Rheology and earthquakes in subduction zones

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A quarter of a century passed since S. Uyeda coined an attractive word, comparative subductology, around 1980 and discussed the origin of the diversity of subduction zones. But still there is no consensus about the origin of this diversity. OD21will start soon and drilling into seismogenic zone is going to be one of the key issues. Existing models will be reviewed critically for comprehensive understanding of subduction-zone seismicity.

Uyeda postulated that the movement of the overriding plate relative to trench is the critical factor. However, irrespective of the movement of the overriding plate, two plates move relative to the other under lithostatic pressure along a cold subducting plate boundary and nearly aseismic behavior of some subduction zones cannot be explained. Shimamoto (1985) discussed rheology and seismicity in subduction zones based on (1) thermal structure, (2) brittle to fully plastic transition, (3) solution-transfer processes promoted by the enormous amount of released H2O that tends to eliminate earthquakes, (4) effects of phyllosilicates such as clay minerals contained in sediments, and (5) effects of dehydration reactions on fault behavior.

Shimamoto, Seno & Uyeda (1992) then simplified the model by taking only (1) to (3) into account and assumed that the lower bound of seismic behavior is determined by temperature and that plate interface in the upper 30 km in depth is aseismic due to (3). Their simple model could predict the diversity of subduction zones by demonstrating a linear relationship between moment magnitude (Mw) of typical earthquakes and the logarithm of the width of the seismogenic zone (w).

Shimamoto/Seno/Uyeda model appeared to have demonstrated the diversity of subduction zone based on the geothermal structures and presence of H2O. However, Hyndman & Wang (1993) revealed that earthquakes begin to occur at much shallower depth than postulated by Shimamoto et al. and proposed that the onset of seismicity corresponds to the montmorillonite-illite transition. Their data are convincing, but nearly aseismic behavior of some subduction zones cannot be explained if this model applies to all subduction zones. Recently, J. Kasahara proposed that the wedge mantle behind Mariana is serpentinized and that the upper aseismic-seismic transition is controlled by the low-temperature to high-temperature serpentine that takes place at around 290 degrees Centigrades. The expected depth for this transition is about 30 km, and hence Kasahara's model, combined with the analysis by Shimamoto et al., offers an alternative model to the nearly aseismic behavior of Mariana.

I will show that a synthesis of the models of Hyndman and Wang and of Kasahara, combined with the assumption on the lower bound of seismicity by Shimamoto et al., leads to a quite similar relationship between Mw and log w as that determined by

Shimamoto et al. This new model is a temperature-material model, rather than the temperature-H2O or temperature-pressure solution model. It is now unclear how much fluids affect the seismicity in subduction zones. Moreover, experimental basis for the temperature-material model is not perfectly clear and future tasks will be summarized in the presentation.