Crustal rheology variation along the San Andreas fault controls its secondary faults and dip direction (?)

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AGU American Geophysical Union

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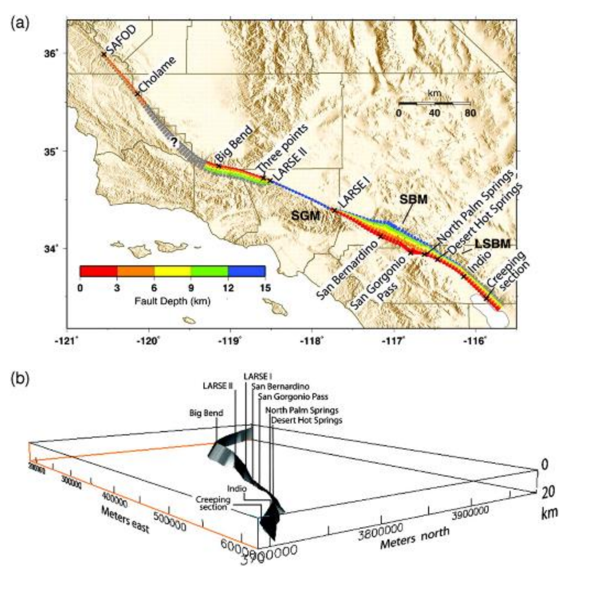
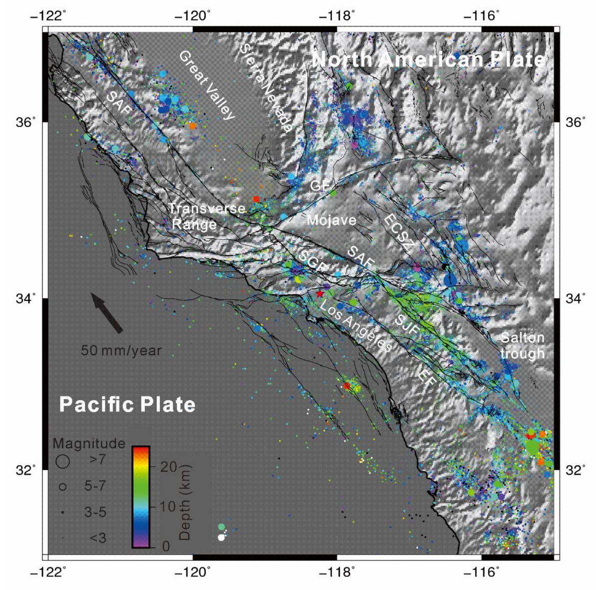
Faults & earthquakes



(a) Plan view of dipping SAF model (from Fuis et al. 2012). SGM, San Gabriel Mountains; SBM, San Bernardino Mountains; LSBM, Little San Bernardino Mountains; SAFOD, San Andreas Fault Observatory at Depth. (b) Oblique view of SAF surface from southeast.



Earthquakes distribution along the San Andreas fault (SAF) system in a shaded relief background with major faults, which works as transform boundary between the North American plate and the Pacific plate. The depth is coloured and magnitude is scaled with circle size. GF, Garlock fault; SGF, San Gabriel fault; EF, Elsinore fault; SJF, San Jacinto fault; ECSZ, Eastern California Shear zone.

WHAT WE **KNOW**:

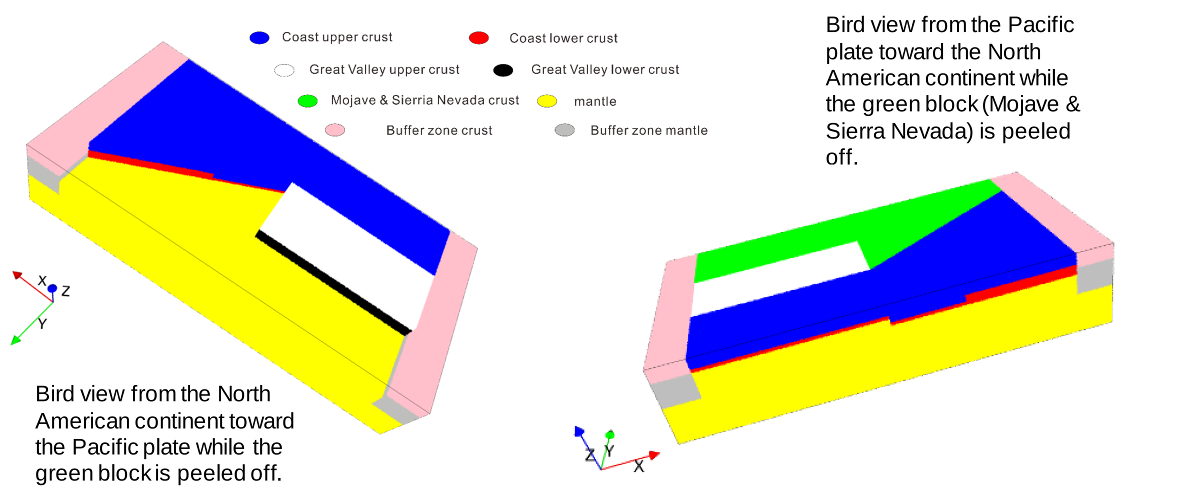
- ❑ San Andreas fault, dextral slip (~20-40 mm/year)
- ❑ Garlock fault, sinistral slip (~3-10 mm/year)
- ❑ Section from SAFOD to Indio, locked fault
- ❑ Mojave has no lower crust
- ❑ …

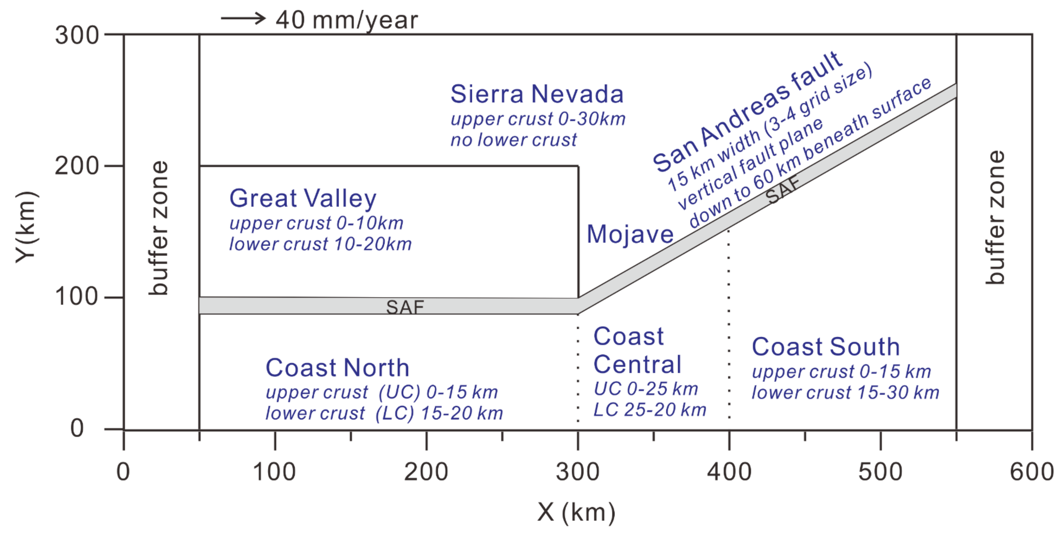
WHAT WE **DO NOT** KNOW:

- ➢ Fault dip varies along the San Andreas fault
- ➢ Very few earthquakes in Mojave block
- ➢ What controls the development of Garlock fault
- ➢ something we don't know that we don't know

Model setup

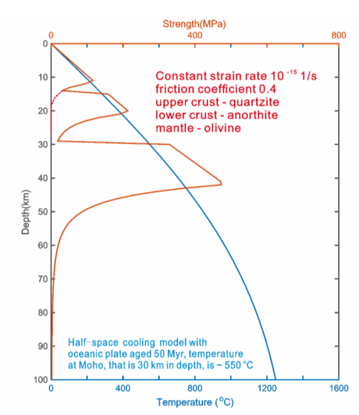
Geometry and boundary conditions





The long-term viscoplastic deformations in the SAF are modelled by the Underworld2, with128*64*32 elements in a calculated volume of 600 km (x) *300 km (y)*150 km (z). The constant velocity 40 mm/year towards the positive x direction is applied on the back vertical plane (y = 300 km) while the velocity in x direction in the front vertical plane (y = 0 km) is zero. Material are not allowed to move out/in the box, and free slip is applied for other velocity components. Here shows the **Real_M model**.

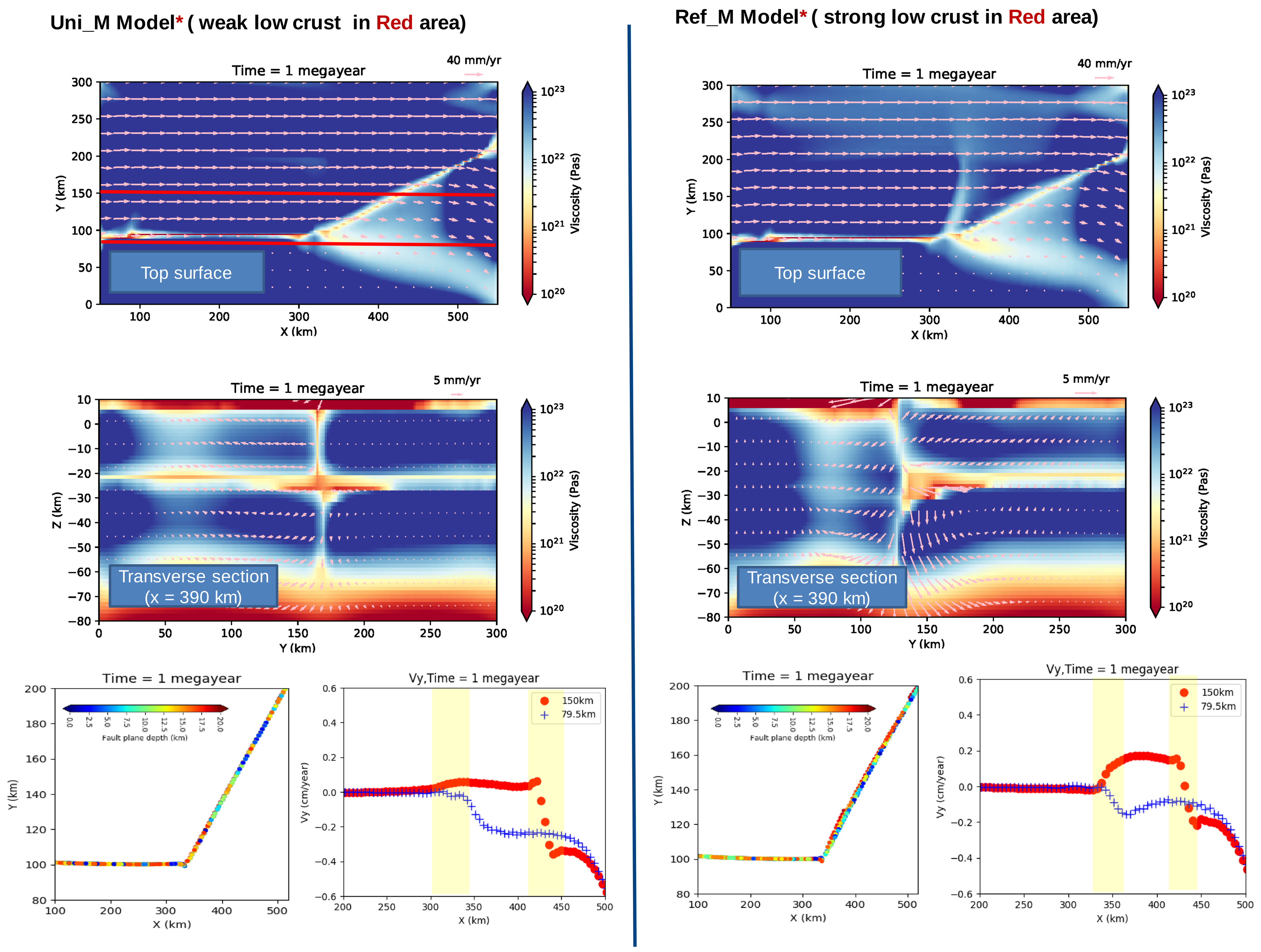
Rheology



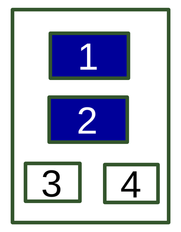
Comparable models

Model Name	Features
Uni_M	One-layer crust in all blocks
Ref_M	Two-layer crust in Great Valley and Coast South
Real_M	Described in figure

Effects of lower crust viscosity contrast

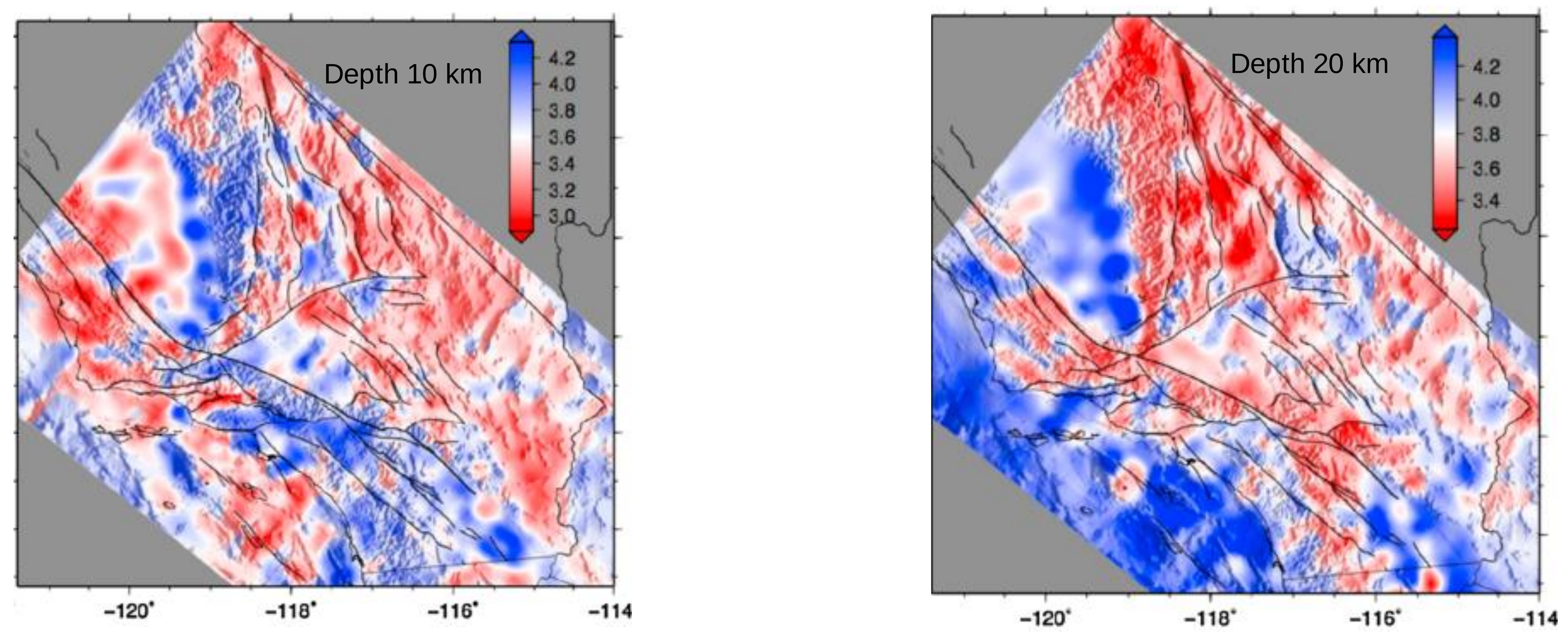


* The uniform model removes the effect of crust thickness (all blocks have a 30-km crust) and lower crust material is replaced with upper crust material instead. The heterogeneous model also removes the crustal thickness effect, and the coast central area has same features as the coast south area.



1. Snapshot of top surface viscosity after 1 Myr. Arrows mark velocity projected to top surface. The red lines at y =150 km and y = 80 km indicate the position for figure 4.
2. Snapshot of cross-section (x = 390 km) viscosity after 1 Myr.
3. Fault plane projected to the top surface. The depth is demonstrated with colours.
4. Velocity in y direction mapped at y =150 km and y = 80 km. The transparency yellow box delimits the shear band in figure 1.

Crustal heterogeneity



S wave tomography at depth 10 km and 20 km in Southern California (after Lee et al., 2014)

References

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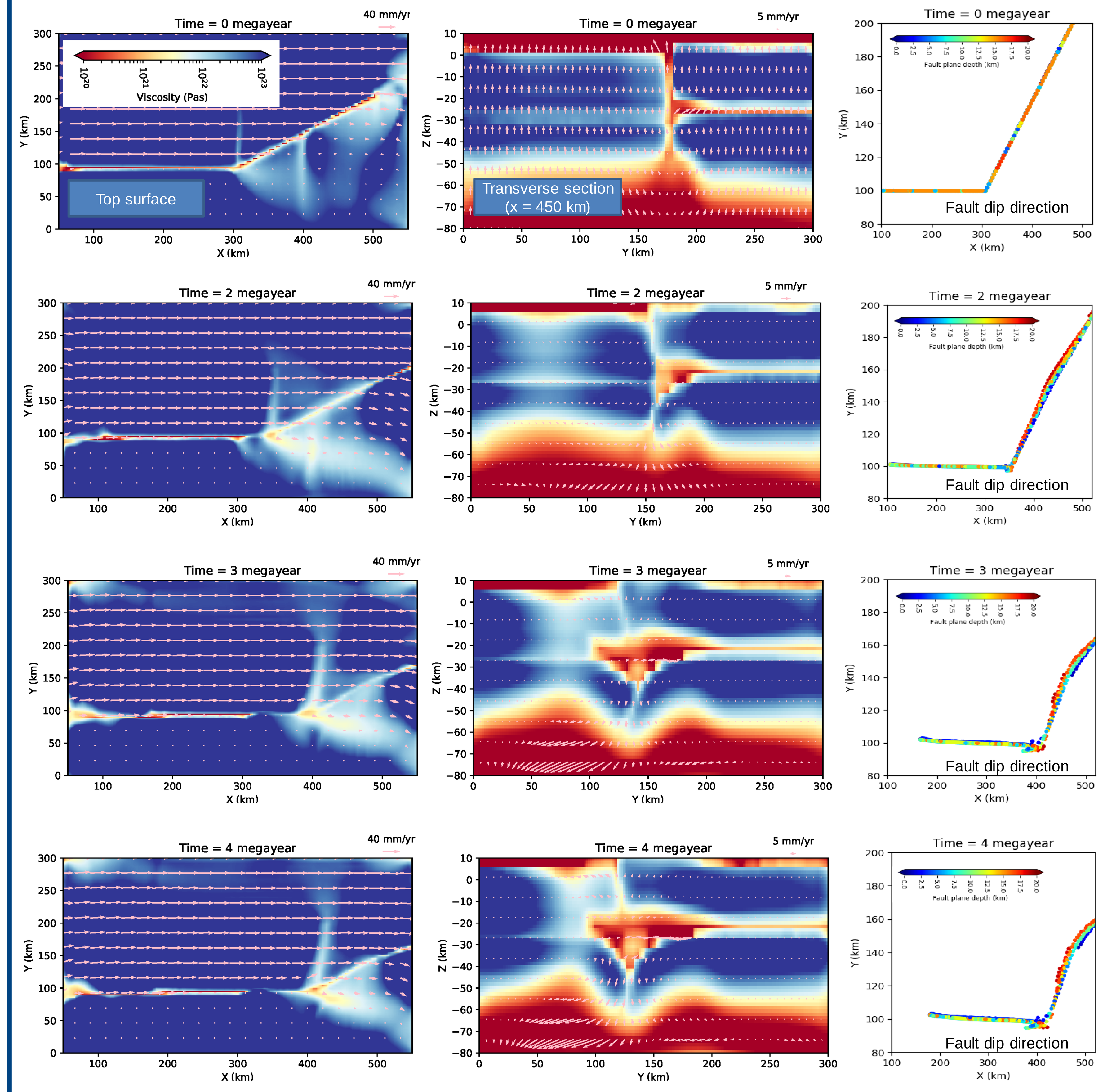
Evolution for Real_M

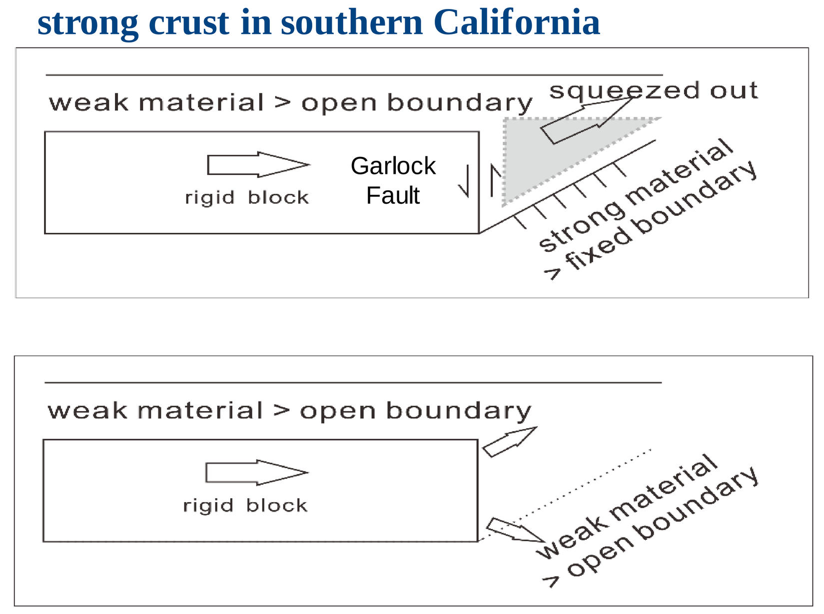


First column shows top surface viscosity evolution, the middle column cross-section (x = 450 km) viscosity and last column mapped fault plane depth.

- ✓ Rightwards moving the rigid Great Valley block causes clockwise rotation of shear band in coast area, which merges with conjugate fault of SAF. Before 3 Myr, the Garlock fault deformation is quite diffusion and the Mojave block is also strained. However, when the Great Valley block approaching the coast south area, the Garlock fault localizes deformation, and then the Mojave becomes less strained.
- ✓ The cross-section shows that the dynamic process alternate the vertical fault plane to the right dip one at x = 450km.
- ✓ The mapped fault depth indicates the straight fault shape in coast south is modified to be stretched "S" after 3 Myr. Apart from the right-dip fault at x>450km, left-dip fault appears at ~ 400km and vertical fault at ~450km. The left-dip fault can be attributed to the viscosity difference between the Great Valley block and the coast central area.

Remarks

1. Conditions for formation of Garlock Fault: a strong crust in southern California



2. Fault dip direction: controlled by lower crust rheology contrast on both sides of fault plane