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Deconvoluted evolution of the intra-plate Rhine Graben during the Cenozoic

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The European Cenozoic Rift Intraplate System (ECRIS) is a deep crustal discontinuity. On the surface, its longest segment, the Rhine Basin, is a large scale asymmetric rift that has been largely studied by sedimentary and tectonic inquiries for its oil and geothermal potential. However, the mechanism behind its development is still under discussion. Different scenarios co-exist, among them an East-West Oligocene extension of unknown origin (Bergerat, 1985), a transtensive opening, associated with a North-South compression linked to the Pyrenean orogeny (Bourgeois et al., 2007) and an opening caused by the alpine slap pull (Merle and Michon, 2001).

This study focuses on the reinterpretation of 1500km of seismic lines and 330 boreholes in the Rhine Graben French part. Four evolutive isochrones and structural maps are proposed, showing the evolution of the fault activity and sedimentary deposition during the Cenozoic. They have been constructed through a seismic stratigraphy analysis that allowed to map five stratigraphic interpolated horizons within the Cenozoic sedimentary pile, including a newly interpolated intra-Chattian horizon. Furthermore, the 3D fault networks active during each period have been constructed, sorting the faults regarding their periods of activity and correlating their expression from one seismic profile to another, including their geometry, their measured throw values, and impact on the sedimentary filling of the Graben.

The first isochrone/structural map extends from the Lutetian to the end of Priabonian (Eocene), lasting 10Ma. It displays a North-South succession of small basins constrained by NS to N40° faults, except in the Erstein transfer zone, where a N70° Variscan suture marks the bedrock. Here, faults adopt a N150° trend. The major West border faults are segmented, alternating with onlap zones.

The second map is of Rupelian (Oligocene) age, lasting 2.9Ma. It displays three larger basins, the Strasbourg, Selestat and the Dannemarie basins, separated by EW thresholds of lower subsidence. In those basins, the three time faster subsidence indicate the climax of the rifting. Interestingly, intra-basin active faults are less numerous during this step and are only reactivated faults from the first step.

The third map points to a transition phase of Rupelian-Chattian age (Oligocene) lasting 4.4Ma. It is characterized by a global slowing down of the subsidence and the tectonic activity except for a small basin at the North-Eastern limit of our study area, constrained by a N10 fault.

The last map is of Chattian to Late Miocene age, lasting 21.1Ma. It is characterized by a new high subsidence in the North, lasting from Chattian to mid-Miocene, but also by the re-activation of the former faults and the development of newly formed normal or transtensive faults. This extensive event is followed by a transtpressive event (supposedly Late Miocene) illustrated by faults-flanked anticlines structures, interpreted as positive flower structures linked to the Alpine orogeny.

This study points to the complex structure of the Rhine basin, involving several sub-basins and fault kinematics evolving in space and time, and the major role of deep structural inheritances in governing the graben asymmetry and fault expression in the sedimentary cover.