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A Question to the Back-slip Analysis (Locked Zone in Tokai, Japan)

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The Back-slip analysis, originally developed by Savage(1983), and named by Matsuura and Sato(1989) has been widely accepted as an effective way to evaluate a seismogenic area of an anticipated earthquake along the subduction zone. However, there is a fundamental problem in this analysis, which is apt to mislead to a wrong understanding. We intend to clarify the point here by introducing a practical example.

In the Tokai area, several back-slip analyses are carried out, which brought out two types of results; One is given by Ochi et al.(2005), and also by Yoshioka et al.(1993), while the other by Kimata et al.(2004), and also by Sagiya(1999). The former presented a result assigning the locked region almost inside the land area. On the other hand, the latter presented a result assigning it in the ocean area. The difference between them is attributed to the utilized data; the former put a weight on the vertical component, and the latter on the horizontal one. Eventually, there happenned a definite deviation of dislocation in the results derived from the back-slip analysis. Here, we tried to execute a model experiment in order to simulate such a situation.

First, we constructed a finite-element-method (FEM) model presenting a locked subduction, where dragging forces are loaded on a locked segment at the bottom of the prism-like block. Then, the ground surface displacements are computed for the vertical and the horizontal components, respectively. Next, the back-slip analysis is executed by regarding the obtained displacements as input data. The results are shown in the attached figure. The left figures are for the vertical components, and the right ones for the horizontal. X, and Y are displacement distributions obtained from the FEM method. Boxes and triangles are results from the back-slip fitting. Bars indicate the range of the input data, which was selected to match the practical observation conditions. The final results of the dislocations distributed on the plate boundary are shown in the bottom figures. For the vertical component, the dislocations distribute around the locked segment (open arrows). On the other hand, for the horizontal component, they distribute rather around the shallower side, approaching the trough axis. Thus, this model well simulate the deciation of dislocations above introduced.

Such a contradiction is caused from the situation that the up-dip part of the prism-like block is moved together with the subducted slab. It is likely to be thought that application of the dislocation model is inadequate only for the locked subduction. However, strictly speaking, application of the dislocation model is generally inadequate for all the cases of the locked sliding. The contradicting points are summarized as follows.

(A) On the extended line of the locked segment, there should exist no shear stress. In contradiction to this, there appear shear stresses along these lines in the dislocation model. (B) The locking range is limited only within the locked segments. However, the analyzed dislocations distribute extended over this segment, that is, exudation of dislocation. (C) At a co-seismic event, we can observe a perturbation of stress field between before and after the dislocating failure. For such a case, the dislocation model is exactly applicable. On the other hand, in an inter-seismic case, we cannot discriminate two types of stress fields, a perturbation due to back-slipping, and increment of the background stress, the latter of which cannot be represented by the dislocation model. As a result, the back-slip analysis is essentially inapplicable for the inter-seismic situation.

These contradictions will be attributed to an identical cause. Replying to the claim appealed by Douglass and Buffett (1995), Savage (1996) explained that the analysis is just an approximation. We consider that exudation of dislocation due to approximation is allowable, but deviation of dislocation is never neglectable.