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Quantifying divergence obliquity: a key control on rifted margin architecture and the formation of long-offset transform faults at mid-ocean ridges

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Oblique divergence at plate boundaries is the kinematic state where the relative plate velocity is not orthogonal to the long-wavelength plate boundary trend. Previous observational and modelling studies suggest that oblique divergence strongly affects syn-rift tectonics, rifted margin formation, as well as the generation of long-offset mid-oceanic transform faults. However, most of these studies focussed on present-day kinematics disregarding past plate boundary configurations. Here we jointly analyse past and present plate kinematics of continental rifts and mid-oceanic ridges worldwide in order to deduce spatiotemporal patterns of oceanic and continental oblique divergence.

We find that oblique extension in continental rifts is a very frequent feature. Our analysis shows that more than ∼70% of all major continent-scale rift systems since the formation of Pangea exceeded an obliquity of 20° (i.e. the angle between plate boundary trend normal and relative plate divergence velocity). The global mean rift obliquity since 230 Ma amounts to 34° with a standard deviation of 24°. Rifting at these obliquities produces 3-D stress and strain fields that cannot be accounted for in simplified 2-D plane strain analysis. Our results therefore stress the importance of 3-D approaches in modelling, surveying, and interpretation of most rifted margin segments on Earth where oblique rifting was the dominant mode of deformation.

Our analysis also shows that at the Atlantic and Indian mid-ocean ridges, the extent of long-offset transform faults (i.e. transforms that exceed 200-300 km length) is primarily controlled by large-scale obliquity while the divergence rate has only secondary importance. In the Pacific Ocean, however, we find the opposite to be true: transform lengths correlate roughly with divergence rate, but not with long-wavelength ridge obliquity. This dichotomy reflects the impact of continental rift obliquity on the Indo-Atlantic ridge network whose overall shape has been inherited from Pangea breakup, whereas the Pacific transforms are entirely unrelated to rifting. We also find that short-offset transform faults with lengths smaller than ∼200 km do not exhibit a correlation with divergence obliquity or velocity and thus appear to be entirely controlled by local ridge dynamics.