Buckling folds of a single viscous layer and possibility of inversion analysis of regional stress field

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The Sambagawa belt, southwest Japan, is a high P/T metamorphic belt that is thought to be related to subduction. Deformation characterized by extreme layer normal thining and nearly arc-parallel stretching, occurred during exhumation in Late Cretaceous. To understand this exhumation process, many studies have been carried out concerning deformation history in the Sambagawa region. Deformation phase in the Sambagawa region is roughly classified into three stages, called D1, D2, D3 (e.g Faure 1983), based on analysis of regional distribution of fold and lineation. To limit the exhumation process, analysis of quartz LPO pattern and distribution of mineral stretching lineation have been carried out (e.g., Takeshita & Yagi, 2004). However, the overall deformation of the metamorphic belt such as those represented by fold, fault and lineation systems on regional scale, are the results that various deformation phase overlapped. It is thought that indicators such as LPO and SPO recorded information of a certain stage, from which it would be difficult to recover the entire subduction-exhumation deformation process. Also the relationship between the observed microstructures and the stress / deformation velocity field is poorly understood at present, it is difficult to estimate past stress field quantitatively. Therefore, the details of exhumation process remain unsolved.

In this study, we focus on buckling folds as strain indicator, which appears on outcrop scales, for example, fold of quartz vein. Since this type of fold is primarily controlled by regional stress field and viscosity contrast between folding layer and its enclosing medium, the modeling can be done in a straightforward manner with a few uncertainties. In addition, since competent layer such as a quartz vein was considered to be flat at the initial stage, its waveform should record finite deformation that reflects the whole exhumation process. To understand how fold waveform varies during exhumation process, we start from forward modeling of high amplitude folding.

A theory for folding in case of a small deformation was presented in 1960's by Biot and Ramberg, which clarifies that viscosity contrast determines dominant wavelength of fold wave pattern (e.g., Biot, 1961). Afterwards, numerical simulation of folding with finite amplitude has been performed, and the behavior of folding for different viscosity contrast was examined (e.g Cruikshank&Johnson 1993). However, behavior of folding for different stress field has not been examined systematically.

In this study, we analyze high-amplitude folding of a single viscous layer embedded in a less viscous medium using a finite element method. The constitutent substances are assumed to be isotropic and nearly incompressible, and the effect of gravity is ignored. We examine the fold wave pattern for various stress field, rock rheology, viscosity contrast, and finally discuss possibility of inversion analysis of the regional stress field.