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Conditions for growth of accretionary prism examined using a particle based model

Takane Hori[1]; Hide Sakaguchi[1]

[1] IFREE, JAMSTEC

In order to reveal the conditions for growth of accretionary prism in subduction zones, many studies have been done. For example, the correlation between geometry of prisms and some observables in subduction zones (convergence rate, sediment thickness, material contents, reflectivity image, etc.) are examined. However, it should be difficult to understand the whole growing process of accretionary prism, which takes millions of years, only using observed data at present. Thus we take another approach.

We construct a simple mechanical model for accretionary prism using particle based method and examine the results of numerical simulation, in order to study the growth process of accretionary prism. Although many factors, such as mechanical or chemical effect of fluid, affect the growth process of real accretionary prism in subduction zones, here we treat only a simple mechanical interaction between particles (no bonding, only frictional interaction). Sediment layer is modeled as piled up particles supplied at constant rate in gravitational field. Sediment is set on a horizontal rigid plate moving at a constant speed toward a vertical rigid backstop.

As a result, even such a simple mechanical model shows complex processes in the growth of accretionary prism. Liquidity or mobility of sediment layer should be low when accretionary prism can growth. The geometry of prism is controlled how sediment obtain kinetic energy moving upward under horizontal movement condition given by plate convergence. We will explain how mobility of sediment layer affects the growth and geometry of accritionary prism. In our simulation, we compare the cases in which only the sediment supply rate is different.

When the supply rate is low, amount of sediment (number of particles) is low and sediment layer is less compacted. In the less compacted sediment, normal force (thus frictional force) acting between particles is low and particles can move easily. Thus, mobility of sediment layer is high. In this case, sediment near the bottom moves with plate in horizontal direction, moves upward along the vertical backstop, and flows downward forming a high angle slope. New supplied sediment layer is totally involved such rotational movement with shear deformation. Thus accretion is difficult to occur. The rotational movement does not continue forever. When the amount of sediment near the backstop becomes large enough, upward movement is decelerated because of both difficulty in upward movement against gravity and less mobility due to higher compaction.

On the other hand, when supply rate is high, the amount of sediment is large from the beginning. Thus sediment layer is less mobility because of higher compaction and upward movement against gravity is difficult. Such undeformable sediment layer is put under shear deformation condition because bottom part is horizontally moved by the plate convergence and one side is stopped the horizontal movement by the backstop. As a result, localized shear deformation (slip) occurs near the bottom of the sediment layer. The upper part of the sediment above the slip plane (so called decollement) is mechanically decoupled from subducting plate and accretion occurs. Thus the low mobility of sediment layer is one of the important conditions for accretion.

Finally, we will discuss the deformation process after accretion. In the accreted sediment layer above the decollement, shear deformation is less dominant but horizontal compression becomes dominant. This compression make the sediment layer more compacted and less mobility. In this condition, upward movement is caused by episodic reverse fault movement in the layer. Thus low taper angle slope can be developed far from the backstop.

We will include more complex mechanical interaction such as bonding between particles and examine deeply the growth process of accretionary prism.