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Distributed deformation along the subduction plate interface: insights from fossil examples and mechanical implications

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Many recent geophysical and geodetic observations in subduction zones have unraveled the diversity of the deformation of the plate interface. Such mechanical complexity is commonly interpreted in the framework of friction mechanics, from experimental and theoretical approaches based on rate-and-state friction laws. Alternately, the deformation along the plate interface can be studied using naturally-deformed structures in fossil subduction zones. We will show in this work the results obtained in the Shimanto Belt in Japan, the fossil equivalent to the deep domains of the modern margin, the Nankai accretionary prism. In particular, we focused on domains of the Shimanto Belt considered as tectonic mélanges, which concentrated a large proportion of the strain resulting from plate differential motion. Several tectonic slivers of mélanges, emplaced at different periods, are intercalated with units where deformation is less intense and where the original sedimentary layering is preserved. In contrast, mélanges have a block-in-matrix structure, where cm- to tens-of-meter scale lenses, constituted of sandstone or basalt, are embedded in a shale matrix. Mélanges are pervasively deformed, with the development of a phyllosilicate-rich foliation and the preferential flattening of the lenses parallel to the foliation. Furthermore, mélanges incorporate a dense network of quartz veins and quartz-filled shear bands, with a consistent direction of motion. At the thin-section scale, the elementary processes governing deformation within the mélanges involve a combination of fracturing, dissolution and precipitation to form quartz veins, along with slip on a network of μm- to mm-scale phyllosilicate-rich shear bands. At the larger scale of the whole tectonic mélange units, the shear bands can be interpreted as a top-to-the-trench shear along the subduction plate interface, at temperatures in the range 150-250°C, typically of the order of the seismogenic zone. Consequently, mélange units can be considered as large shear zones that accommodated at depth the plate differential motion over their whole thickness. Such type of large shear zones, where the strain is distributed over a thickness of at least tens of meters, contrasts with narrow faults or pseudotachylytes, where strain is localized over a few centimeters. While the localized endmember of deformation is well accounted for by friction laws, the distributed endmember of deformation is not, although it constitutes an appropriate candidate for domains of the plate interface where deformation is aseismic. To describe the whole range of the deformation modes occurring along the plate interface, more complete models should therefore incorporate a larger variety of elementary deformation processes, in particular pressure solution, as able to accommodate the strain.