Effect of lithospheric drip on the seismicity in the Central and Southeastern US

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Why this study?

Amongst the intraplate seismic zones in Central Eastern US, Eastern Tennessee Seismic Zone (ETSZ) is unique in its earthquake generation above the unrifted basement.

Proposed models for ETSZ:

- Crustal zone of weakness [1]
- Preexisting faults aligned with regional stress[2]
- Reactivation of shear zone from a major fault[3]

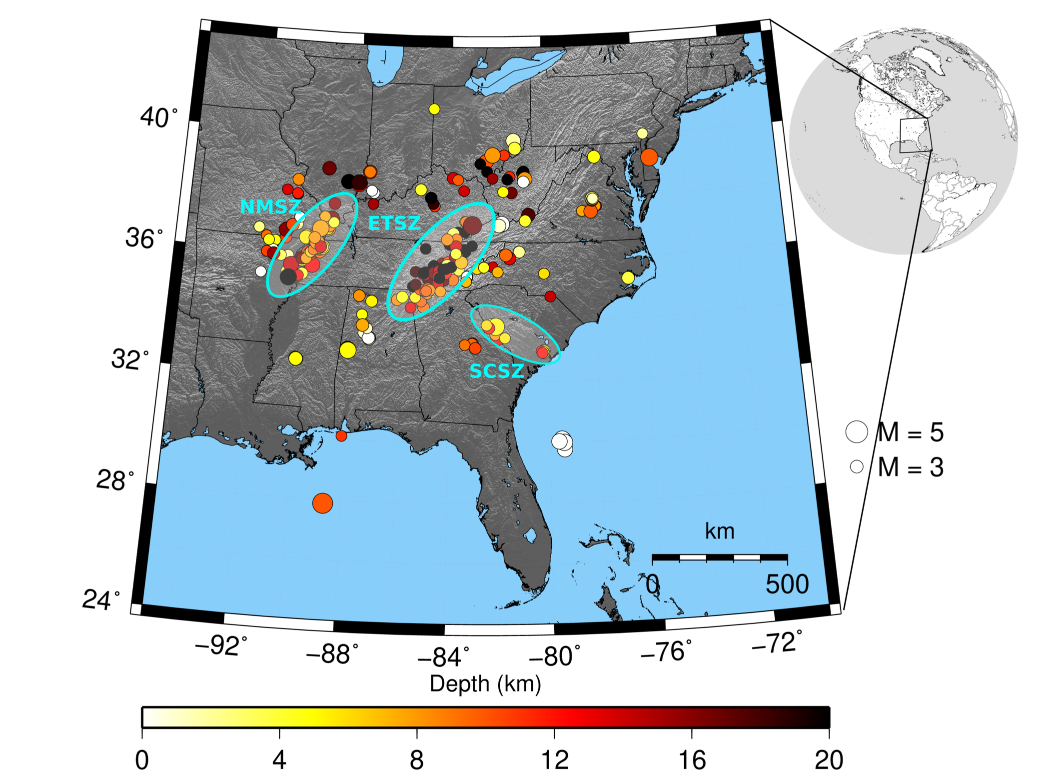

Figure 1: Earthquake epicenters (> Mw2.5) in the CEUS from Nov., 2011 to Nov., 2018

We observe the stress concentration due to lithospheric drip on the ETSZ using numerical model converted from a recent tomography.

Recent observations

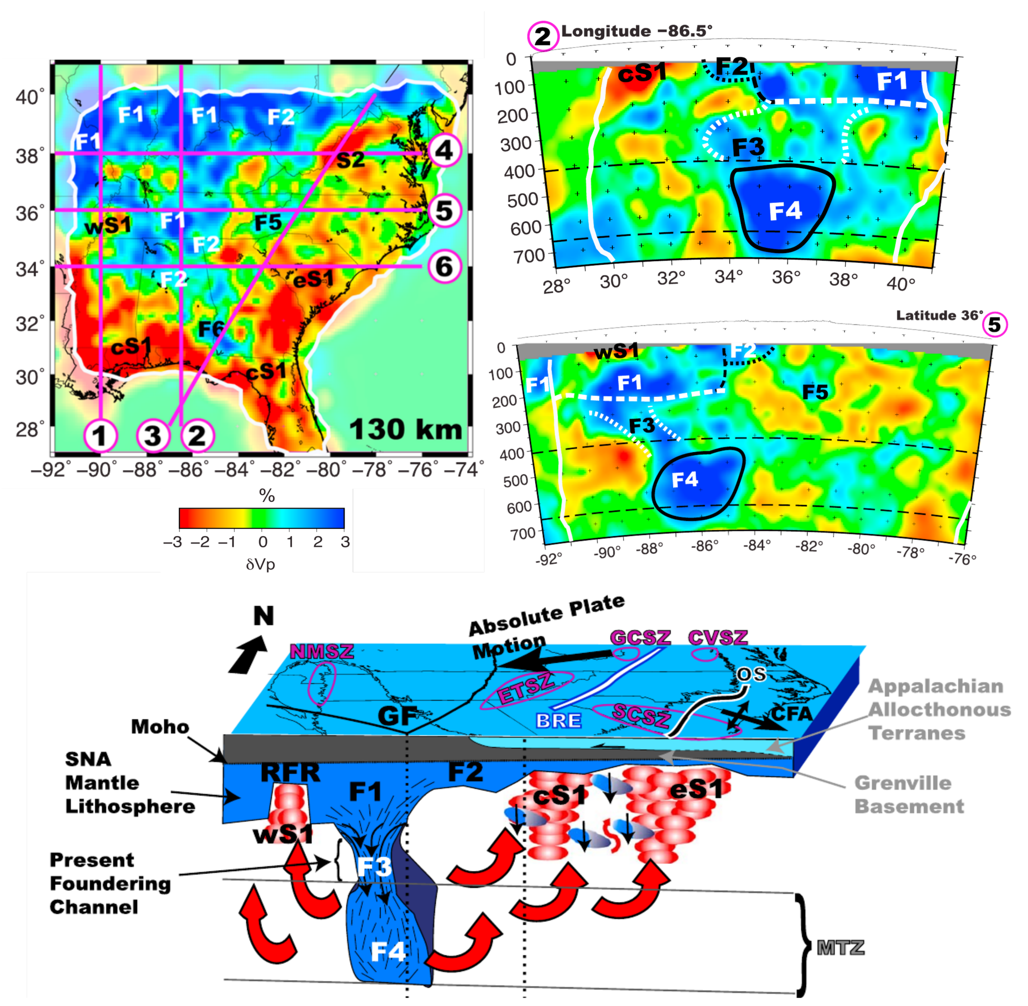

Figure 2: P-wave tomography results by *Biryol et al., 2016*[4] where high velocity patterns interperted as lithospheric drip concentrating stress below the seismic zones

Temperature calculation

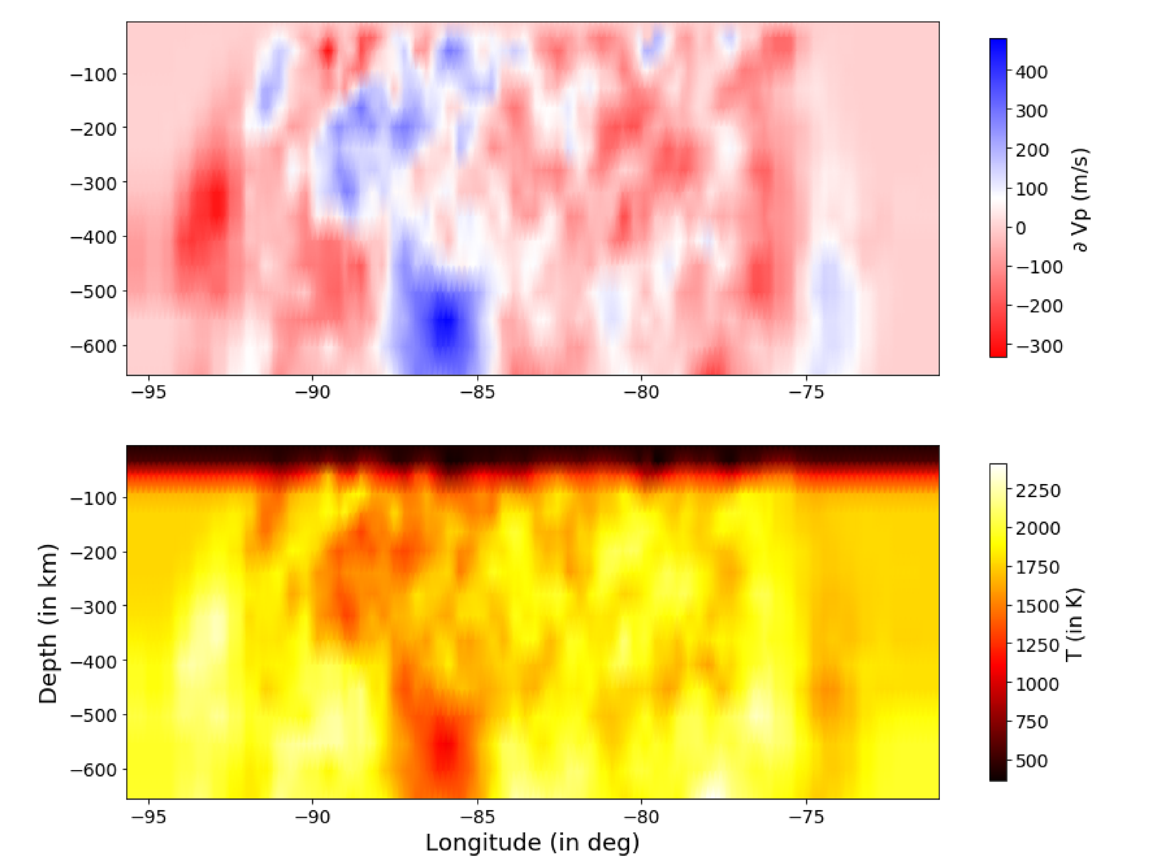

Figure 3: Temperatures calculated based on the Vp tomography results and a reference geotherm, along the dashed cyan line

The sensitivity of Vp to temperature is based on the study by *Goes et al., 2000* [5]:

$$\frac{\partial Vp}{\partial T} = \frac{1}{2Vp_0}\frac{\partial K}{\rho\,\partial T} + \frac{2}{3Vp_0}\frac{\partial \mu}{\rho\,\partial T} + \frac{Q_p^{-1}aH}{2RT_0^2\tan(\pi a/2)}$$

Model setup

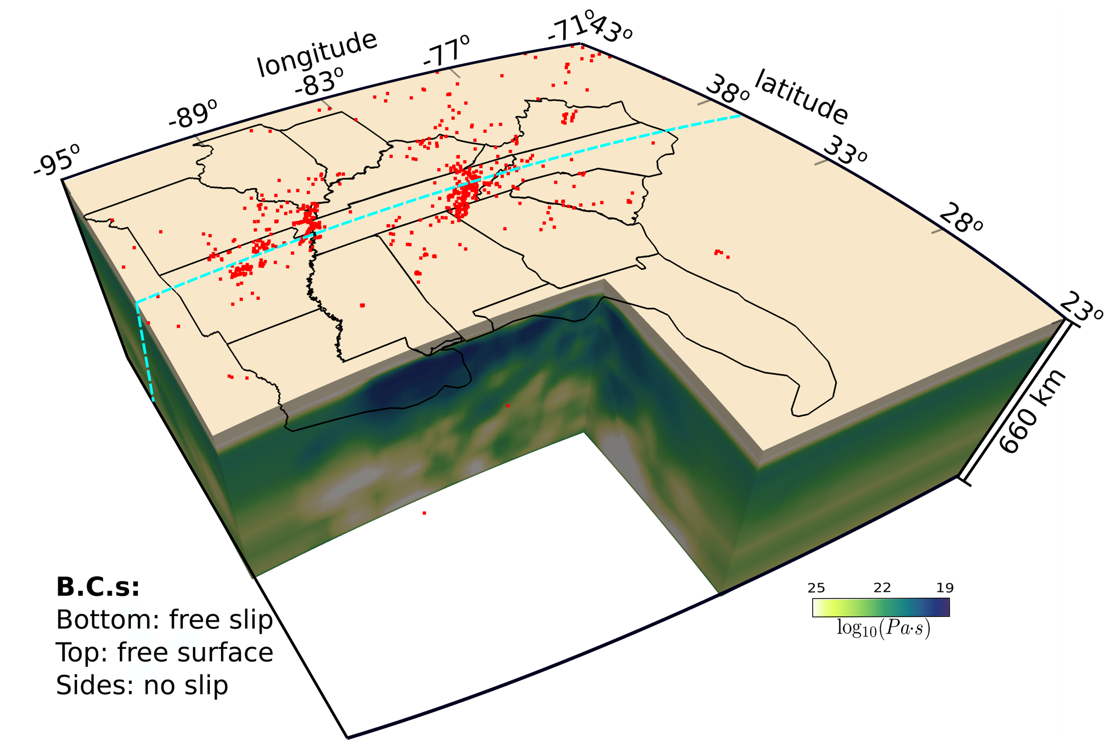

Figure 4: Viscosity distribution computed based on the temperatures in ASPECT

The viscosity distribution is computed in ASPECT[6] based on the temperatures, T, as the average of the dislocation creep and diffusion creep. Taking relevant values of upper mantle, effective viscosity is:

$$\eta = 0.5\dot{\varepsilon}^{\frac{1-n}{n}} A^{-1/n} d^{m/n} \exp\left(\frac{E+PV}{nRT}\right)$$

Results of the numerical simulation

To quantify the effects of the lithospheric root on the seismicity, we compare our model results with another model that has laterally homogeneous temperatures below the depth of 220 km.

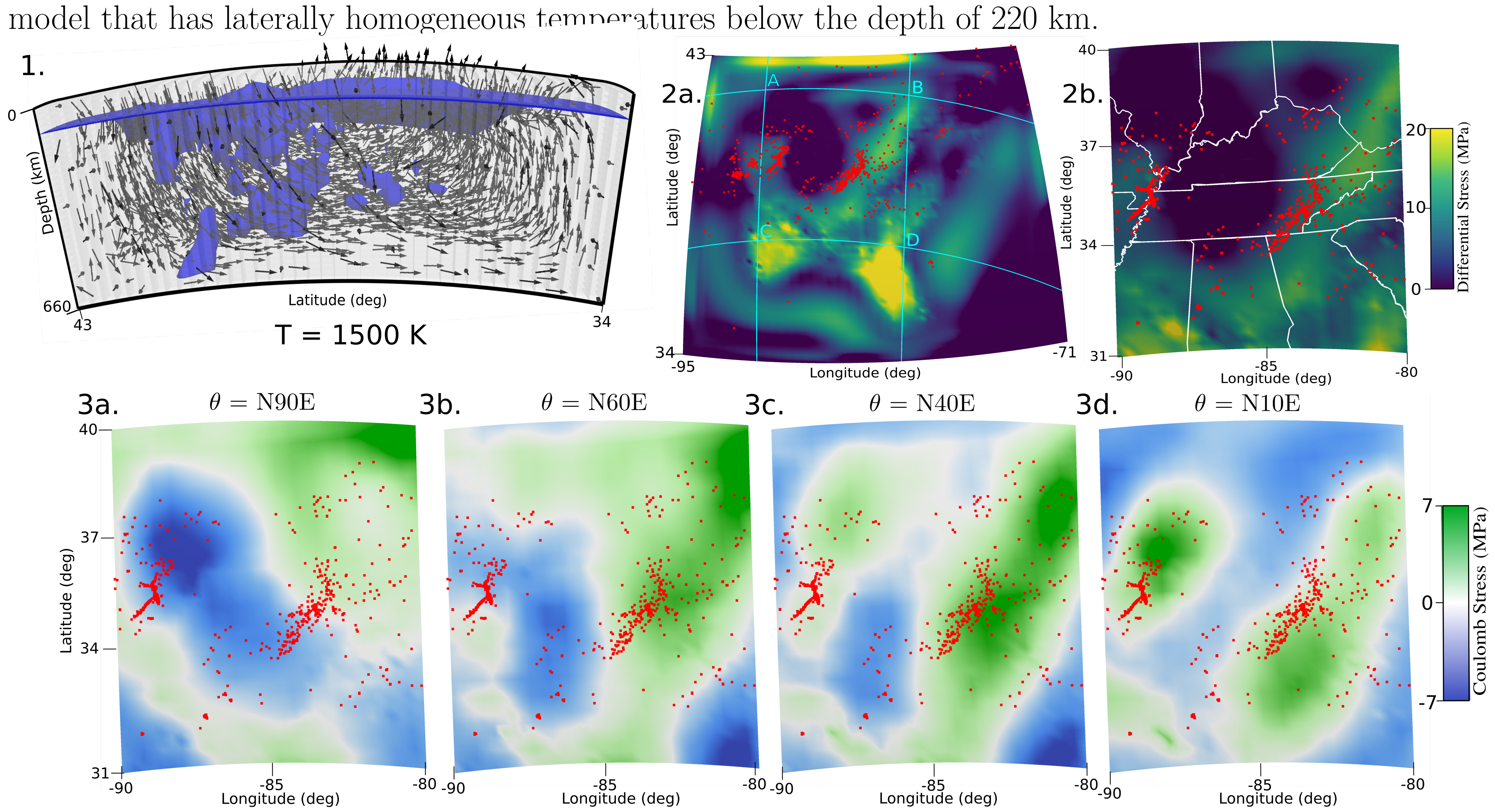

Figure 5: (1) Instantaneous flow generated in the model due to the root indicated by the isosurface of Temperature 1500K. (2(a,b)). Differential stress, $\sigma_1 - \sigma_3$, change between the two models. (3(a-d)) Coulomb stress change between the two models for a strike-slip fault with different strike directions indicated by θ

Interpretations

- The upward flow indicated by the velocity field in our model (Figure 5, 1) is directed southwards into the high stress regions illuminated in the Figure 5 (2(a,b)). We suspect this flow to be due to the boundary effects in our model.
- There is an increase in the differential stress at the ETSZ and SCSZ when the drip is present (Figure 5 (2(a,b))).
- We calculate the difference in the coulomb stress between the two models for various strike-slip fault geometry and observe higher stresses for the fault striking at lower angles, i.e. < than N40E (Figure 5 (3(a-d))). This is in agreement with the fault orientations in the seismo-tectonic model by *Powell and Thomas, 2016*[3].

We propose that the observed differential stress and coulomb stress indicates higher tendency of fault slip for the model which has the lithospheric root. Higher stresses along with the pre-existing faults may promote seismicity in the ETSZ.

Possible future work

- Dynamic topography generated from the sinking root in this region can be compared with the observed topography less the isostatic component.
- The initiation of the lithospheric root in this region is unclear. Based on the present observations (viscosity, temperature and density), adjoint approach can be used to reconstruct the initial conditions in this region.

References

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