

Details for Numerical Model Used in Fuller et al.

A coupled mechanical-thermal model, used in previous studies (Willett, 1992; Willett and Pope, 2003) of collisional wedges, was modified to account for features associated with a subduction wedge, such as accretion of a relatively thin sedimentary layer and flexure of two elastic half plates. The subduction process is simulated with a hybrid kinematic-dynamic method in which the subducting slab and mantle of both plates have a prescribed motion, but the crust of the overriding plate is allowed to deformation in response to body forces and boundary velocities. The model has two domains over which solutions are obtained: a mechanical domain extending from the base of the crust to the surface (Fig. DR1a), and a thermal-kinematic domain extending from the upper asthenosphere to the surface (Fig. DR1b). Crustal deformation is calculated for a combined frictional plastic rheology and a thermally-activated power-law viscous rheology using a two-dimensional finite element method. Frictional plastic deformation is calculated using a non-linear viscosity formulism that mimics the limit condition associated with the Coulomb yield criterion. This method is capable of simulating deformation of frictional materials, such as sand and rock, and has been verified by comparison to the analytical solutions of the critical wedge theory (Willett, 1992; Willett and Pope, 2003).

Velocity boundary conditions drive deformation within the mechanical domain. The basal boundary has a specified tangential velocity, equal to the convergence velocity v_c , to the left of the point S, and zero to the right of S. The subduction thrust is simulated by a thin low-strength zone located at the base of the model to the left of the point S (Fig. DR1).

The upper surface is stress free, and its position and velocity is determined dynamically during the calculation. In Model 2 the surface is modified by sedimentation, which occurs by filling surface depressions to capacity. Basin sediment has the same physical properties as the subduction wedge and is assumed to be from a distal source. Neither model includes any erosion. We recognize that sediment can be supplied by erosion of the forearc high as it becomes subaerial; exclusion of this process does not affect the results presented here.

The lower boundary of the mechanical domain is allowed to move vertically to account for isostasy. The evolution of this boundary is determined using a calculation for flexural isostasy assuming two elastic half plates that remain in contact at the point S (Fig. 2a, Fig. DR1).

Temperature is determined within the larger, thermal-kinematic domain using a finite-element method to solve the two-dimensional, time-dependent heat transport equation including conduction, advection, and radiogenic heat production. Heat advection is calculated using the dynamically calculated velocity field from the mechanical domain and a kinematically prescribed velocity for the remaining regions. The slab velocity is prescribed at the plate convergence rate in a direction tangential to the boundary between the two plates.

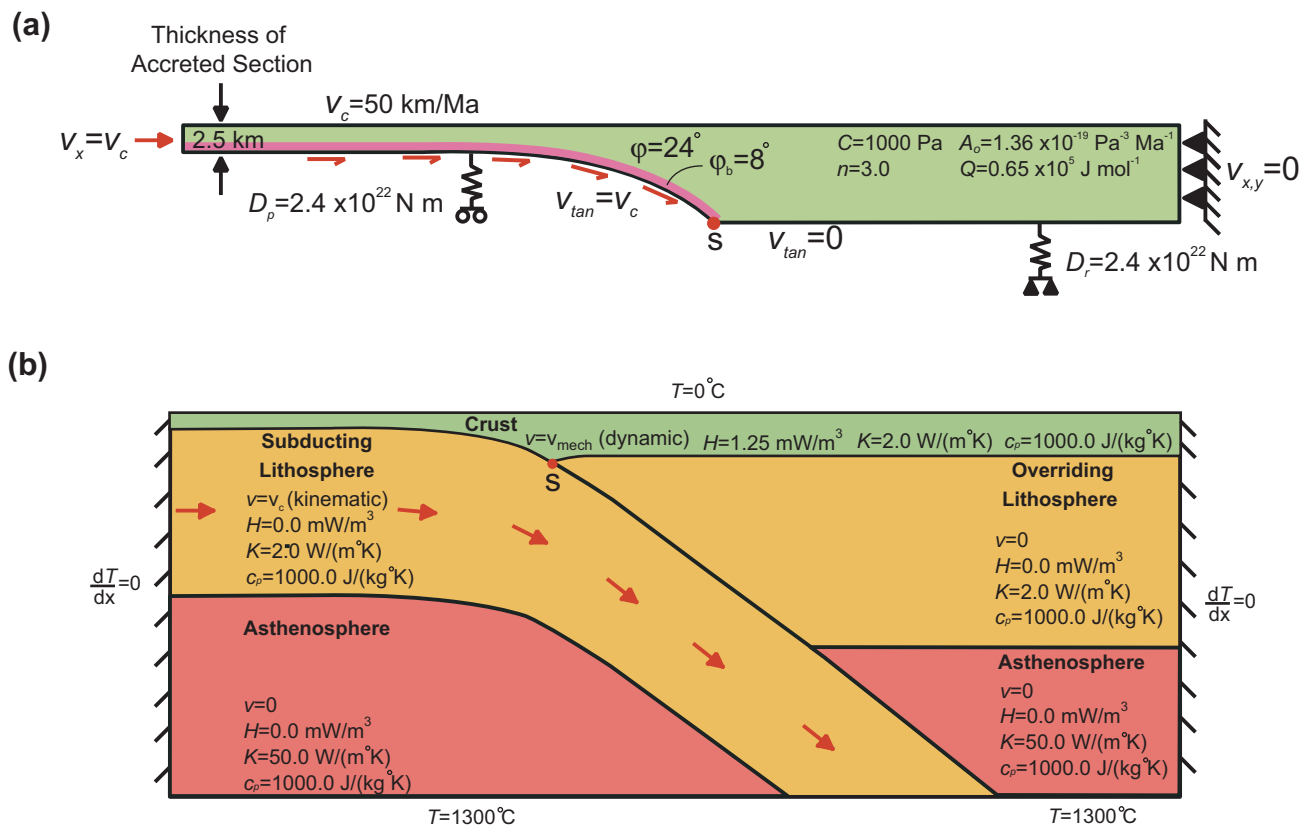
Model results presented here were run with convergence velocity $v_c = 50$ km/Ma and an accretionary thickness $h = 2.5$ km, indicating an accretionary flux of 125 km²/Ma. The nominal time in the model is inversely proportional to the accretionary flux. For example, our models (Fig. 2, DR2, DR3; Videos DR1, DR2) are directly applicable to a subduction margin with half of the accretionary flux (62.5 km²/Ma) at twice the nominal

time shown with our results. The last step shown here with $t = 6.4$ Ma would correspond to a time of 12.8 Ma. This scaling argument holds as long as the thermal field in the subduction wedge remains the same, given that temperature influences the rheology. In our experience, the thermal field is only weakly dependent on accretionary flux when perturbed relative to the model conditions used here.

References

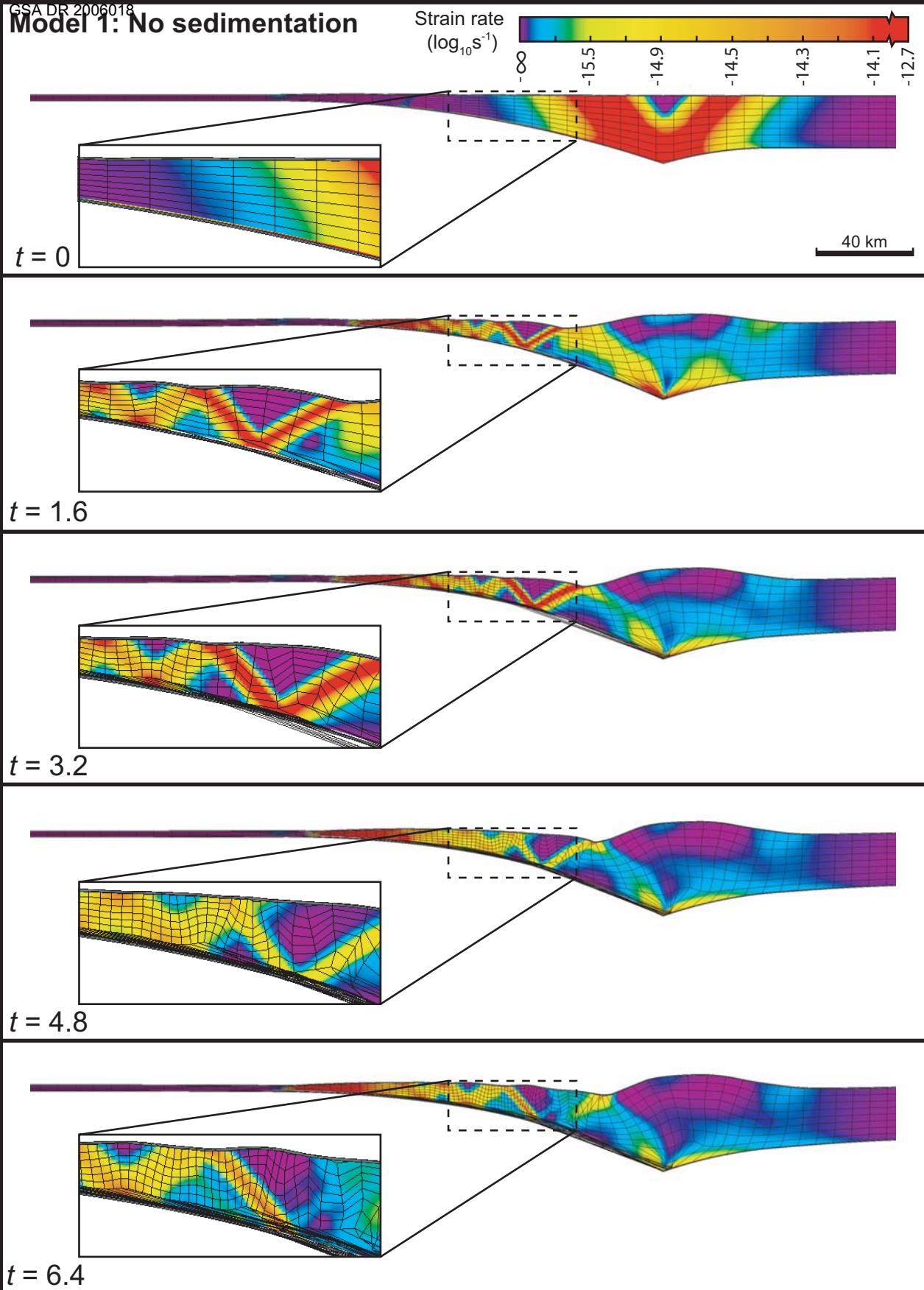
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- Willett, S.D., and Pope, D.C., 2003, Thermo-Mechanical Models of Convergent Orogenesis: Thermal and Rheological Dependence of Crustal Deformation, *in* Karner, G.D., Taylor, B., Drisoll, N.W., and Kohlstedt, D.L., eds., *Rheology and Deformation of the Lithosphere at Continental Margins*: New York, Columbia University Press, p. 166-222.

Figure DR1: Boundary conditions and parameterization of the coupled thermo-mechanical model used in this study. (a) The domain of the mechanical component representing the deforming crust. The viscous rheology is characterized by a power-law exponent n , the activation energy Q , and pre-exponential A_0 . The Coulomb yield criterion is characterized by the internal angle of friction φ and cohesion C . The detachment is assigned a lower friction angle φ_b , so that it is weaker than the wedge. In the paper, we define four parameters: two friction angles (φ for the wedge and φ_b for the basal thrust) and two fluid pressure parameters (λ for the wedge and λ_b for the basal thrust). The numerical model does not calculate fluid pressures, so φ and φ_b in the model are used as effective friction angles that include the influence of fluid pressure. The basal boundary has an imposed tangential velocity v_{tan} . To the left of the point S, $v_{tan} = v_c$, which is the plate convergence velocity, and to the right of S, $v_{tan} = 0$. The evolution of the lower boundary of the dynamic model is calculated assuming flexural isostasy for two elastic half plates with rigidities D_p and D_r that are kept in contact at point S. Densities are 2800 kg/m^3 for the crust, 3300 kg/m^3 for the mantle, and 1030 kg/m^3 for water. (b) The domain of the thermal model, extending from the surface to the asthenosphere. The velocity field v , used to calculate heat advection, is taken from the velocity solution in the mechanical domain (green) described in (a), and the kinematic velocity for the subducting lithosphere. The slab velocity is set at v_c in the direction tangent to the surface of the subducting lithosphere. The slab geometry is initially prescribed, but subsequently allowed to evolve due to the flexural isostatic response of the lithosphere to the changes in crustal load as described above. Radiogenic heat production H is non-zero and uniform in the crust and zero elsewhere. The thermal conductivity k of the upper asthenosphere is set artificially high to simulate the approximately isothermal condition associated with a convecting mantle. Specific heat capacity c_p is uniform throughout the model domain.



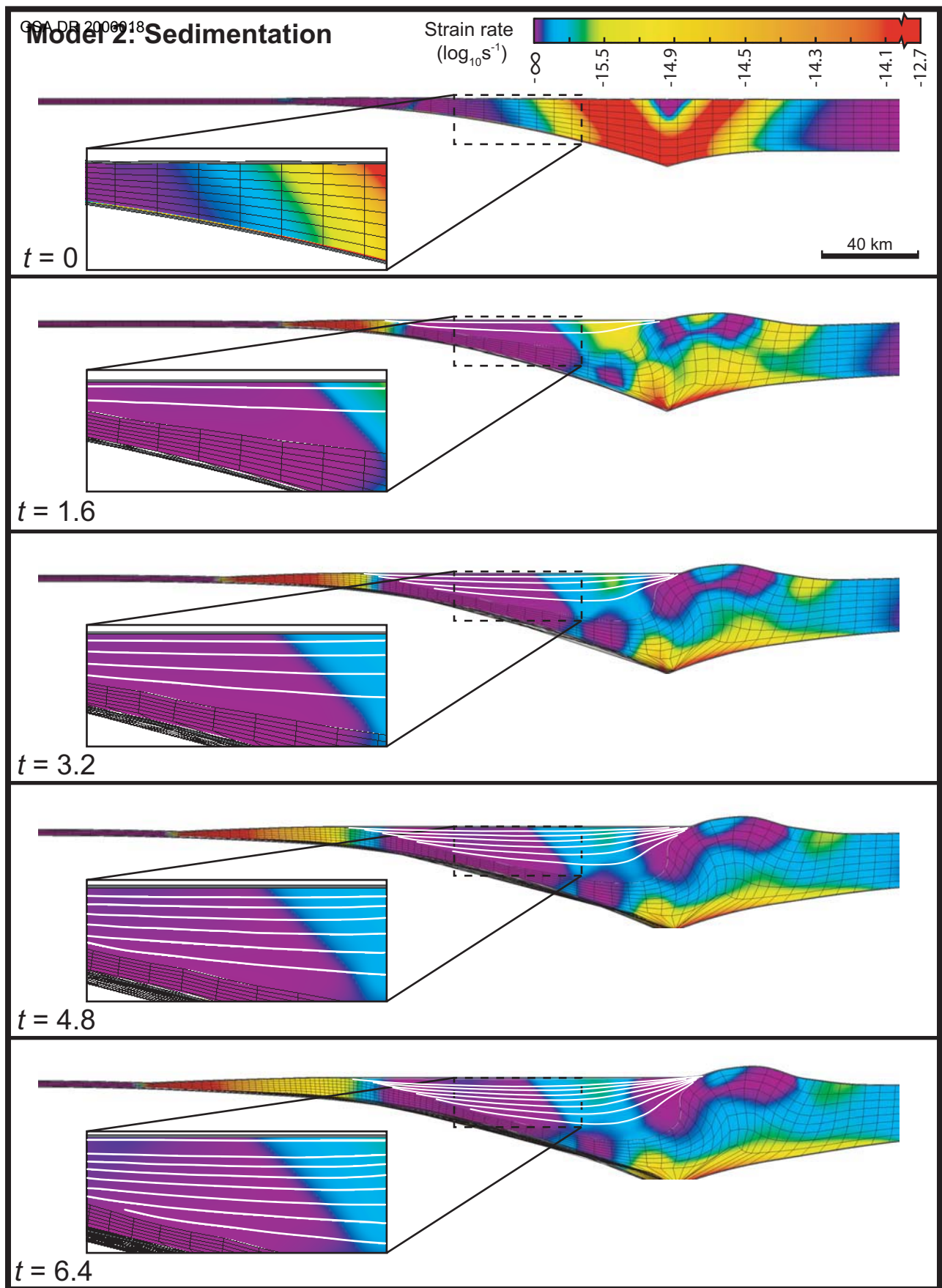
Fuller et al., 2005. Fig. DR1

Figure DR2 and Video DR1: Evolution of Model 1, with no sedimentation, shown in Fig. 2b. A nominal time t is shown in Ma and is calculated for a convergence velocity of 50 km/Ma and a 2.5 km thickness of accreted sediment. The colors indicate strain rate (second invariant of the strain rate tensor). The Lagrangian mesh is a passive feature that shows the integrated motion and deformation in the wedge. Note the persistent deformation from the trench to the landward side of the model, as shown by the strain rate and the Lagrangian mesh. Also note the seaward migration of the trench, growth of the subduction wedge, and uplift of the forearc high, as described in the text. The model has no vertical exaggeration.

Model 1: No sedimentation

Fuller et al., 2005. Fig. DR2

Figure DR3 and Video DR2: Evolution of Model 2, including sedimentation, shown in Fig. 2C. The nominal time, t , is given in Ma, using the same convergence velocity and accretionary thickness as in Fig. DR2 and Video DR1. The synthetic stratigraphy (indicated by white lines) shows the growth of the forearc basin. Strain rates are high seaward of the basin, but very low beneath the basin. The model has no vertical exaggeration.



Fuller et al., 2005. Fig. DR3