How was forearc removed from southern Mexico at the end of the Oligocene?

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1. Introduction

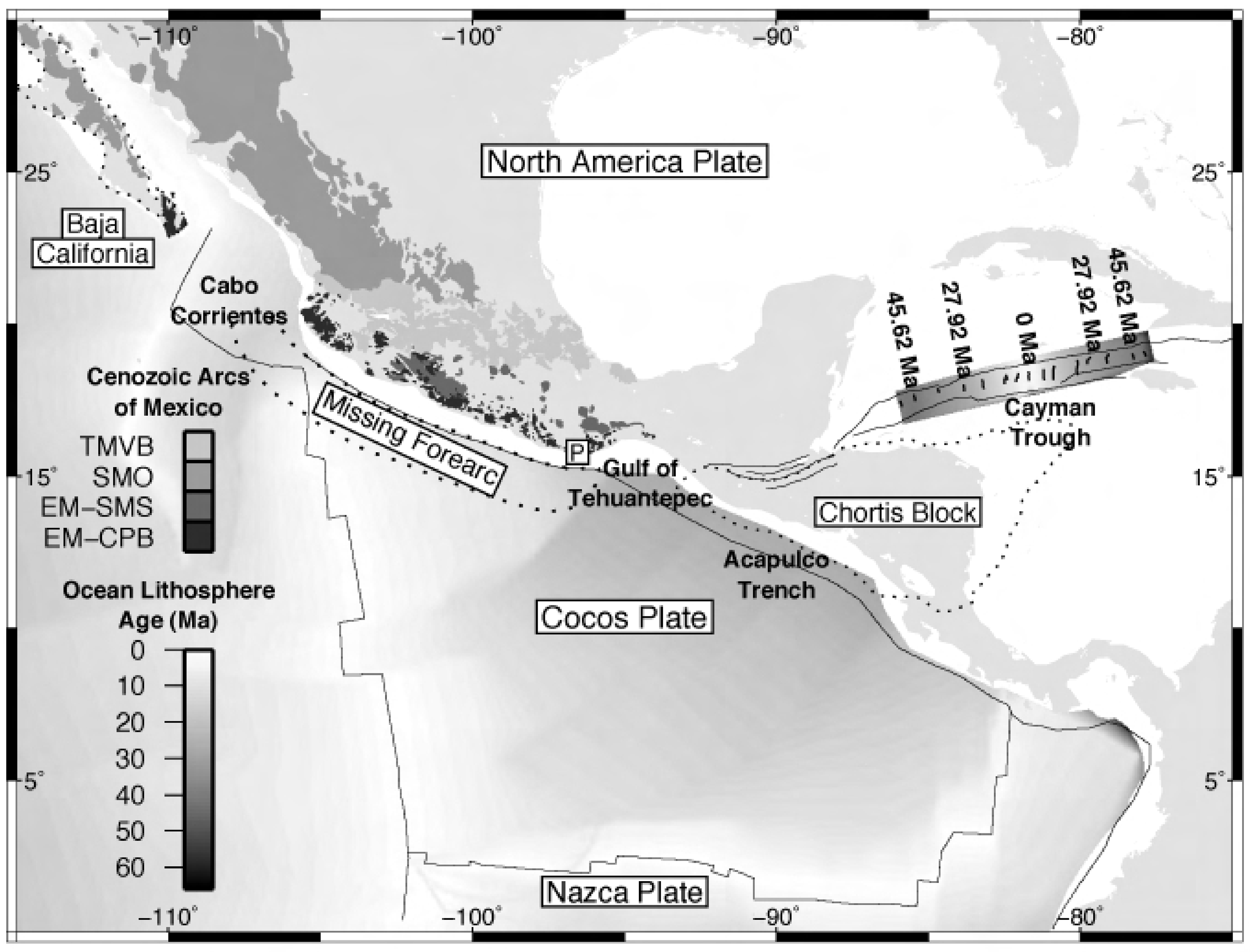

Figure 1: *Inferred location of forearc missing from southern Mexico.*

Removal of a large forearc block from the active margin of southern Mexico between Cabo Corrientes and the Gulf of Tehuantepec (Fig. 1) has been inferred because structural and magnetic trends of basement terranes in southern Mexico are truncated by the present-day subduction zone [1]. If the forearc was removed due to dextral strike-slip migration, Baja California would be the missing forearc [1]. If the forearc was removed due to sinistral strike-slip migration, the Chortis Block would be the missing forearc [2]. If the forearc was removed due to subduction erosion, the missing forearc has subducted to depth [3].

2. Geological Context

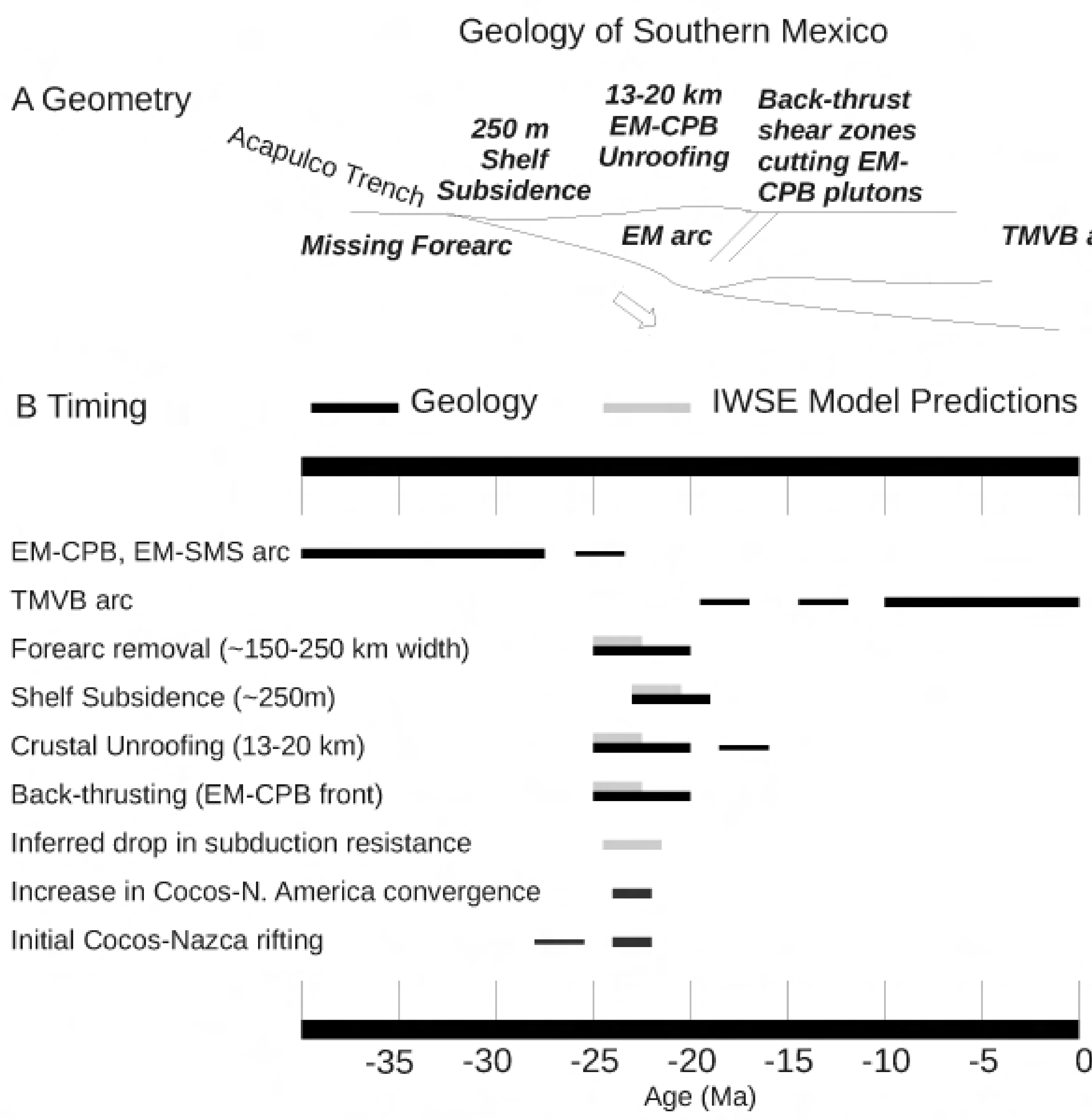

Figure 2: *Summary of the late Oligocene/early Miocene geological record of southern Mexico. A comparison to tectonic features predicted by the internal-weakening subduction erosion mechanism are also indicated.*

Forearc removal probably occurred between ca. 27-25 Ma and 21-19 Ma when arc magmatism migrated rapidly northward from the Eocene-Miocene Coastal Plutonic Belt (EM-CPB) and Eocene-Miocene Sierra Madres del Sur volcanics (EM-SMS) to the Trans-Mexican Volcanic Belt (TMVB) (Fig. 2) [4]. A 150-250 km width may be estimated for the missing forearc based on comparing the exposed width of the Eocene-Miocene arc rocks in southern Mexico with global relationships between forearc width, arc width and slab dip for modern subduction zones [4]. The mechanism of forearc removal in southern Mexico is uncertain because tectonic reconstructions place neither Baja California nor the Chortis Block off southern Mexico at the end of the Oligocene and slow subduction erosion processes which remove material from the side and basal edges of the upper plate are too slow to remove a 150-250 km wide forearc in 4-8 Ma [4, 5].

3. Numerical method

A thermo-mechanical incompressible Stokes flow finite element method was used to investigate ocean-continent subduction processes at an upper mantle scale [6]. Model evolution is controlled by kinematic convergence applied to the oceanic lithosphere at the left model boundary and internal buoyancy forces due to density variations. Model materials have compound power-law viscous and strain-softening frictional-plastic rheologies, and temperature-dependent densities. A new mode of subduction erosion, called internal-weakening subduction erosion (IWSE), is observed for numerical models with moderate shear traction at the ocean-continent interface.

4. Internal-weakening subduction erosion

During subduction, convergent stresses transmitted into the upper plate cause the orogenic zone to deform by bending and thickening (Fig. 3, 12.5Ma to 14.5Ma). This triggers frictional strain-softening which leads to weakening in the continental interior and eventual failure (Fig. 3, 15.5Ma). Ongoing failure in the upper plate develops into a new subduction zone across the continental interior which replaces the old subduction zone at the ocean-continent interface (Fig. 3, 16.5Ma). Forearc located between the old and new subduction shear zones is entrained with the lower plate and subducted (Fig. 3, 16.5Ma to 20.5 Ma). The rate of trench migration approaches the rate of orthogonal plate convergence. During passage of the entrained forearc down the new subduction zone, it initially acts as a collisional element. This drives the upward extrusion and unroofing of mid- to lower-crustal rocks in the upper plate as well as producing back-thrusting at the deformation front (Fig. 3, 16.5Ma to 20.5 Ma). As the entrained forearc is subducted to depth, the top surface of the outer toe of the upper plate, i.e., the continental shelf, subsides (Fig. 3, 20.5 Ma).

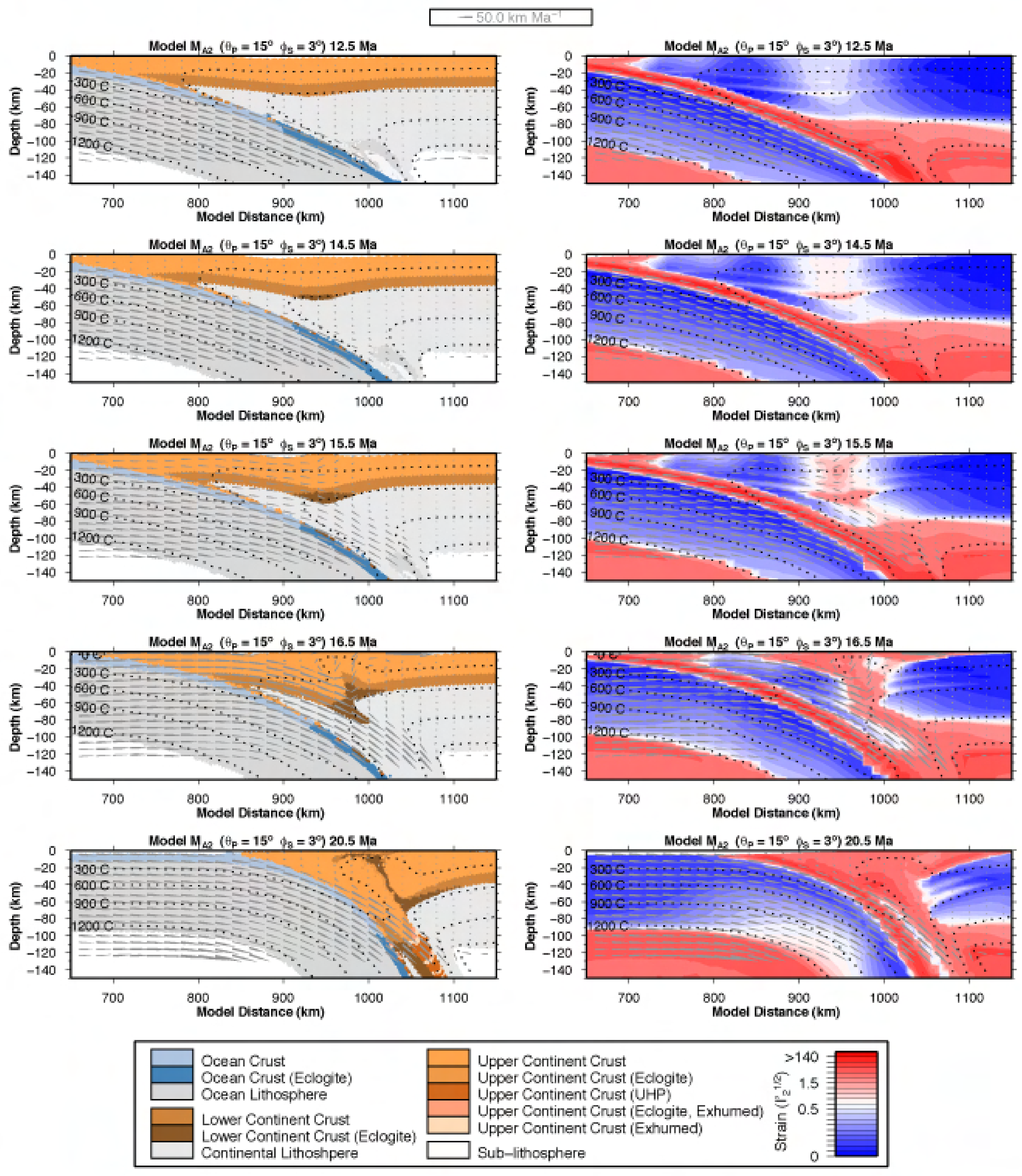

Figure 3: *Progressive material positions and cumulative strain for a finite element numerical model of internal-weakening subduction erosion. Shown are closeups of the subduction zone occurring within an upper mantle scale (2000 km x 660 km) model.*

Internal-weakening subduction erosion is a good candidate mechanism for forearc removal from southern Mexico at the end of the Oligocene. It predicts the rapid removal of a large forearc block, the rapid trench migration, the lower crust unroofing and back-thrusting in the orogenic zone and the late-stage subsidence of the continental shelf, all observed in the geological record of southern Mexico (Fig. 2).

References

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