Delamination of the subducting lithosphere and exhumation of ultrahigh-pressure metamorphic rocks

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Prior to the exhumation of ultrahigh pressure metamorphic terranes, it is necessary for them to be separated from the subducting plate. This kind of phenomenon is generally called delamination, which usually occurs at shallower depths, like offscraping of the upper part of the continental lithosphere in collision zones, and ophiolite obduction of the oceanic lithosphere. I investigate the conditions for delamination. Previous studies included a buoyancy force as a driving force (e.g., van den Beukel, 1992). However, this force only operates after delamination has occurred (Archimedes's principle). The only available driving force for delamination is then the shear stress at the plate interface (thrust zone). I evaluate the shear stress required to cause detachment of an upper crustal block of the subducting slab by faulting, calculating temperatures of the slab and its surface by the analytical formulation of Molnar and England (1990). The shear stress and temperature at the ductile part of the thrust zone is determined to be consistent with the shear heating. The shear stress at the brittle part is a strong function of the pore fluid ratio, i.e., the ratio of the pore fluid pressure to the lithostatic pressure. I find that the detachment of an upper crustal block is only possible for very small pore fluid ratios and when the lower edge of the block has subducted deeper enough (depth larger than ˜30 km). The subduction of the continental or island-arc crust inhibits the dehydration from the slab (Seno and Yamasaki, 2003), resulting in high shear stresses at the thrust zone with a small pore fluid ratio (Seno, 2006). In the early stage of the collision, however, there occurs dehydration from the subducted oceanic plate trailing the continent. This lubricates the thrust zone and makes it possible for the continental plate to be subducted at a large depth without delamination. As the collision proceeds, the thrust zone becomes less lubricant, causing detachment of UHP terranes. In matured collision zones, offscraping of the continental crust occurs at shallow depths. On the other hand, when an oceanic plate is subducting, it is impossible to cause delamination generally because of the absence of a ductile shear zone within the subducting oceanic lithosphere and of the large pore fluid ratio. Even in this case, delamination is possible when weakening occurs along the dehydration loci of the serpentinized slab mantle, given a moderate amount of shear stresses. This may lead to detachment of UHP terranes in subduction zones, like Sanbagawa, and obduction of some ophiolites.