Constraint on the yield strength envelope of subducting oceanic plate from stress neutral surface depth and bending moment

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1. Introduction

Many previous studies attempted to estimate the yield strength envelope (brittle strength and ductile flow law) of the oceanic plate from flexural topography and gravity anomalies in outer rise [e.g., Goetze and Evans, 1979; Hunter and Watts, 2016]. Their approaches can constrain the bending moment, which reflects depth-integrated yield strength envelope. Estimated bending moments of world outer rise are consistent with the standard yield strength envelope estimated from rock experiments [Hunter and Watts, 2016].

In addition, recent seismic studies succeeded to constrain stress neutral surface depth (SNSD) in the oceanic plate around the trench and double seismic zone in intermediate depth slab, in few km of precision. The SNSD reflects relative strength between shallower-half brittle part and deeper-half ductile part, while bending moment reflects integrated absolute strength. Thus, combining these two independent observed parameters enables us to constrain the yield strength envelope in more detail, which will contribute to understand rheology, magnitude of stress, and pore-fluid pressure in the oceanic plate and slab.

This study attempted to constrain the yield strength envelope of the oceanic plate around outer rise and intermediate depth slab from observed SNSD and bending moment. The target is the Pacific plate subducting from the Japan Trench and the Kuril Trench.

2. Bending moment

We estimated the bending moment at the outer rise from topography and gravity anomalies following the study of Hunter and Watts [2016]. In addition to their study, we considered the effect of thermal stress on estimating the bending moment. We estimated the bending moment of subducting, intermediate depth slab from gravity anomalies [Sasajima and Ito, 2016, *SSJ fall-meeting*] and corner flow stress in the mantle wedge.

3. Stress neutral surface depth (SNSD)

We used observed SNSD around the Japan Trench that is 30-35 km from the plate upper surface based on Hino *et al*. [2009] and Obana *et al*. [2012]. We used observed SNSDs of intermediate-depth double seismic zone that are 22 km from the slab upper surface under the Tohoku region, and 10 km from the slab upper surface under the Hokkaido region based on Kita *et al*. [2010b].

4. Modeling stress evolution in subducting oceanic plate

In order to connect observed SNSDs and the bending moment to the yield strength envelope, we conducted a model simulation of stress evolution of the oceanic plate. The model describes differential stress of 1D column of the oceanic plate in the Lagrangian description by time integral of elastic stress changing, brittle stress release, and ductile stress relaxation.

The factors controlling SNSD are (1) brittle strength, (2) ductile flow law, (3) thermal structure, and (4) net-horizontal force. We tested to change them within conceivable range and compared the resulting modeled SNSD and bending moment with observed them.

5. Results
Observed SNSD (30-35 km) and bending moment around the trench are explained by standard ductile flow law with moderate pore-fluid pressure for brittle strength. On the other hand, observed SNSD (22 km) at intermediate depth under the Tohoku region requires further higher pore-fluid pressure than around the trench. This is because the compressional brittle strength in the intermediate depth without high pore-fluid pressure is extremely strong and it shifts the SNSD to too shallow. This high pore-fluid pressure in the intermediate depth slab is consistent with many previous studies. On the other hand, much shallower SNSD (10 km) at intermediate depth under the Hokkaido region may be caused by both of relatively low pore-fluid pressure than Tohoku region [Shiina *et al.*, 2017] and extensional net-horizontal force [Kita *et al.*, 2010b].

Keywords: Stress neutral surface depth, Yield strength envelope

