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Constraining Paleo-Fluid Flow Events at Rifted Continental Margins: 3-D Seismic Evidence From the Exmouth Plateau, Northwest Australia

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ABSTRACT

The study of focussed subsurface fluid flow mechanisms provides insights into the dynamics of fluid related geological processes such as hydrocarbon migration and overpressure generation, though most research focusses on geologically recent fluid flow systems. Here we present evidence for highly focused paleo-fluid flow events in the Jurassic using high quality 3D seismic data from the Northern Carnarvon Basin of Northwestern Australia. This passive margin sedimentary basin contains up to 15km of Mesozoic to Cainozoic sediments, and is Australia's premier hydrocarbon-producing region. Despite this, there are few studies on focused fluid flow within the basin. We have identified 315 paleo-fluid flow features in Triassic, and Jurassic syn-rift sequences of the Exmouth Plateau of the Northern Carnarvon Basin using three different seismic surveys. The fluid flow features are identified as columnar pipes that disrupt seismic reflectors and cross-cut stratigraphy. They terminate at the top of the Jurassic sequence and are overlain by paleo-pockmarks. Though the Triassic and Jurassic sequences contain rift-related faults with multiple orientations, the pipes and paleo-pockmarks form parallel linear trends aligned to the strike direction of only one set of normal faults in each study area – NNE in the first , and NNW in the second and third study areas. The upper tips of these faults also terminate along the top of the Jurassic sequence, with paleo-pockmarks developed at lateral offsets of 500-750 m. The basal tips of the faults terminate within the Triassic sequence while bases of the pipes are interpreted to intersect with, and terminate along the faults. We suggest that pipes and paleo-pockmarks were generated by faulting that intersected an overpressured unit within Triassic deltaic sediments. Overpressure reduced the differential stress of overburden, with the lowest differential stress becoming focussed at the point of fault intersection, creating local high permeability zones that facilitated fluid escape prior to vertical migration in the direction of maximum negative pressure gradient. The source of fluid overpressure is interpreted to be either in situ hydrocarbon generation or sediment consolidation following under-compaction. Our results provide a better understanding of the history of overpressure generation in the Carnarvon Basin and help reduce uncertainty regarding the timing of hydrocarbon charge in frontier exploration areas.