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High- and ultrahigh-pressure metamorphism: Past results and future prospects

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Abstract

Fifty years ago, geologic conditions attending the formation of blueschists, eclogites, and garnet lherzolites were not known. But, with the advent of high-pressure phase-synthesis equipment and precise calorimetry, minerals like jadeite, aragonite, pyrope, and the dense polymorphs of SiO_2 and C were shown to be stable at elevated pressures and relatively low temperatures. Metamorphic conditions required by *P*-*T* stabilities of these minerals reflect the operation of plate tectonics, lithospheric subduction, and inferred mantle convection. Integration of phase equilibria with dynamic tectonic processes has illuminated the petrogenesis of the crust. Combined with geochemical, geophysical, and isotopic data, high-pressure phase equilibria are also providing new constraints on the constitution and evolution of the mantle.

Circumpacific blueschists and eclogites occur in penetratively sheared nappes that are overturned seaward, indicating 30–50 km descent of an oceanic plate during metamorphism before partial exhumation of mainly low-density crustal material. Neoblastic coesite and microdiamond inclusions in tough, rigid host minerals show that continental collision involves fragmentary recovery of subducted rocks from depths of 100–130 km, far deeper than traditionally thought. Even more surprising, garnet peridotites from the central Alps, western Norway, Bohemia, and China display intergrowths and exsolution lamellae reflecting the former existence of majoritic garnet, stishovite, and other phases requiring depths of origin >300 km. Exsolved nanominerals attest to the decompression of precursor phases that had formed at profound depths preceding mantle upwelling. Times of deep-seated storage and rates of exhumation remain as major problems. Fluid-rock and lithosphere-asthenosphere interactions have recycled volatiles to the deep Earth through subduction of both hydrous and nominally anhydrous minerals. Mantle petrochemistry and plume-plate dynamics control the evolving architecture of the Earth's crust and the interdependent biosphere. Applications of advanced technologies to condensed materials are leading to a fuller understanding of the planetary interior in time and space.

Keywords: Metamorphic petrology, high-pressure belts, phase equilibria, subduction-zone belts, high-pressure studies, convergent plate junctions, thermobarometry, ultrahigh-pressure rocks