Investigating the physical mechanism behind deep-focus seismicity in South America: observations from focal mechanisms and centroid depths in the Peru-Brazil region

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Abstract

Deep-focus earthquakes are defined as events occurring at depths greater than 300 km, and are generally restricted to only a few subduction zones in the world. Despite appearing to be very similar to their shallow counterparts, deep brittle events are not supposed to occur due to the extreme pressure and temperature conditions. Thus, deep earthquakes must be mechanically different from shallow earthquakes and probably require one or more generating mechanisms to explain their occurrence. These mechanisms, however, remain a matter of debate, and the main candidates include transformational faulting, thermal runaway, and dehydration embrittlement. Aiming at investigating this generating mechanism, we employed a Cut-and-Paste (CAP) method to determine moment tensor solutions and centroid depths for a total of 42 deep-focus events that occurred in the period of 2014-2022 along the Peru-Brazil border, and for which stations from the Brazilian Seismic Network (RSBR) provided near-source coverage. We were able to develop a total of 28 moment tensors ($4.2 \leq Mw \leq 7.5$) with centroid depths in the 557-659 km range. Most solutions revealed a normal mechanism, consistent with down-dip compression (DDC) as the predominant stress regime in the near-vertical Nazca plate. Nodal planes suggested a broadly uniform orientation of the normal faults, nearly parallel to the local slab strike. We observed that, in principle, the orientation of the nodal planes is in agreement with predictions from the transformational faulting mechanism. Moreover, comparison between centroid depths and hypocentral depths suggests that ruptures in this region tend to propagate downwards for depths larger than 580 km. We submit that deep-focus earthquakes in this region nucleate through transformational faulting in a metastable olivine wedge (MOW), and that the presence of a MOW in the warm Nazca plate could be explained through a postulated older slab segment currently at ~500 km depth. Due to its lower temperatures, this older slab segment may have preserved olivine metastably deep into mantle transition zone depths. This hypothesis could additionally explain a seismic gap between 300-500 km reported for the Nazca plate, and the increase in seismicity at depths larger than 500 km, where the MOW is present. Nonetheless, to account for larger ruptures such as the 1994 Bolivia earthquake, it is likely that - after initiated - ruptures can propagate further by thermal runaway or other plausible mechanisms.