Tectonic stress fields in subduction zones: Basic concept

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In subduction zones, one (oceanic) plate moves under another (oceanic or continental) plate against some frictional resistance and descends into the earth's mantle. Long-term deformation of the overriding plates varies from mountain building to back-arc spreading, whereas the descending oceanic plates are only bent convex upward. The patterns of long-term deformation are generally considered to be the reflection of background tectonic stress fields. In the case of subduction zones, not only frictional resistance at plate interfaces but also steady subduction of oceanic plates itself cause the tectonic stress fields. The frictional resistance fluctuates with the occurrence of large interplate earthquakes, but it can be regarded as constant on a geological timescale. So, the stress field due to frictional resistance is constant in time, and its pattern is basically compressional in the direction of plate convergence. On the other hand, the steady plate subduction brings about convex upward bending of both the overriding and descending plates at a constant rate by the effect of gravity (Fukahata and Matsu'ura, GJI, 2016). So, the rates of stress increase due to steady plate subduction is constant in time, and its pattern is basically tensile (compressional) in the upper (lower) half of plates in the direction of plate convergence. To evaluate the first type of stress field, we need to know the present distribution of frictional strength along plate interfaces, which will strongly depend on fault-confined fluid pressure. To evaluate the second type of stress field, we need to know the past history of plate subduction and the rheological property of the earth's lithosphere, which will control the rate of inelastic deformation (brittle fracture and/or plastic flow) to release the tectonic stress caused by mechanical interaction at plate interfaces. However, all of these problems are very difficult to directly solve except one specific case; the stress fields of oceanic plates produced by steady plate subduction. In this case, the oceanic plate passes through the plate-to-plate interaction zone within a limited time (1-2 Myr), and so we need not to consider the whole past history of plate subduction. Furthermore, the rheological property of oceanic plates is much simpler than the overriding plates. Using the evaluated stress field of an oceanic plate as a reference, we can determine the frictional strength distribution along a plate interface so as to reproduce the spatial pattern of stress tensor orientation at and below the plate interface, estimated from observed focal mechanism data of seismic events (Terakawa & Matsu'ura, Tectonics, 2010). In this way, we finally got a starting point to reveal the tectonic stress field and inelastic deformation of the overriding plate.

Keywords: Tectonic stress fields, Steady plate subduction, Steady frictional resistance at plate interfaces, Descending oceanic plates