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Shear stress distributions of a subduction zone as inferred from elastic plate models

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It is important to understand shear stress and fracture strength of a sesismogenic zone for the study of a seismogenesis mechanism. Shear stress characterisics of elastic oceanic and continental plates near a subduction zone are investigated using 2D finte element method in the case of plane strain. The present elastic plate model UMB-Plate (Figure) is composed of oceamic plate (Plate 1), continental plate (Plate 2), upper mantle (LMS), and two transitional layers, a plate boundary (PB) layer between Plate 1 and Plate 2 and an upper mantle boundary (UMB) layer between LMS and Plate 1. The two transitional layers correspond to low viscosity layers.

The Young's modulai (E) and Poisson's ratios (p) for Plate 1, Plate 2, and LMS are adopted from those used in the study of earthquake cycle simulation in Southwest Japan (Hori, et al., 2004). The Young's modulus is calculated from the rigidity (G) using the formula E=2(1+p)G (Tokawa, 1980). Young's modulus of mild steel of rubber-like-elasticity (Rikagakuziten, 1988) and Poisson's ratio of elastic rubber (Rika nenpyo, 2002) are used for those of PB and UMB. The size of the model is 625 and 325 mm in x- and y-directions, respectively, the thickness being 2 mm. The lengths enlarged to 200,000 times are ahown in the figure. A horizontal compressive force of 1.4 ton corresponding to a ridge push force of 4.7 MPa is applied to the left side of Plate 1. The right side of Plate 2 is fixed. The right side of Plate 1 is firstly assumed to be stress free. The dip angle of the subducting oceanic plate (Plate 1) is 10 deg. at shallow parts between sites C and I and 27 dig. at deeper parts between sites I and X. Site I corresponds to a convergent boundary.

The shear stresses calculated for UMB-Plate show that they are positive as a whole for Plate 2 above PB and are mostly negative for Plate 1. A positive shear stress zone exists in the inner part of Plate 1 at depths of 10-30 km beneath site C. The region showing a maximum shear stress of 1.095 MPa is located at edge of Plate 2 near site I. High shear stress zones are distributed at the thrust zone in Plate 2 above PB at depths less than 30 km. The region showing a minimum shear stress of -2.8x10E-06 MPa is located at a lower part of UMB near at a depth of 55 km. Mises stress defined by shear strain energy, which is one of the yield criterion (Kikuchi and Wada, 2004), is also highest at the left side of Plate 2 beneath site I, with a maximum stress of 19.25 MPa.

The elastic model UMB-Plate does not specify any particular region in Japanese island arc. However, the thickness 30 km and length 60 km of the oceanic plate is rather close to the vertical section of the crust and upper mantle in the Tokai district, Southwest Japan. If the slab is short the earthquake mechanism in the slab is likely to show a normal fault in the negative shear stress field and the thrust zone is characterized by a low-angle reverse fault in the positive shear stress field (Seno. 2001). The shear stress distributions calculated seem to be in harmony with the stress field mentioned above.

The effects of negative buoyancy which corresponds to a slab pull force were examined. If the downward pull force is applied to the right side of Plate 1, the area showing a positive shear stress increases inside the subducting Plate 1, while the area showing a negative shear stress increases inside Plate 2.

Figure. Configulation of elastic plate model UMB-Plate and elastic constants of media.

Keywords: Shear stress, Subduction zone, Elastic plate model, 2D FEM

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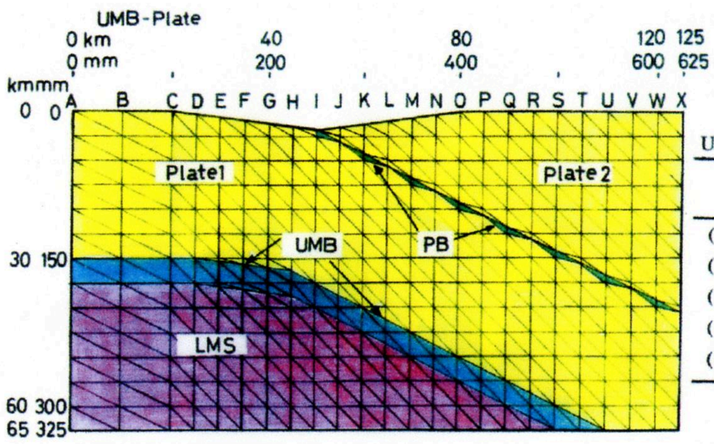

UMB-Plate

No.		Young's Modulus [MPa]	Poisson's ratio
(1)	Plate 1	$1.65 * 10^5$	0.25
(2)	Plate 2	$1.65 * 10^5$	0.25
(3)	PB	1.65	0.46
(4)	UMB	1.65	0.46
(5)	LMS	$1.708 * 10^5$	0.298