

# Visualizing 3D mantle structure from seismic tomography and geodynamic model predictions of the India-Eurasia and East Asia convergence zone

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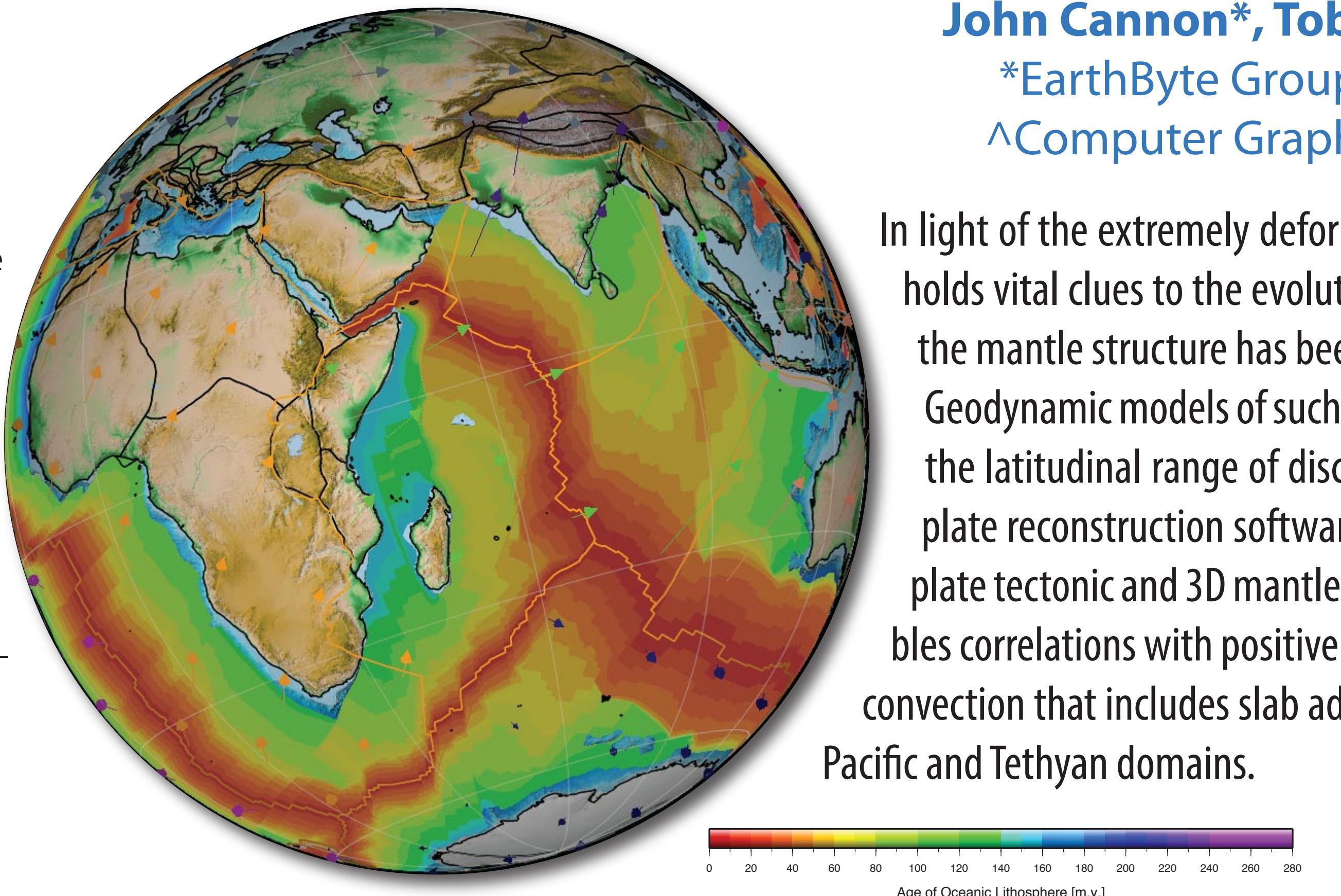
**GPlates**  
[www.gplates.org](http://www.gplates.org)

AGU Poster T51E-2645

**CitcomS**  
<http://www.geodynamics.org/cig/software/packages/mc/citcoms/>

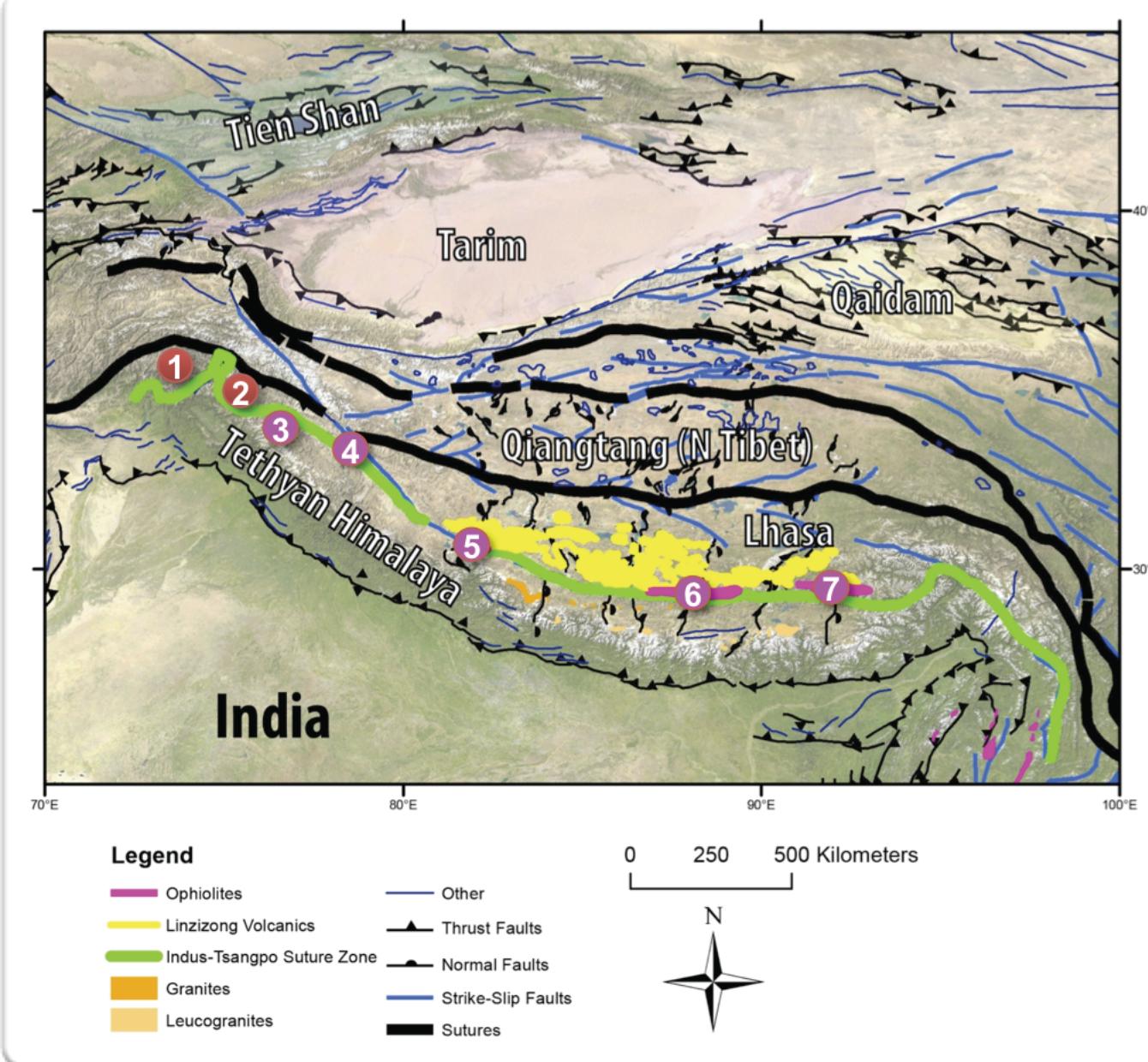
## What is GPlates?

GPlates is an open-source, interactive and cross-platform tool for plate reconstructions. Plate motion models have been implemented using GPlates (Gurnis et al., 2011; Seton et al., 2012) that contain a detailed set of evolving and intersecting plate boundaries in order to separate the Earth's surface into discrete plates through time. We have used the 3D volume visualisation capability of GPlates 1.3 to track the evolution of Tethyan and Asian subduction zones from our global geodynamic models implemented in the finite-element code CitComS. The prediction of the numerical models is then validated using P- and S-wave mantle seismic tomography models. GPlates can be downloaded from [www.gplates.org](http://www.gplates.org) and plate motion models with accompanying data can be downloaded from [www.earthbyte.org/Resources](http://www.earthbyte.org/Resources).

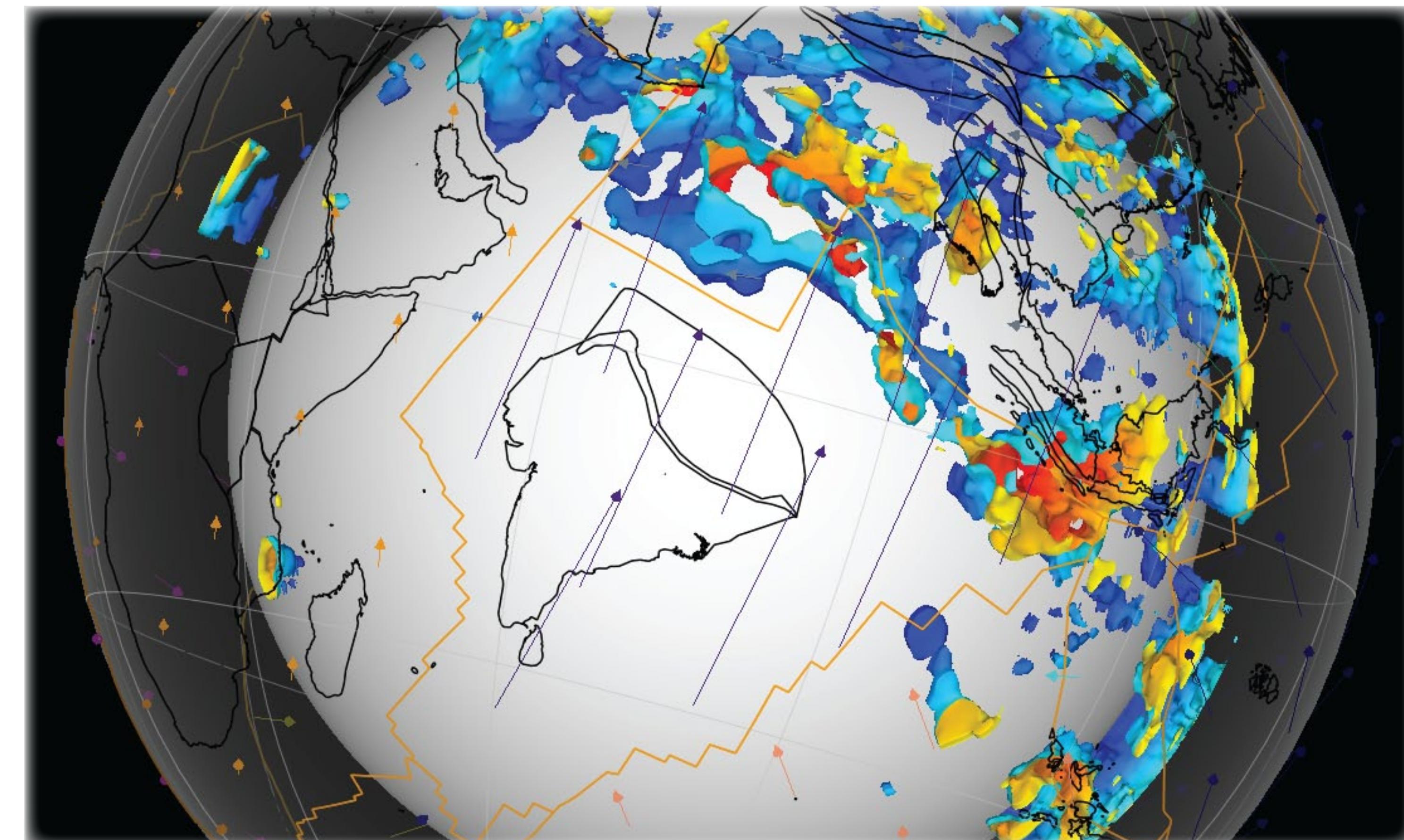
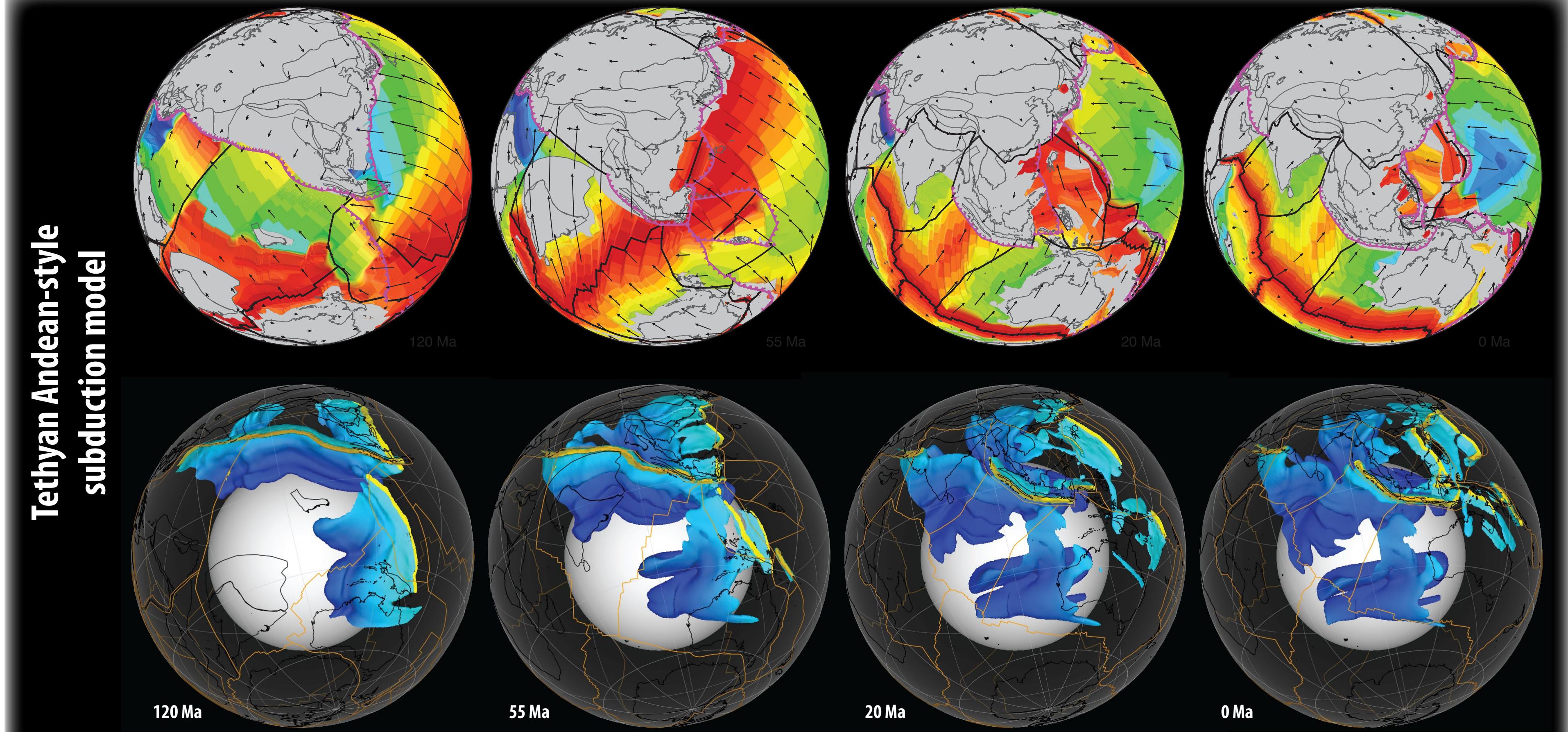


In light of the extremely deformed and complex surface geology in the Central and Eastern Asian convergence zones, the subsurface mantle structure holds vital clues to the evolution of the subduction zones and collisional chronologies. This is especially true for the Tethyan convergence zone, where the mantle structure has been used to suggest intra-oceanic subduction preceded the terminal collision between the Indian and Eurasian continents. Geodynamic models of such a scenario have confirmed that a two-stage collision better reproduces the present-day mantle structure, and particularly the latitudinal range of discrete Tethyan mid-mantle slabs. We demonstrate the 3D visualisation of predicted and observed mantle structure in our plate reconstruction software, GPlates ([www.gplates.org](http://www.gplates.org)), and account for the evolution of subduction zones in Central and East Asia in a combined plate tectonic and 3D mantle structure context for times since the Jurassic. By visualising the source and trajectory of slabs in the mantle over time enables correlations with positive seismic velocity anomalies at present day with higher confidences. Our approach emphasises the need to capture mantle convection that includes slab advection resulting from return flow and the complex slab interactions from multiple nearby subduction zones such as the Pacific and Tethyan domains.

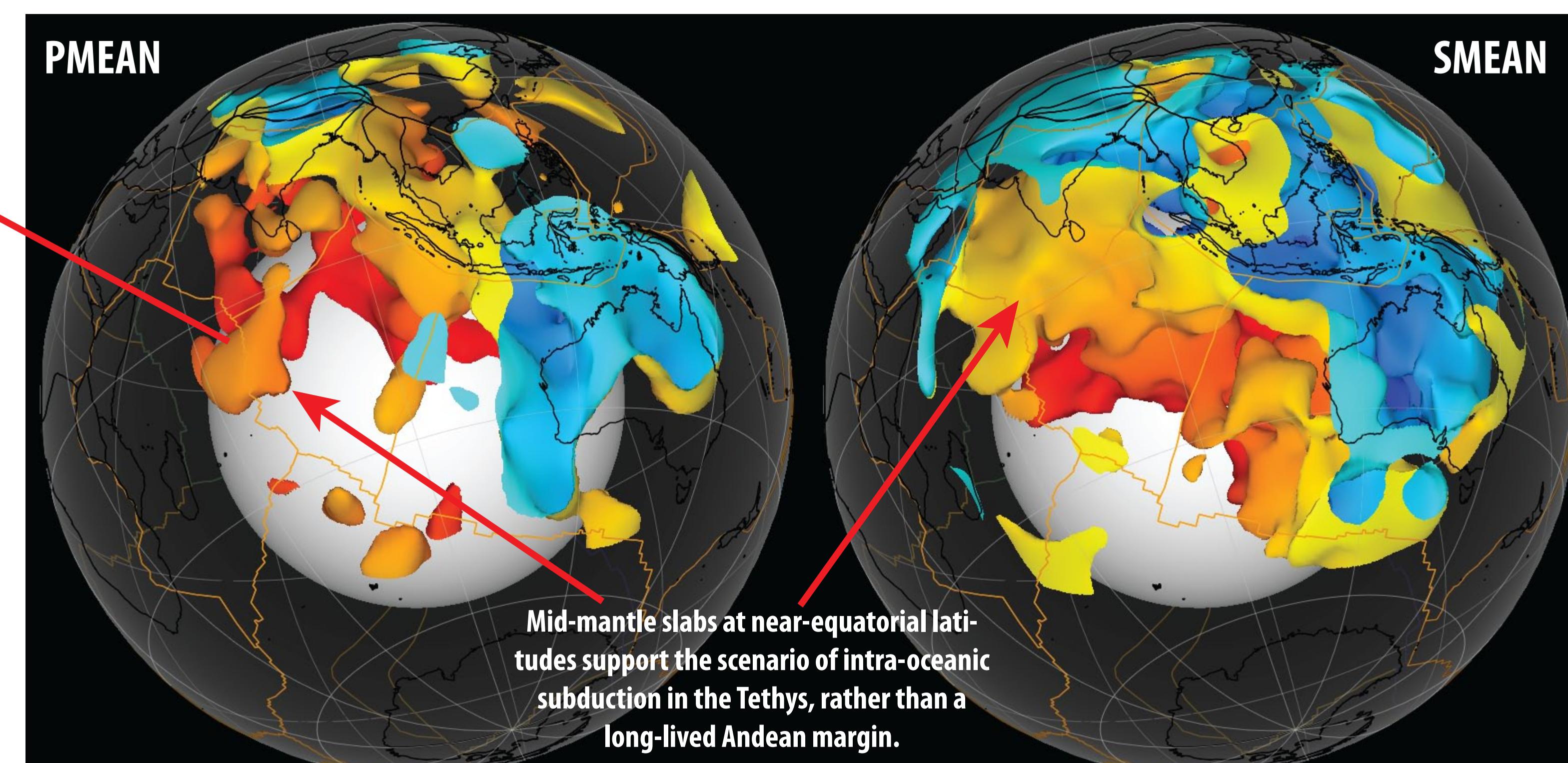
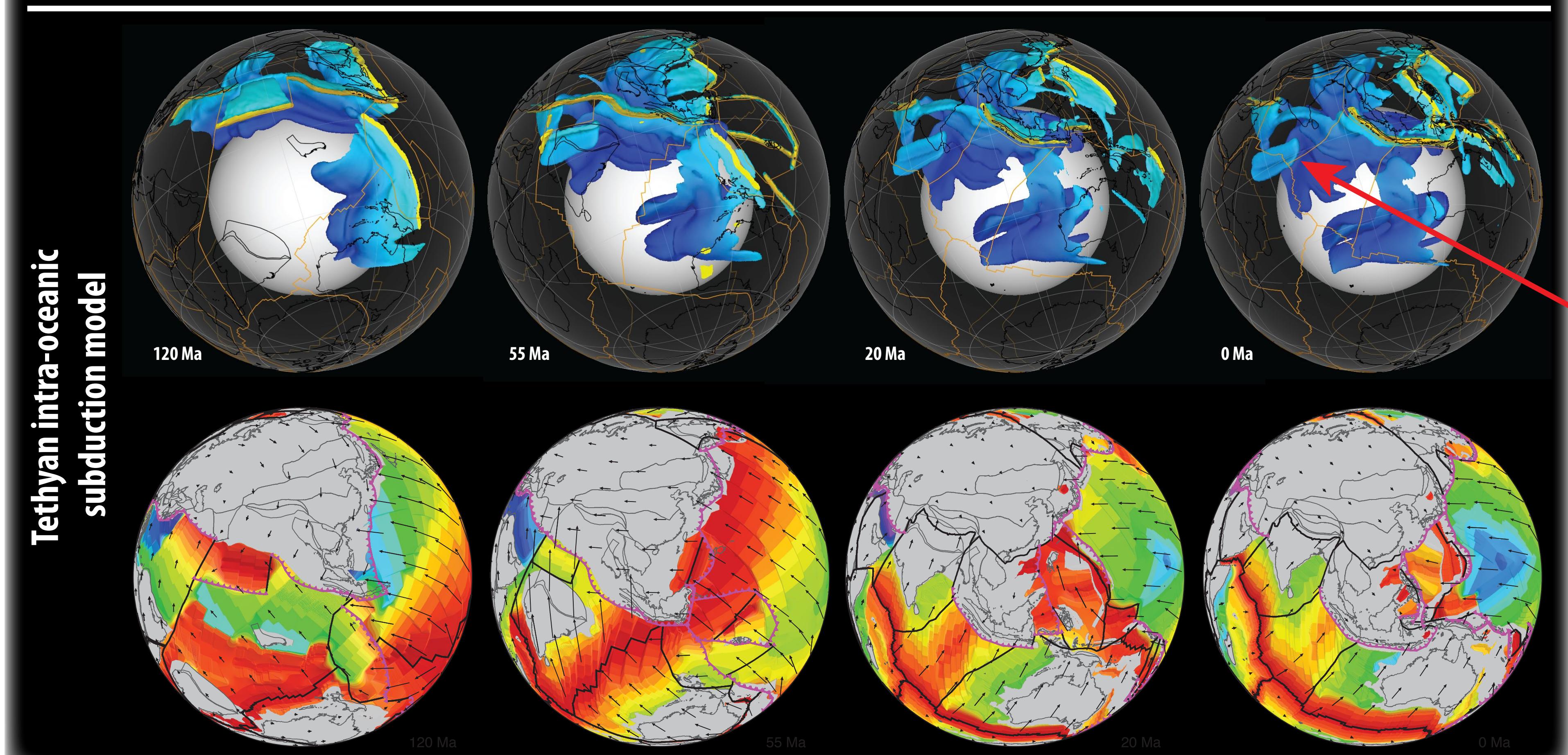
- References**
- Aitchison, J., J. Ali, and A. Davis (2007), When and where did India and Asia collide?, *Journal of Geophysical Research*, 112, 1-19.
  - Ali, J., and J. Aitchison (2008), Gondwana to Asia: Plate tectonics, paleogeography and the biological connectivity of the Indian sub-continent from the Middle Jurassic through latest Eocene (166–35 Ma), *Earth-Science Reviews*, 88(3–4), 35–42.
  - Hakenkeschel, E., M. Wortel, and W. Spakman (2006), Subducting history of the Tethyan region derived from seismic tomography and tectonic reconstructions, *Journal of Geophysical Research-Solid Earth*, 111(B8), B08401.
  - Hall, R., 2012, Late Jurassic-Cenozoic reconstructions of the Indonesian region and the Indian Ocean: *Tectonophysics*, v. 570, p. 1–14.
  - Lee, T.-Y., and L. A. Lawver (1995), Cenozoic plate reconstruction of Southeast Asia, *Tectonophysics*, 251(1–4), 85–138.
  - Müller, R., M. Sdrolias, C. Gaina, and W. Roest (2008), Age, spreading rates, and spreading asymmetry of the world's ocean crust, *Geochimica et Cosmochimica Acta*, 72(10), 2712–2720.
  - Seton, M., et al. (2012), Global continental and ocean basin reconstructions since 200 Ma, *Earth-Science Reviews*, 113(3–4), 212–270.
  - Zahirovic, S., R. D. Müller, M. Seton, N. Flament, M. Gurnis, and J. Whittaker (2012), Insights on the kinematics of the India-Eurasia collision from global geodynamic models, *Geochimica et Cosmochimica Acta*, 13(1Q04W11).



**Figure 1 [above]** Supra-subduction zone ophiolite belts in Indus Tsangpo Suture Zone indicate active intra-oceanic subduction in the NeoTethys. Forming part of the intra-oceanic subduction zone, the Kohistan-Ladakh, Spong, Nidar, Purang, Xigaze and Zedong ophiolites were likely obducted onto leading edge of Greater India during initial collision with an intra-oceanic island arc at ~55 Ma (Aitchison et al., 2007).



**Figure 3** Even without geodynamic models, plate motions can be compared to the distribution of slab material in seismic tomographic models by assuming approximated vertical trajectory of sinking slabs. The plate reconstruction from Zahirovic et al. (2012) at 60 Ma is reconstructed on a 3D visualisation of MIT P-wave tomography (Li et al., 2008) between depths of ~1000 and 1600 km in the mid-mantle, assuming an approximate sinking velocity of 3 cm/yr in the upper mantle and 1.2 cm/yr in the lower mantle. However, such analyses are valid only to the first-order as they do not account for mantle return flow and slab advection that are better accounted for in geodynamic models (left).



**Figure 2 [right]** As the geology of the suture zone indicates the presence of intra-oceanic subduction, we implemented two end-member scenarios to test the effects of varying pre-collision geometries. The conventional model with Andean-style subduction along continental Eurasia was constructed in GPlates, and varied to include a large Tethyan back-arc that opens between 150 and 120 Ma for the alternative scenario. Plate velocities were applied to drive subduction in a finite element numerical code, CitComS, which was also supplied the thermal lithospheric structure using the seafloor age-grids and slabs imposed to a radius of 350 km of a subduction zone. The 3D mantle temperature field time-series are shown here, with Tethyan and East Asian slab volumes representing material 10% colder than ambient mantle. Subduction in the Meso- and Neo-Tethys occurs further south than in the Andean-style case, resulting in a two-stage collision at ~55 and 40 Ma. The present-day numerical predictions are compared to a suite of P- and S-wave mantle tomography models. Here we only show the mantle structure from PMEAN and SMEAN (far bottom right) as these models represent a weighted average of a number of other models. Both PMEAN and SMEAN indicate the intra-oceanic subduction scenario better reproduces the latitudinal range of slab material at mid-mantle depths. For the East Asian margins, the MIT P-wave model (Li et al., 2008) is advantageous due to higher resolutions resulting from the inclusion of Chinese seismic stations to increase coverage (Figure 3). Notably, the southward offset of the Tethyan slabs are also observable in MIT-P, along with a large volume of slab material corresponding to the Java-Sunda subduction zone. Recent models, including Hall (2012), argue that subduction was not active along this margin during this time, but the continuous subducted slab features suggest otherwise – assuming average sinking velocities of 3 and 1.2 cm/yr for the upper and lower mantle, respectively, can be applied to this region.