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Development of a thrust fault branching from a plate interface : Its effect on tectonics in Himalaya

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The Himalayas is a tectonically very active region where rapid crustal uplift due to the collision of India and Eurasia is still going on. The present-day convergence rate between the Indian and the Eurasian plates has been estimated as about 50 mm/yr. About 40 % of the total convergence rate are consumed at the collision boundary along the Himalayas by the subduction of the Indian plate beneath the Eurasian plate. The rest of 60 % is consumed by internal deformation of the Eurasian plate.

In the Himalayas the plate interface is associated with a series of under-thrusting branch faults, called the Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and so on. The slip motion along the plate interfaces with these under-thrusting branch faults has caused the long-term crustal deformation in the Himalayas. In general, the geometry of these fault systems prescribe the internal deformation field. An important point is that the geometry of the fault system will be changed because of the internal deformation caused by the fault system itself. Thus, it is necessary to reveal this feedback mechanism to understand the tectonic evolution process of the Himalayas. In this study, we revealed the mechanism which prescribes the geometric evolution of plate interface with an under-thrusting branch fault, and we estimated its effects on the tectonic evolution of the Himalayas.

At first, we constructed a kinematic model for steady subduction of the Indian plate beneath the Eurasian plate on the basis of elastic dislocation theory. The crust and mantle structure is modeled by an elastic surface layer overlying a Maxwellian viscoelastic half-space, and the kinematic interaction between the adjacent plates is represented by the increase in tangential displacement discontinuity (dislocation) across the plate interface.

With this model, we calculated the internal velocity field caused by steady slip on the plate interface with an under-thrusting branch fault to examine how the fault geometry prescribes the internal deformation field.

Next, considering the changes in fault geometry with time caused by internal deformation, we developed a simulation algorithm for the geometric evolution of the fault system. Through numerical simulations we revealed the fundamental properties of geometric evolution of an under-thrusting branch fault. We can find the accelerative increase in dip-angle of the branch fault and also the development of a ramp-and-flat structure on the plate interface around the branching point. Since the branch fault with a steeper dip-angle is harder to consume the horizontal convergence, we may conclude that the increase in dip-angle results in the cessation of slip along the branch fault at last. The shallower the depth of the branching point is, the faster the rate of increase in dip-angle of the branch fault is. It means that the branch fault with a shallow branching point can not produce the large-scale mountain range, because large amount of slip can not be accommodated by the branch fault.

Incorporating the mechanism of the geometric evolution of branch faults into the geological knowledge, we may conclude that there are following two stages in the tectonic evolution of the Himalayas during the last 30 Myr. From 30 Ma to 15 Ma, the MCT with a deep branching point has accommodated large amount of slip and produced very high mountain ranges. From about 10 Ma the MBT with a shallow branching point became active instead of the MCT, and produced middle-class mountain ranges.

We should note that the high mountain ranges produced by the MCT has been rapidly eroded and reduced its altitude with time. Therefore, the remaining important problem to be addressed is how the present Himalayas with peak altitude of 8000 m have been formed. We have solved this problem by simulating geometric evolution of the ramp structure of the plate interface beneath the high Himalayas. But, we do not report the results in this meeting.