Systematics of intermediate-depth earthquakes: what have we learned recently?

*Geoffrey A Abers[1]

1. Cornell University

Since their discovery by Wadati in the 1920’s the physics responsible for intermediate-depth earthquakes (IDEs) have remained problematic. Common explanations require either dehydration reactions to reduce effective stresses or otherwise weaken subducting plates, or ductile shear instabilities to localize in slab conditions. Despite the seemingly large difference between these two processes it has been difficult to identify clear observations that differentiate them. Several systematics of IDEs are robustly observed, particularly with the advent of high-precision hypocenters from dense networks. IDEs occur almost exclusively in subduction zones where cold and hydrated material descends, and form a plane or planes subparallel to the slab surface. High-precision hypocenters show a primary zone that is 10 km thick or much less –in many cases limited by the accuracy of hypocenters –and generally decrease in abundance with increasing depth. IDEs almost always show double-couple focal mechanisms, often on fault planes at high angles to the seismic zone. They exhibit rupture duration scaling (stress drops) within the range of crustal earthquakes, once shear modulus variations are accounted for. The largest IDEs reach M8 and exceed M7 in many subduction zones, and require rupture on planes of tens of km length to generate the source durations. Thus the conditions for rupture propagation persist outside of the thin regions in which IDEs typically nucleate. Converted-wave studies provide high-resolution information on slab locations independent of the seismicity, and show that IDEs sometimes take place in subducting crust and sometimes in subducting mantle; earthquakes in subducting crust are only seen in cold subduction zones. Analysis of metamorphic reaction systematics suggests that the volume changes associated with dehydration can regulate the occurrence of IDEs, such that IDEs only occur in crust where net volume of fluid produced exceeds the production of porosity (reduction in solid volume). This behavior is evidence that fluid pressure plays an important role in creating IDEs. However, the process remains enigmatic in mantle rocks because serpentine does not exhibit velocity-weakening instability in most conditions. Local maxima in earthquake abundance have been observed beneath well-instrumented volcanic arcs, again indicating a role for metamorphic dehydration, but they are modulated by incoming plate structure in complex ways. The existence double seismic zones indicate that temperature may be most important in the mantle, since many zones lie 25-40 km below the plate interface where hydration is hard to observationally confirm.

Keywords: subduction, wadati-benioff zone, earthquakes

