Why giant earthquakes occur at subduction zones with well-developed accretionary prism?

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An accretionary prism is a wedge-shaped mass consolidated from pelagic sediment, oceanic-floor basalt, and trench-fill turbidite, scraped off the down going plate and accreted to overriding plate during the subducting process. Thus, unless amount of sediment that can subduct with the plate increases drastically, a prism develops more when larger amount of incoming sediment is supplied. For such a well-developed accretionary prism with thick incoming sediment, it is observed in subduction zones that the slope of the prism decreases during the formation process. This phenomenon has been explained in text books of geology or structural geology with 'the decrease of friction along the plate boundary' based on the critical taper theory, which is a strange theory but is believed by most of the researchers in this field. However, if friction along the plate boundary decreases due to the development of accretionary prism, subduction becomes smoother and less strain energy is stored along the plate boundary or within the prism. Then no great earthquake occurs in subduction zones with well-developed accretionary prism. This is, of course, a wrong conclusion inconsistent with observational facts.

This wrong conclusion is due to the assumption in the critical taper theory that an accretionary prism is a block of constant strength. In fact, an accretionary prism is an elastoplastic material whose density and strength spontaneously change with repeating rupture and consolidation in it.

To begin with, upward movement against the gravity is necessary for flat sediment to form a wedge-shaped prism. The driving force of the upward movement is mainly reverse faulting cased by horizontal movement of plate. If the reverse faulting frequently occurs all over accreted sediment, a prism with high slope angle can be formed. On the other hand, if incoming sediment is thick or accreted sediment becomes large, the sediment is consolidated by self-gravity. Then, because of the increase in density, it becomes difficult to occur upward movement due to reverse faulting. During the suppression of reverse faulting, the accreted sediment is continuously compressed by tectonic force in subduction direction and becomes more consolidated. In reality, besides such mechanical compression and consolidation, chemical consolidation also proceeds: particles in sediment are melted and pores between remained particles are effectively filled up. Thus sediment becomes sediment rock with high strength. In this process, decrease in friction of plate boundary is not necessary to occur at all.

Then, because of the lower occurrence rate of reverse faulting, uplift is suppressed and the slope of plastic prism is kept lower. However, compression and consolidation cannot continue infinitely. Fault slip along the plate boundary or reverse faulting in the accretionary prism occurs at last when tectonic stress reaches the strength of them. Furthermore, in this case fault movement is much more localized than in the case of less-developed prism where fault movement occurs all over. We consider that this is the reason why infrequent great earthquakes occur in the well-developed accretionary prism.

Based on such evolution of accretionary prism with strength variation, we can consistently explain the relation of the observations that have been separately treated, such as occurrence of great earthquakes, b-value in seismicity, reflectivity images of the prism, direction of in-situ principal stress, and so on.

We will report in detail the results of numerical experiments to verify the new original hypothesis mentioned above.