metamorphism, particularly at extremes close to the liquidus or the 'point of no return' before plunging irretrievably into the mantle, is important to understanding global geodynamics and evaluating secular change. This is because the imprint of metamorphism in the rock record is evidence of coupling between the lithosphere and the asthenosphere, that either raised the lithosphere-asthenosphere boundary to increase the heat flow or dragged continental crust down the subduction channel to achieve extreme pressures.

Ultrahigh temperature metamorphic (UHTM) belts occur from late Neoarchean to Cambrian. The first occurrence of UHTM in the record signifies a change in global geodynamics that allowed aggregation and stabilization of continental crust and generated transient sites of very high heat flow. Many UHTM belts developed in settings analogous to modern backarcs that were subsequently inverted; on a hotter Earth destruction of oceans floored by thinner lithosphere may have generated hotter backarcs than those in the Pacific Ocean. Medium-temperature eclogite–high-pressure granulite metamorphism (E-HPGM) also is first recognized in the Neoarchean, and occurs at intervals throughout the Proterozoic and Paleozoic. E-HPGM belts are complementary to UHTM belts, recording subduction-to-collision orogenesis. Blueschists first appear in the Neoproterozoic; they record the low thermal gradients associated with modern subduction. Lawsonite blueschists and eclogites, and ultrahigh pressure metamorphic (UHPM) belts characterized by coesite or diamond are predominantly Phanerozoic phenomena related to deep subduction during the early stage of subduction-to-collision orogenesis.

The hallmark of plate tectonics is the development of two contrasting thermal environments where plates converge – these are the subduction zone and the arc–backarc. The imprint of this duality appears in the record of metamorphism only since the Neoarchean, with the first occurrences of two contrasting types of metamorphism – E-HPGM and UHTM. A pre-Neoarchean tectonics regime may have involved plates, but if so these were probably thinner with an ultramafic crust; if contrasting thermal environments were generated, evidence is not preserved in the metamorphic record. The occurrence of E-HPGM and UHTM in the Neoarchean records the onset of a 'Proterozoic plate tectonics regime', although total ridge length and number of plates were larger than today and there are differences in the pattern of orogenic belts. A transition to the 'modern plate tectonics regime' in the Neoproterozoic registers a change to colder subduction, evidenced by the appearance of blueschists and UHPM, but still paired with LP–HT metamorphic belts.