Deep focus earthquakes and slab-like structure beneath Northeast China and surrounding regions

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Earthquakes with hypocentral depth >60 km are generally observed only in areas of subduction zone. Northeast China is one of good places for studying deep-focus earthquakes and subducting slabs. The deep seismicity forms narrow, inclined Wadati-Benioff zones which sometimes are continuous throughout the upper mantle and outline the shape of subducting slabs. Consequently, the deep seismicity zones also correlate well with the subducting slabs, as shown in regional/global tomography studies. Two issues are included in this proposition: namely, the mechanisms of deep-focus earthquake and the fate of subducted slab. Note that both of the included issues are debated topics. Three major hypotheses suggested for the mechanism of earthquakes are brittle shear failure in the subducting slab, polymorphic phase transformations, and sudden minerals transformation. The fate of slab whether or not it subducted into the lower mantle remains uncertain. So the relationship between shapes of subduction slabs and deep-focus seismicity zones is not a simple link to each other as mentioned above.

The relationship between slab shape and deep-focus seismicity is variously dependent on several physical mechanisms producing seismicity within Wadati-Benioff zones. Two items are required for earthquake activity, a source of stress and a material undergoing unstable strain localization. In the western Pacific, a reasonable relationship between the slabs and seismicity zones is provided through slab buckling by Myhill study (2013). This mechanical model of deep-focus earthquakes is based on slab buckling. Apperson and Frohlich (1987) supposed that the majority of deep-focus earthquake physical mechanisms are not explained by slab shape in any simple way due to the uncertain role of slab morphology. Another physical mechanism is volume changes within subducting slabs, which providing an alternative to stresses associated with deep-focus seismicity. Inside or around the subducted oceanic lithosphere, that olivine phase transformation has been considered as volumetric reduction, which caused deep-focus earthquake.

Both slab buckling and volume change can explain well the clustering of deep-focus earthquakes observed in depth distributions within subduction zone. Note there is a lack of intense seismicity in the mantle transition zone beneath the Changbaishan volcanic site where oceanic lithosphere was observed by several tomographic studies. Neither slab buckling or volume change can interpret this possible gap in earthquake prone area beneath Changbaishan volcanic site.

In Northeast China area, we derived a 3D P and S velocity model to 800 km depth using P and S joint inversion method. The data used here were recorded by a temporary deployment as well as the permanent stations coexisted during the same period. We constrain an integrated model based on previous and this study, and thus give a possible explanation for few deep-focus seismicities occurring within the subducted oceanic lithosphere and surrounding area beneath Changbaishan volcanic site.

The main conclusions are: 1) not all of the deep-focus seismicities occurred in high-V anomaly zones because of the different physical mechanisms of deep earthquake. 2) A part of the deep-focus seismicities were due to the brittle shear failure in the subducting slab while other part of the deep-focus seismicities stemmed from volume change. 3) The piled up small slab block zones seem to be broader than the known deep seismicity zone because of the horizontal flow.

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