Introduction and Motivation
Following the July 2019 Ridgecrest earthquakes, multiple field investigators noted that pebble- to boulder-sized rocks had been displaced from their place in the desert pavement in a compressional stepover along the right-lateral strike-slip M7.1 rupture trace. This suggests that localized ground accelerations exceeded 1 g, in contrast to instrumentally recorded ground accelerations which peak at ~0.7 g. Similar observations of displaced rocks concentrated in stepovers exist for the predominantly right-lateral strike-slip 2010 M7.2 El Mayor-Cucapah earthquake. Together, the Ridgecrest and El Mayor-Cucapah examples suggest that some aspect of how earthquake rupture negotiates a strike-slip fault stepover produces extremely localized strong ground acceleration.

Geometrical Parameter Space
Fault stepovers are complex regions, often with nonplanar geometry on the main strands, and many smaller faults within the stepover. Here, we isolate the effects of the primary stepover geometry: a strike-parallel overlap or separation between the two main fault strands, and the strike-perpendicular separation.

We modeled rupture on two planar right-lateral strike-slip faults, one 30 km long and one 10 km long, both with a seismogenic thickness of 12 km. We vary stepover width (strike-perpendicular separation) between 1 km and 5 km. For each stepover width, we also vary the strike-parallel position of the second fault from overlapping the first fault by 5 km to being 5 km separated from the first fault, at increments of 1 km.

Rupture Behaviors
We set our initial conditions such that the first (leftmost) fault always fully ruptures. From there, our simulations produced four different possible behaviors on the second (rightmost) fault.

- **Complete Rupture**: The entire second fault slips.
- **Partial Rupture**: Only part of overlapping second fault does not slip.
- **Triggered Slip**: A small patch of triggered slip occurs at the top of the second fault, but a propagating rupture front does not develop.
- **No Slip**: No portion of the second fault slips at all.

These rupture patterns do change ground motion patterns in that ruptures which do involve the second fault also produce a ground motion signature along the second fault. However, this has little effect on peak ground motions, as discussed in the interpretation section below.

Ground Motion Results
Each combination of a stepover width and an overlap/separation distance represents one dynamic rupture simulation; a single simulation has five cells on the chart.

We color code magnitude (M) according to the rupture behaviors described above, and peak horizontal and vertical particle velocity (VHmax and VVmax) and particle acceleration (AHmax and AVmax) according to the color bars on the right. White spaces represent simulations we have yet to run. We will explore the same parameter space for extensional stepovers later on.

### Supershear Ruptures Across Compressional Stepovers

<table>
<thead>
<tr>
<th>Stepover Width</th>
<th>1 km overlap</th>
<th>2 km overlap</th>
<th>3 km overlap</th>
<th>4 km overlap</th>
<th>5 km overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Subshear Ruptures Across Compressional Stepovers

<table>
<thead>
<tr>
<th>Stepover Width</th>
<th>1 km overlap</th>
<th>2 km overlap</th>
<th>3 km overlap</th>
<th>4 km overlap</th>
<th>5 km overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5 km overlap</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Computational Method
We use the 3D finite element software FaultMod (Barall, 2009) to conduct our dynamic rupture simulations. We implement linear slip-weakening friction in a homogeneous fully-elastic half space. We nucleate our ruptures by raising the shear stress to over the yield stress and then maintaining it there. We conduct our dynamic rupture simulations. We implement linear slip-weakening friction in a homogeneous fully-elastic half space. We simulate the rupture of a fault by raising the shear stress to over the yield stress and then maintaining it there. We conduct our dynamic rupture simulations. We implement linear slip-weakening friction in a homogeneous fully-elastic half space.}

Interpretation (So Far)
For supershear ruptures, the stepover geometry has a negligible effect on peak ground motion because the largest velocities and (particularly) accelerations occur at the point of the supershear transition along the first fault. The mach cone pattern associated with supershear rupture also results in motion at the end of the first fault directing diagonally away from, rather than toward, the stepover.

For subshear ruptures, the stepover geometry (and whether or not rupture jumps the stepover) seems to make no significant difference in peak ground velocities or accelerations. For subshear ruptures, there is a slightly more noticeable variation in values across geometrical parameter space, but the difference is still a matter of less than 10 cm/s and less than 0.05 g.

### What's Next?
- Finish running these compressional stepover simulations.
- Explore the same parameter space for extensional stepovers.
- Investigate which stress/material/rupture velocity conditions are necessary to produce >1 g ground accelerations in the stepover region.
- Also consider other possible mechanisms for the displaced boulders.

References

We suspect that these overall low (<1 g) ground motions are related to our choice of initial stresses. We will experiment with this in the future.