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Process of strain buildup and release in subduction orogens

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Among a wide variety of subduction orogens in the world, one extreme is the Mariana type, which is characterized by strong extension in the back-arc region. The other extreme is the cordilleran type, which is characterized by strong contraction. A cordilleran type orogen has a fold-and-thrust belt on its back-arc side, which causes crustal thickening and resultant mountain building.

In some orogenic belts, changes in tectonic styles from one extreme to the other are known to have occurred. One example is the Northern Rocky Mountains and present-day Basin and Range Province, which have changed from a thrust-and-fold belt to a highly extensional rift zone. Another example is the Northeast Japan arc, which was a Mariana type orogen in Early-Middle Miocene time. After ˜10 Myr of tectonic quiescence, it has become strongly compressive since Pliocene time. As a result, the Uetu-Northern Fossa Magna basin on the back-arc side of the arc has changed from a rift basin to a fold-and-thrust belt.

Cordilleran type orogens are particularly interesting in terms of strain buildup and release, because known gigantic earthquake ruptures of magnitude larger than Mw 9 are likely to have occurred in, or at least started from within, cordilleran type subuction zones. In Geodetic observations in the last ˜100 years have revealed that the Northeast Japan arc has contracted horizontally at a rate as high as several tens mm/yr, which value is comparable to the rate of plate convergence (˜90 mm/yr) at the Japan Trench. On the other hand, geologically observed shortening rates are one order of magnitude lower than the geodetic rates. Discrepancy between long-term and short-term crustal deformation exists also in vertical movements. Tide gauge records indicated that the Pacific coasts of Northeast Japan have been subsiding at a rate as high as ˜10 mm/yr during the last ˜80 years, whereas geologic data indicate slow uplift (0.1-0.4 mm/yr). These indicate that most of the strain that has accumulated in the past ˜100 years is elastic, and should be released in association with subduction earthquakes at the Japan Trench; only a fraction (less than 10%) of plate convergence is accommodated within the arc as permanent deformation. However, significant strain release has not occurred in association with earthquakes of Mw 7-8 that occurred in the past ˜100 years; instead, some of them caused additional subsidence. Thus, elastic strain in the arc should be released by gigantic (Mw 9 or larger) decoupling events with deeper and wider rupture areas on the plate interface.