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Basement fault reactivation and its influence on fracture orientation at different scales

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Throughout the life of a rift basin, pre-existing basement structures commonly reactivate, resulting in variable fracture patterns in the overlying basin. Nonetheless, the impact of reactivation on natural fracture patterns at different scales is poorly understood. The issue is of particular significance for the unconventional hydrocarbon and geothermal energy industries, where it becomes difficult to determine the fracture distributions required for reservoir modeling and subsequent fluid flow simulations.

Advances in unmanned aerial vehicle (UAV) technology, digital photogrammetry, and computer-assisted mapping tools greatly improve the efficiency of fracture sampling on outcrop analogues. This enables us to link outcrop data more effectively to the larger scales of fracture characterization captured in geophysical datasets. In this field-based case study in the Cretaceous Gippsland Basin of southeast Australia, we use high-resolution, UAV-derived orthophotographs and digital outcrop models to map fractures in outcrops of the clastic sedimentary basin fill and its underlying Devonian basement. We also use fracture maps interpreted from geophysical potential field data and near-shore bathymetry to compare reservoir-scale fractures with large (>1 km long) fault zones. The array of data and field observations allows us to link fracture sets with deformation events throughout the basin's history, from initial Cretaceous rifting to recurring periods of post-rift Cenozoic shortening and inversion.

We have identified a regional joint set that likely formed during post-rift shortening. Comparison between different outcrop localities show that this regional joint set is either absent or rotated near larger, pre-existing faults, highlighting the role of pre-existing discontinuities during fracturing. Mapping of large fault zones across the basin also shows that some faults are similarly oriented with the structural grain in the underlying basement, suggesting that basement anisotropies exerted considerable control on rift fault orientations. A significant implication from these results is that fracture distributions are not self-similar from outcrop to kilometer-scale when basement reactivation is occurring. As a consequence, outcrop studies become essential when interpreting fracture distributions from regional datasets.