The Influence of Inelastic Yielding on Dynamic Rupture Termination and Ground Deformation at Fault Bends

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Introduction

1. **Fault zones are complex structures:**
   a. Faults may have geometric complexities, such as fault bends. (Fig. 1).
   b. Fault bends can affect how rupture propagates along the fault. [1,2]
   c. Fault zones may experience coseismic inelastic yielding.
   d. Inelastic yielding can affect rupture propagation and deformation. [3,4,5]

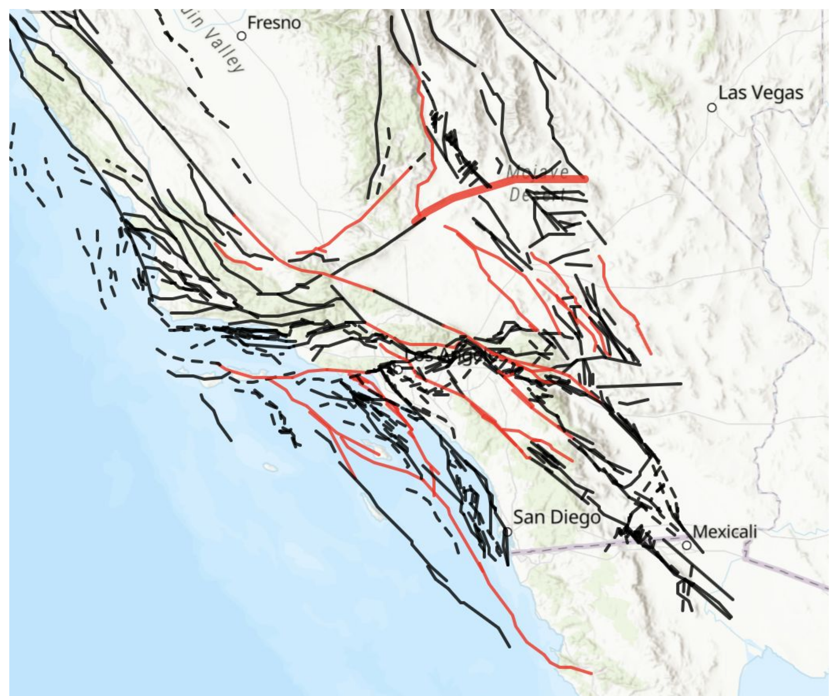

Figure 1: SCEC Community Fault Model. Red lines denote some examples of fault segments with bends [6].

2. **How might inelastic yielding effect rupture and deformation at bends?**
   a. Would it hinder the propagation at bends compared to elastic models?
   b. Would there be increased ground deformation at the bend? (Fig 2) [5]
   c. Would it affect the width of the deformation zone?

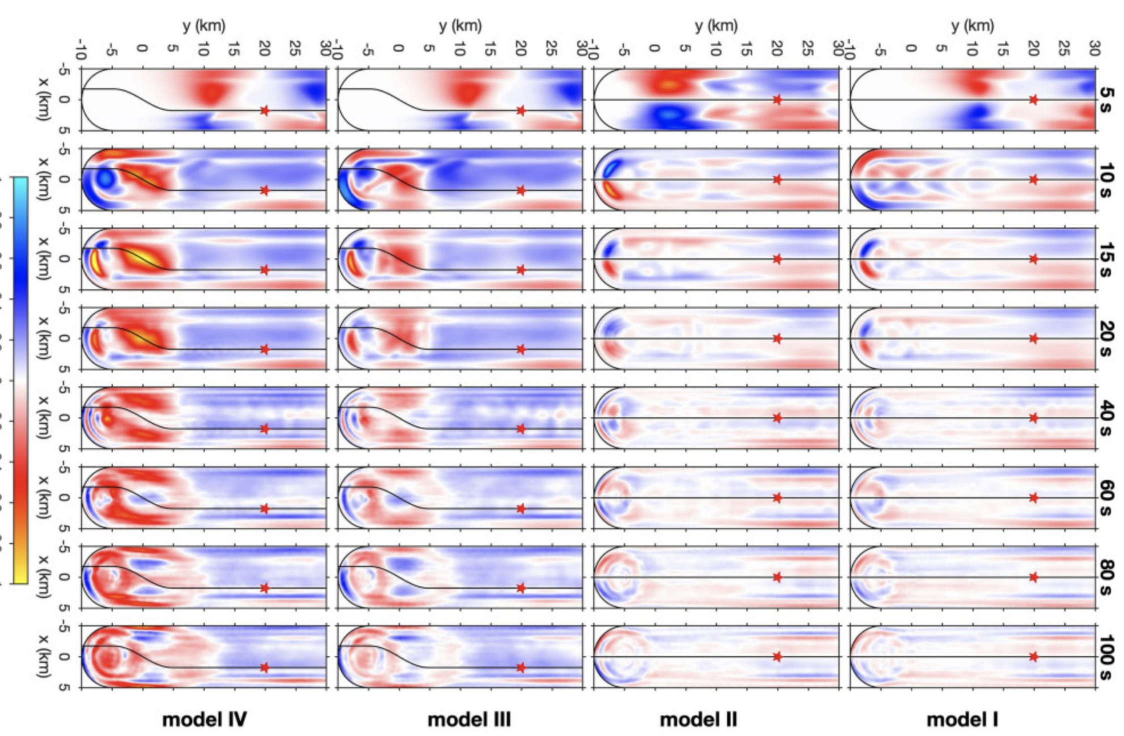

Figure 2: Adopted from Ma (2022) [7] showing the associated wave height from rupture on strike slip faults. Models I & III are purely elastic, while models II & IV have inelastic off-fault deformation. Note that the inelastic yielding leads to larger wave heights indicating increased vertical deformation.

Methodology

4. **Construct Finite Element Mesh for bend geometries.**
   a. Construct bend geometries: angles of -30° to 30° varying by 10°.
   b. Meshes geometries using Cubit (https://coreform.com).
      i. On-faul tetrahedral element size = 100 m.
      ii. Gradually increases away from the fault.

Methodology Cont.

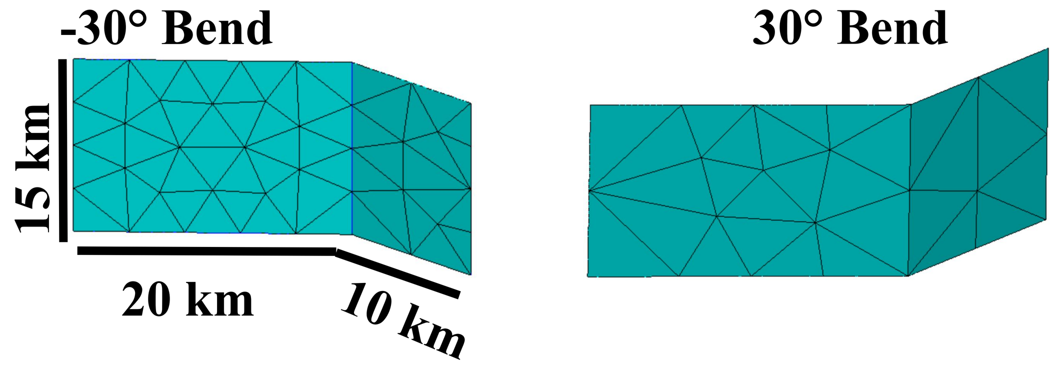

Figure 3: Examples of the -30°, 30° bend geometries. The total fault length is 30 km and fault width is 15 km. The mesh size is much larger here for viewing.

4. **Run Dynamic rupture simulation (FaultMod [7]).**
   a. Set up regional stresses
   b. Assign linear slip weakening friction law
   c. Implement elastic or inelastic material response
      i. $Y(\sigma) = c\cos(\varphi) - \sigma_m \sin(\varphi)$: **Yielding occurs** $J(\sigma)^{1/2} \geq Y(\sigma)$
      ii. c = cohesion, φ = internal friction, σ_m = mean stress, $J(\sigma)$ = second invariant
   d. Nucleate rupture

Parameter Table

Static Friction	*0.5*
Dynamic Friction	*0.1*
Slip Weakening Distance	*0.4 m*
Internal Friction	*0.75*
Cohesion	*Elastic, 5 MPa/km, 2.5 MPa/km*

Results

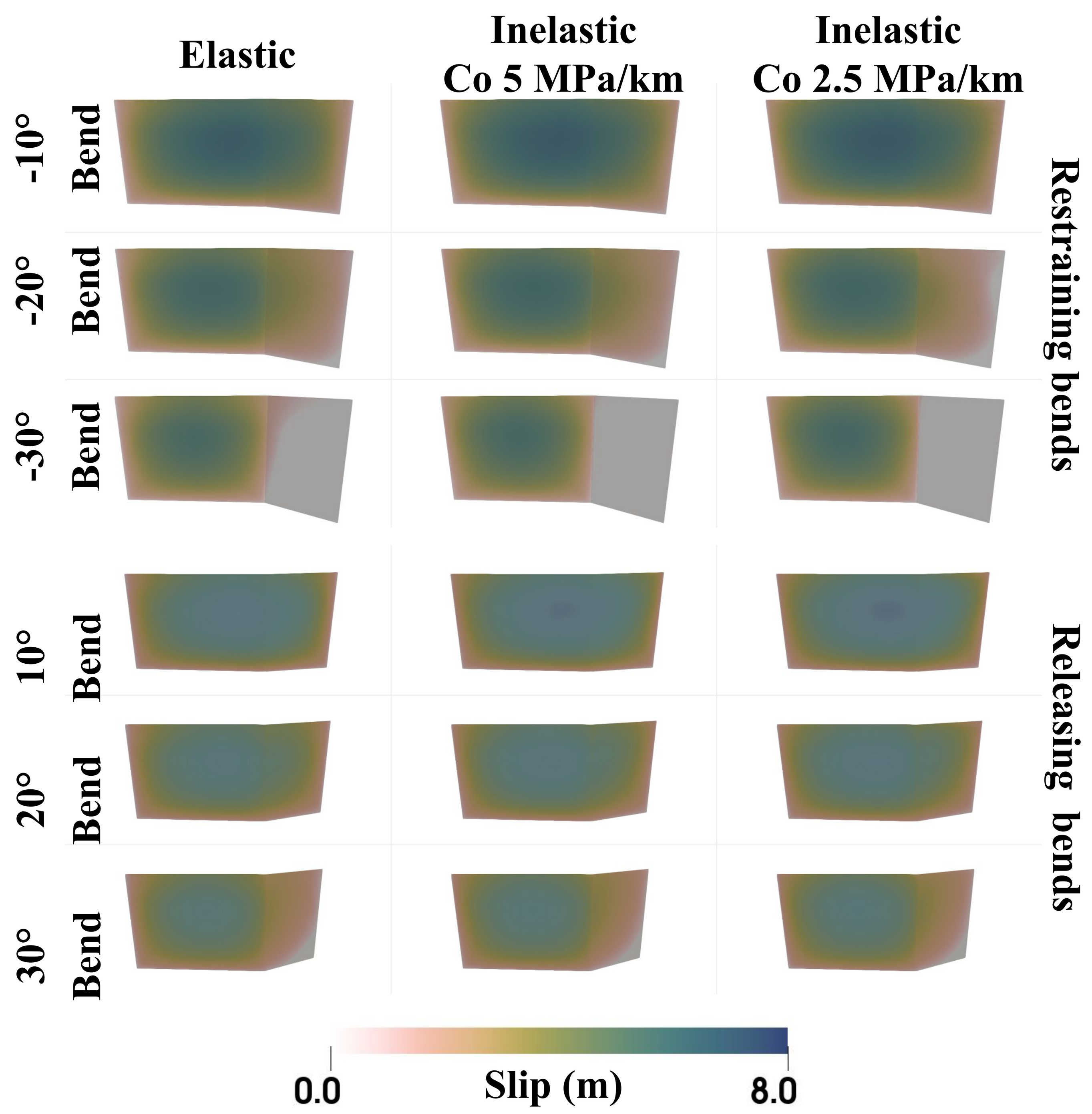

*Figure 4: Final slip for **restraining bends** of -10°, -20° and -30° and **releasing bends** of 10°, 20° and 30°. The material properties vary from Elastic, Inelastic with cohesion of 5 MPa/km and Inelastic with cohesion of 2.5 MPa/km. For **restraining bends** the extent of slip decreases as angle increases and cohesion decreases. However, for **releasing bends**, the inelastic yielding may promote increased slip.*

More Results

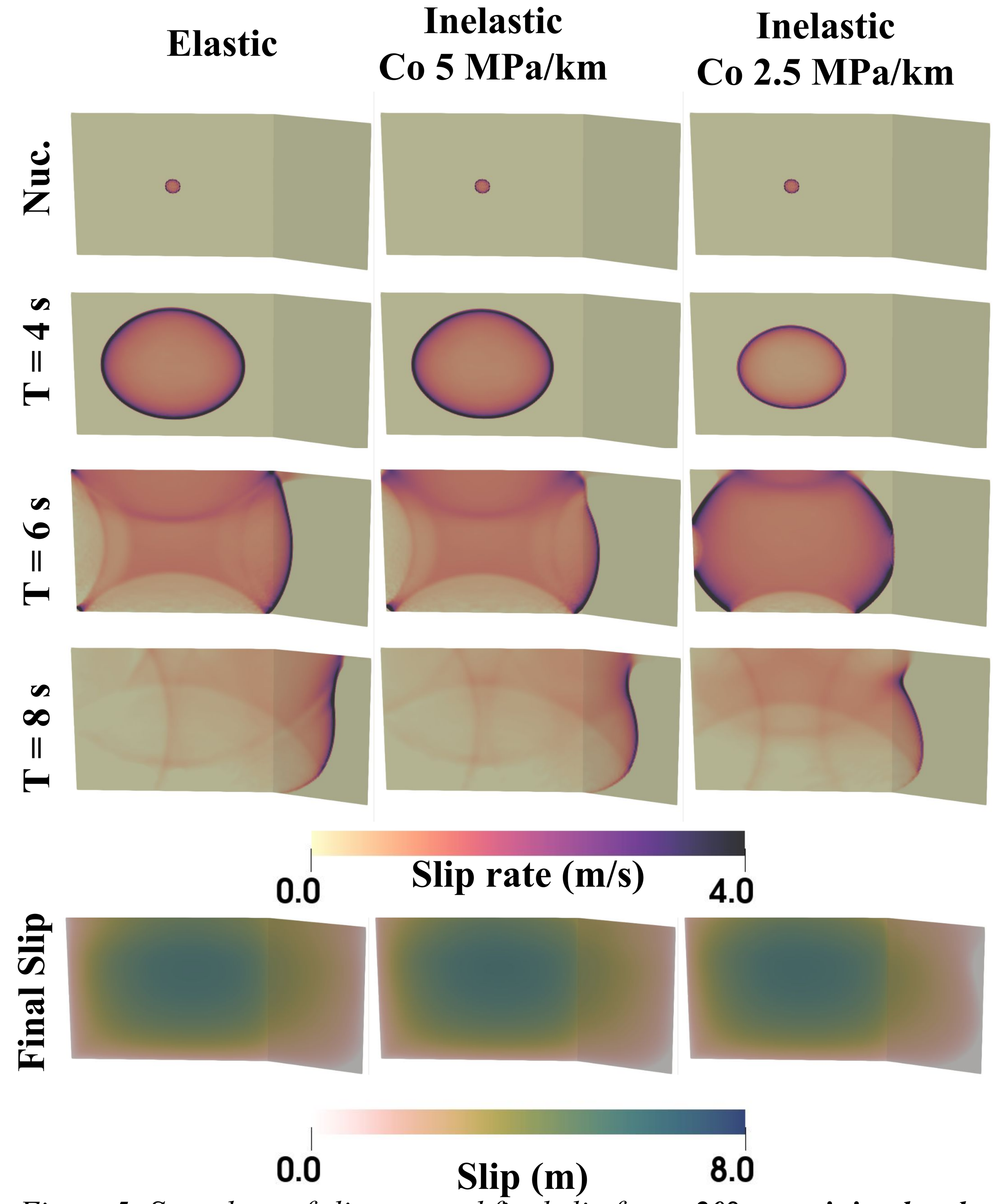

*Figure 5: Snapshots of slip rate and final slip for a **-20° restraining bend** with differing material responses. The inelastic yielding leads to lower slip rates, reduced slip and termination along the bend.*

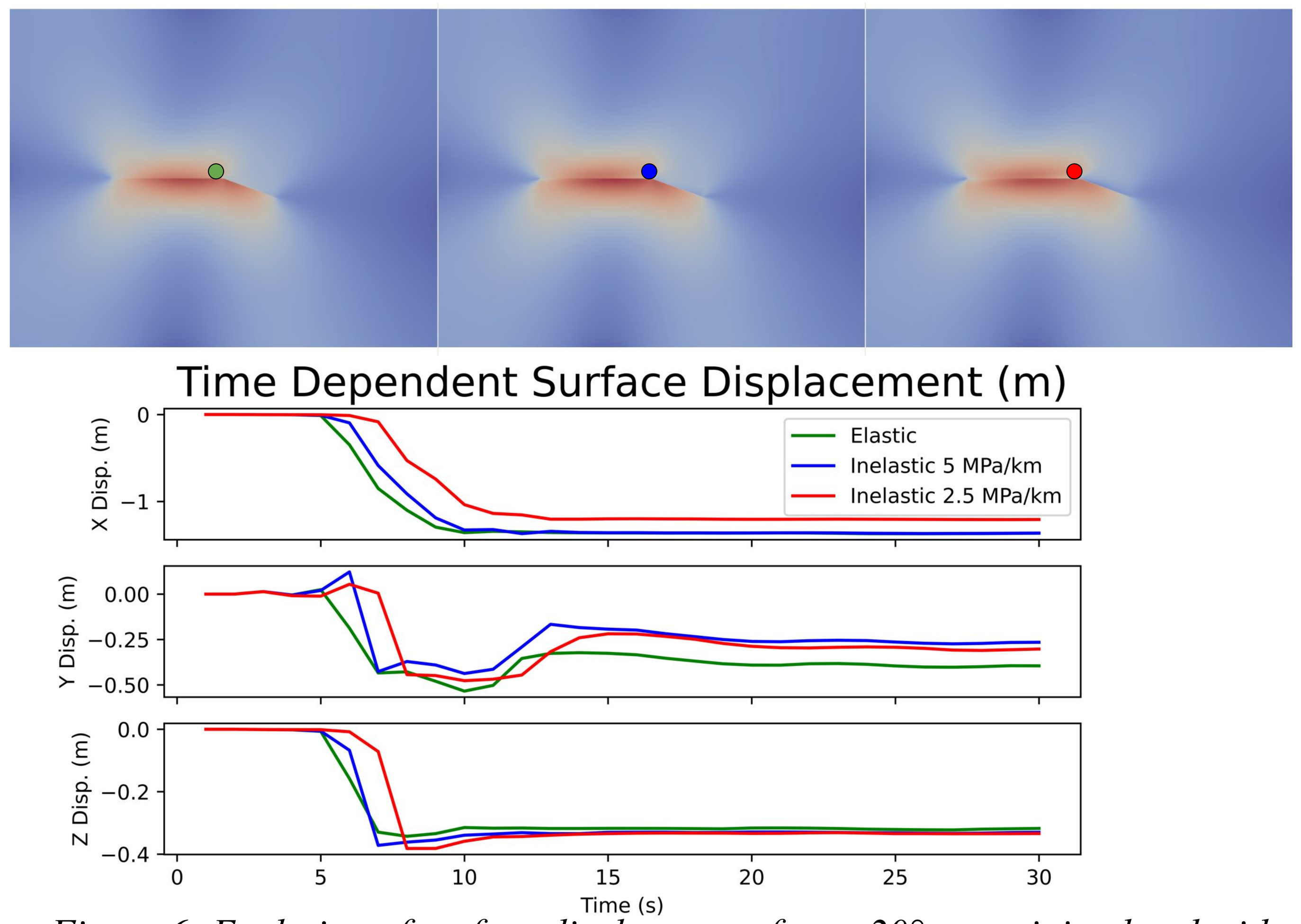

Figure 6: Evolution of surface displacement for a -20° restraining bend with differing material responses. Some slight differences in deformation.

Conclusion/Discussion

5. **Initial takeaways**
   a. Inelastic yielding can hinder propagation along releasing bends
   b. Inelastic yielding may increase slip along releasing bends
   c. Initially, we don't see a big differences in off-fault deformation.

References

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