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Application of slip-line analysis to the mechanical model of active accretionary wedge

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An active accretionary wedge is formed from sediments accreted continuously at a continental margin by a subducting plate and mechanically characterized by a plane-strain compressive frictional flow throughout its entire volume. Continuous deformation induced by incoming sediments raises the distortional stress eventually leading to an ultimate condition known as a critical state. According to the critical taper theory (Davis et al., JGR, 1983), the angle of wedge increases as the incoming materials are accreted into the wedge until it reaches a critical value where the shear force on the basal detachment is in equilibrium with the basal friction. Under this concept, we applied the plastic slip-line theory for the computation of stress and velocity fields throughout the continuously deforming area of the wedge. For the simplicity, we assumed that the tapered wedge overlying a basal décollement fault is described by a perfectly plastic rheology complying with the Coulomb failure criterion and the associated flow rule. A complete description of soil rheology at the critical state requires the determination of stress tensors and velocity vectors at given points within the deforming region. For the boundary condition of stress, the effective normal and shear tractions on the upper surface of wedge are equal to zero, and thus the maximum principal stress acts parallel to the surface. Considering the two-dimensional plane strain deformation, we numerically obtained the slip-line solution for the mean effective stress with respect to the orientation of the maximum principal stress at each intersection point of the potential (conjugate) slip lines given by the Coulomb criterion. Then the maximum shear stress was calculated using the failure criterion. After the stress solution was yielded, the velocity field was determined by the same procedure using the boundary condition of the velocity of incoming sediments obtained from the velocity of subducting plate. Our result shows that the solution for the simple geometry of accretionary wedge is equivalent to the critical taper solution given by Davis et al. (1983). If a sedimentary formation covers the critical wedge, the stress underneath the formation is reduced to maintain the equilibrium with the basal friction strength. Thus the formation of sediment basin on top of the active accretionary wedge leads to the stress relaxation in the region below the basin. The topography of seafloor plays a crucial role in changing the basal friction along the base fault so that the geometry of the fault might be changed. Our numerical analysis also reveals that the pore pressure within the wedge and the décollement fault has no effect on the accretionary wedge angle.