High- and low-stress subduction zones recognized in the rock record

*Kazuhiko Ishii[1], Simon Richard Wallis[2]

1. Department of Physical Science, Graduate School of Sciences, Osaka Prefecture University, 2. Department of Earth and Planetary Science, Faculty of Science, The University of Tokyo

Knowledge of the frictional strength along subduction plate boundaries is an essential part of understanding the conditions necessary for plate tectonics, the processes leading to great earthquakes occur along subduction megathrusts and the thermal structure of subduction zones. The frictional strength of faults increases with depth until ductile deformation becomes dominant and is usually expressed as the ratio of shear to normal stress known as the coefficient of friction, mu or the apparent coefficient, mu', when the effects of fluid pressure are taken into account. Lamb (2006) uses force balance for forearc domains to infer mu' = 0.03-0.09 along subduction boundaries. Gao and Wang (2014) infer mu' = 0.02-0.13 based on the comparison between heat flow data and numerical modeling, while England (2018) estimates relatively uniform values mu' = 0.05-0.07 from analytical modeling of heat flow data. In addition, a global 3D thermo-mechanical model presented by Osei Tutu et al. (2018) suggests the average mu' along plate boundaries is required to be <= 0.05 to match the observed present-day plate motion and net rotation.

The published estimates of mu' for subduction boundaries are significantly lower than Byerlee's Law (mu' ~ 0.4, assuming hydrostatic fluid pressure) and closer to values published for seismic slip rates with mu' ~ 0.1 (Di Toro et al., 2011). However, estimates for different subduction zones or obtained by different methods show variations over an order of magnitude. It is desirable to obtain direct estimates of shear stresses from ancient subduction zones both as an independent test of the suggested values and because if high- and low-stress subduction zones can be identified in the ancient record then observations of the associated geology can help identify those characteristics that are responsible for differences in shear strength along subduction zone boundaries.

Thermal modelling shows that high- and low-stress subduction zones can potentially be recognized in the ancient record based on the shape of the prograde P-T path in the forearc region. For all but very young and very slowly subducting slabs, high-stress subduction can be distinguished by curved P–T paths with higher P/T gradients at greater depths. Low-stress subduction over the same domain results in straight paths.

The Cretaceous Sanbagawa belt of SW Japan records metamorphism developed as a result of rapid (20-24 cm/yr) subduction of the Izanagi plate with a slab age of around 60 Ma. The prograde P-T paths show the characteristics predicted for high-stress subduction. Comparisons with thermal modelling suggest an apparent coefficient of friction, mu', of > 0.11, and the corresponding peak shear stresses are ~60 MPa.

Prograde P–T paths and geochronological information from high grade blocks of the Franciscan Complex, USA, indicate rapid cooling during the initial 10-20 Myr subduction with low mu' <= 0.02.

P–T paths in subduction-type metamorphic belts have the potential to be used as paleo stress indicators. Examining differences between high- and low-stress subduction-type metamorphic belts can help determine what controls the strength of different subduction boundaries and assess the potential for

great earthquakes in modern settings.

Keywords: High pressure metamorphic rocks, Stress along subduction boundaries, Sanbagawa belt,
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