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An application of multiple inverse method to ancient accretionary complex: Example from Mugi melange, the Cretaceous Shimanto Belt

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The multiple inverse method (Yamaji, 2000) was applied to the Mugi melange in the Cretaceous Shimanto Belt for meso-scale fault analysis. As the result, several kinds of stress fields were obtained. The maximum compressive principal stress axes (sigma_1) of them are commonly directed normal to bedding plane. These stress fields appear to have occurred during accreting (underplating) or rising to be exhumed. A more research is needed to determine the order of them or understand the deformation history of tectonic melange.

The Shimanto Belt is an ancient accretionary complex formed at the trench. The Mugi melange, which is placed on the eastern coast of the Shikoku Island, is a mixture of upper Cretaceous turbidites of terrigenous origin, pelagic sediments and pillow basalts. A duplex structure is recently identified bounded by thrusts there (Ikesawa et al, 2002). Bedding planes trend ENE-WSW to E-W and dip steeply northward. The Mugi melange was undergone heavy shear deformations, and primary flow structures have been researched in detail (Onishi & Kimura, 1995, etc.) On the other hand, this study focuses on secondary faults and estimates tectonic stress fields for the purpose of understanding the deformation history of the melange.

Directions of principal stress axes and stress ratio (phi = (sigma_2-sigma_3)/(sigma_1-sigma_3)) were estimated by using the classical inverse method (Angelier, 1979, 1984). In the method, an optimal averaged stress field is fitted to a fault slip data set by computation. Meanwhile, the multiple inverse method (Yamaji, 2000) was developed to distinguish plural stress fields from heterogeneous fault slip data. In it, the classical inverse method is applied to all possible subsets extracted from a fault slip data set. If plural clusters of principal stress axes are obtained, plural stress fields are gained as the modes of clusters. Numerous faults were observed in the Mugi melange, including out-of-sequence thrusts, in-sequence thrusts, lateral faults, and normal faults of various attitudes. Therefore, the existence of plural stress fields are indicated, so the multiple inverse method appears useful.

Consequently, some reduced (lacking in information about magnitudes of stress) stress tensors were identified from faults in the Mugi melange. They were (1) N-S trending (normal to bedding plane) axial compression, which was obtained most clearly, (2) triaxial stress with N-S trending sigma_1 and E-W trending sigma_3, (3) triaxial stress with similar sigma_1 and vertical sigma_3, (4) E-W trending axial extension, and (5) steeply plunging axial extension. (1)-(2)-(4) and (1)-(3)-(5) are associated solutions (defined by Yamaji, 1999), which share directions of principal stress axes. Based on crosscut relationships and conjugate faults, it was deduced that the triaxial stresses, the axial compression, and axial extension occurred in this order. However, the result of the multiple inverse method does not positively assert the existence of obtained stress fields, but it merely suggests that these stress fields can explain some parts of fault slip data. Then there are possibly several interpretations of the solutions. In this study, it is proved that the fault slip data in the melange can not be explained by one stress field, and the maximum compressive principal stress axis was directed normal to bedding plane through the history of brittle deformation. This tendency of sigma_1 is consistent with the shortening direction caused by plate convergence after the rotation of beds as the formation of duplex structure. It is necessary to confirm the existence of stress fields and to determine the order of them according to other independent proofs.