Transition of stress state of the oceanic lithosphere from shallower-half compression to shallower-half extension in outer rise

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1. Introduction
Recent studies revealed that hydration progresses in shallower part of the oceanic lithosphere from outer rise to the trench (within 100-200 km from the trench) [e.g., Contreras-Reyes *et al.*, 2008, *JGR;* Fujie *et al*., 2013, *GRL*]. In addition, high and variable heat anomalies were found in outer rise (within 150 km from the trench) [Yamano *et al.*, 2014, *EPSL*]. These studies proposed that these phenomena are caused by water infiltration and circulation due to bending-related normal faulting and fracturing. The initiation and development of bending-related faulting depends on stress evolution of the oceanic lithosphere in outer rise. In addition, the stress state may control the easiness of the water infiltration. Thus, understanding the stress evolution of the oceanic lithosphere in outer rise will give us useful clues to clear the mechanism of these phenomena.

2. Origin of lithospheric stress
Stress in the oceanic lithosphere has history since it was generated at the oceanic ridge. Thermal stress due to cooling of the oceanic lithosphere is the main origin of stress in the oceanic lithosphere where is far away from the trench. Its stress state is characterized by shallower-half compression and deeper-half extension, and it well explains focal mechanism and seismicity rate of oceanic intraplate earthquakes [Sasajima and Ito, 2015, *SSJ fall-meeting*].
On the other hand, bending stress due to flexure in outer rise is shallower-half extension and deeper-half compression. Thus, transition of the stress state may occur around outer rise. In this study, we focus on this stress transition.

3. Simulating stress evolution
In order to clear the stress transition in outer rise, we modeled stress evolution of the oceanic lithosphere in the Lagrangian description since it was generated at the oceanic ridge. The target of this study is the Pacific plate around the Japan Trench (120-130 Ma). The model describes differential stress of 1D column of the oceanic lithosphere by time integration of elastic stress generation, brittle stress release, and ductile stress relaxation. Dominant components of elastic stress generation are thermal stress in young age and bending stress in outer rise.

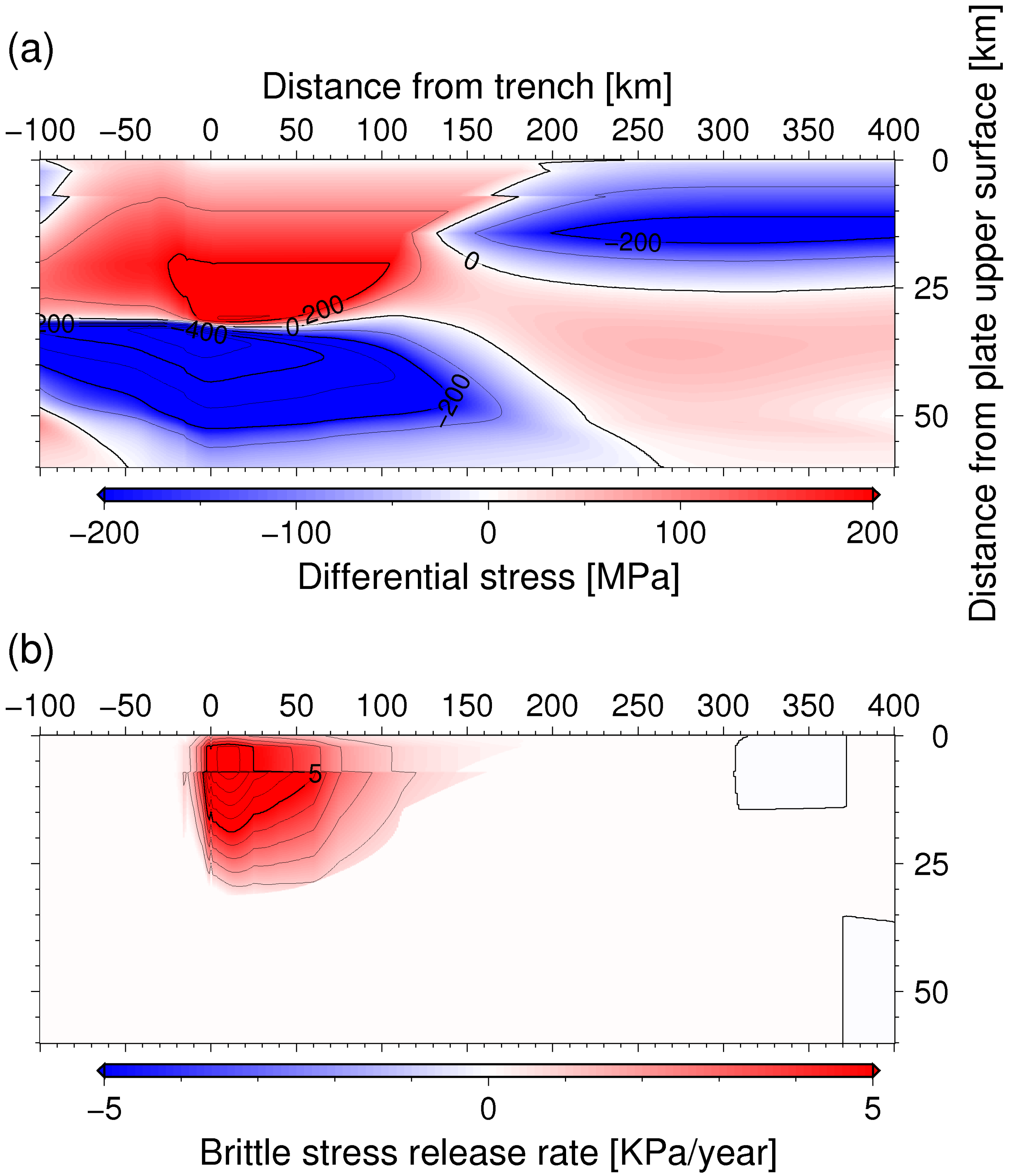
4. Results
Figure 1 (a) shows cross-section of modeled stress evolution of the oceanic lithosphere around the outer rise. Until the oceanic lithosphere reaches to 200 km from the trench, shallower-half stress state is compression due to residual thermal stress. The transition from compression to extension occurs during 125-175 km from the trench. The transition initiates at the shallower-most portion, and it expands to deeper portion. Figure 1 (b) shows modeled brittle stress release rates. Although bending deformation initiated at about 300 km from the trench, no normal faulting is expected during 175-300 km from the trench because of residual compressional stress. Thus, the thermal stress delays initiation of bending-related normal faulting.

5. Discussion

The horizontal location of the stress transition from compression to extension (125-175 km from trench) is consistent with the offshore-end (i.e., initiation) of observed hydration and heat-flow anomalies. It corresponds to the initiation of bending-related normal faulting, which may cause the water infiltration into the oceanic lithosphere. In addition, the stress transition from compression to extension likely promotes the water infiltration. Thus, we propose that the residual thermal stress is also important factor to control these phenomena in addition to the bending stress.

Figure 1. Cross section of the oceanic lithosphere. Horizontal axis indicates distance from the trench along the plate upper surface. The right side of figures is offshore. Vertical axis indicates distance from the plate upper surface along the depth direction. (a) Modeled differential stress (extension is positive (red)). (b) Modeled brittle stress release rates (normal faulting is positive (red)).

Keywords: Oceanic lithosphere, Thermal stress, Bending stress, Outer rise


(a)
Distance from trench [km]
−100 −50 0 50 100 150 200 250 300 350 400
0
25
50
Distance from plate upper surface [km]
−200
0
−400
0
200
−200
200
−200 −100 0 100 200
Differential stress [MPa]
(b)
−100 −50 0 50 100 150 200 250 300 350 400
0
25
50
5
−5 0 5
Brittle stress release rate [KPa/year]