Some thoughts about eclogites: recent progress and remaining challenges

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Soon after the paradigm shift from geosynclinal theory to plate tectonics the IEC was established to promote communication and cooperation among scientists studying HP–UHP rocks. In 40+ years we have progressed from clues based on calculated *P* (1979), to Coe (1984) and Dia (1990), and way beyond (based on *e.g.*, exsolution microstructures). Supported by an ever-wider range of instrumentation and enhanced computational capabilities, and new developments in petrochronology, we have discovered new minerals and enjoyed a golden age of quantification, leading to robust estimates of *P*–*T* and rates. But, just as we adjusted to exhumation at plate speeds, the lithostatic assumption came under increasing pressure. Subduction and exhumation mechanisms to and from HP conditions are quite well understood, but how much continental crust reaches extreme UHP conditions, how much continental lithosphere returns to the mantle and the implications of such a return flow are largely unknown. The golden age generated data sufficient to investigate the spatiotemporal distribution of metamorphism and secular change, but not without controversy in relation to the rare occurrence of low T/P metamorphism prior to the Cryogenian. Are preservation and survivorship bias a problem? We have long appreciated the importance of metasomatism during subduction, but the role of fluids has received renewed interest now that we have models of the global water cycle. The role of fluids around the metamorphic peak and during exhumation, sourced by dehydroxylation of nominally anhydrous minerals and breakdown of hydrous minerals, is more limited, but commonly involves supercritical fluid and hydrous melt.

In the future, we should expect incremental improvements to thermobarometry (*e.g.*, in elastic barometry) and phase equilibrium modeling, and continued advances in petrochronology. However, characterization of *P*–*T*–*t* is largely routine and determination of average rates of burial and exhumation is common, if bedeviled by tectonic overpressure. Further progress in understanding metamorphic and orogenic processes will require the application of thermodynamics under nonhydrostatic stress conditions in addition to ongoing studies of disequilibrium features and kinetics; we should expect improvements to and wider application of diffusion modeling in studies of eclogites. The flow of reactive fluid at grain- and nano-scales is a key challenge for future research. However, with increasing interest in processes at smaller scales, are our observational, particularly field and petrographic skills in danger of being lost? Maybe our ability to measure natural variability in chemical composition and mechanical properties at small scales has outstripped our capability to interpret it? The crustal-scale role of tectonic overpressure remains enigmatic—do measured local variations in stress extrapolate to the regional-scale and, if so, what is the magnitude of the deviations from lithostatic? Studies of detrital minerals and sedimentary rocks should yield new insight into the record of UHP metamorphism. Topics such as subduction initiation, the variation of slap-top geotherms through time, and the role of subducted fluids on the genesis of deep earthquakes remain important challenges. Finally, our ability to interrogate inclusions in super-deep diamonds at ever finer scales should lead to a better understanding of how the deep interior and surface are linked in the context of Earth as a fully-coupled system.