EGU25-14789, updated on 21 May 2025
https://doi.org/10.5194/egusphere-egu25-14789
EGU General Assembly 2025

Evolution of Quadruple Junction: Example from Afro-Arabia plate boundary

Thamer Aldaajani, Balazs Attila, Taras Gerya, Philip Ball, Khalid Almalki, and Essam Abd El-Motaal
KACST, National Labs, Riyadh, Saudi Arabia (thamer@caltech.edu)

A quadruple junction is a distinctive phenomenon in plate tectonics characterized by the convergence of four tectonic plate boundaries at a single geographic location. While such occurrences are infrequent within the realm of plate tectonics, they provide a valuable opportunity to explore the processes involved in the evolution of the solid Earth. In this context, we examine the Afro-Arabia plate boundary as a pertinent example of a quadruple junction. The establishment of the Makkah Madinah Transform Zone (MMTZ) as a significant tectonic boundary has profoundly influenced the geological framework of western Arabia, offering a fresh perspective on the geodynamics of the broader Red Sea area, particularly with the advent of the central Red Sea triple junction. The MMTZ is estimated to have an age ranging from 27 to 30 million years, inferred from the configuration of plate boundaries surrounding the southern Red Sea, Sirhan, eastern Mediterranean, and the Zagros orogenic zone. In our reconstruction of the Red Sea, we apply a rotation of 6.7 degrees for Arabia relative to Africa, utilizing the topographic alignment of both rift flanks to facilitate basin closure. We establish a connection between the MMTZ plate boundary and the Ader Ribad depression in Sudan, grounded in both spatial and temporal analyses. Chronological investigations of the Ader Ribad depression indicate an exhumation event occurring approximately 31 million years ago, coinciding with the timeline of the MMTZ. The coexistence of these two plate boundaries exemplifies a unique tectonic scenario of a quadruple junction. We present reconstructions of the Afro-Arabia plate and 3D thermo-mechanical numerical models with the code I3ELVIS of the Afro-Arabia plate boundary to substantiate our hypothesis. The code implements a marker-in-cell approach with finite differences method. The model consists of upper and lower continental crust, lithospheric and sublithospheric mantle until 220 km depth. Multi-directional extension is simulated by imposing variable divergence velocities on the right and rear model sides. Extensional and transtensional deformation is initially localized along implemented rheological and thermal weaknesses.