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Natural fracturing, by depth

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Natural opening-mode fractures commonly fall upon a spectrum whose end-members are veins, which have wide ranges of sizes and are mostly or thoroughly cemented, and joints, which have little opening displacement and little or no cement. The vein end-member is common in metamorphic rocks, whose high temperature and pressure of formation place them outside typical reservoir settings; conversely, many uncemented joints likely form near the surface and so too have limited relevance to subsurface exploration. Sampling of cores retrieved from tight-gas sandstone reservoirs suggest that it is intermediate fractures, not true joints or veins, that provide natural porosity and permeability. Such fractures have abundant pore space among fracture-bridging cements, which may hold fractures open despite varying states of stress through time. Thus the more sophisticated our understanding of the processes that form veins and joints, i.e. how natural fracturing varies by depth, the better our ability to predict intermediate fractures.

Systematic differences between veins and joints, in terms of size-scaling and lateral and stratigraphic spatial arrangement, have been explained in the literature by the mechanical effects of sedimentary layering, which likely exert more control over fracture patterns at shallower depths. Thus stratabound joints commonly have narrow size ranges and regular spacing; non-stratabound veins have a wide range of sizes and spacings. However, new fieldwork and careful literature review suggest that the effects of mechanical layering are only half the story. Although atypical, veins may be highly stratabound and yet spatially clustered; non-stratabound fractures may nonetheless feature narrow size ranges. These anomalous fracture arrangements are better explained by the presence of precipitating cements during fracture opening than by mechanical layering. Cement is thought to be highly important for fracture permeability, but potential effects of synkinematic cement on fracture size and spacing have been largely overlooked. Such effects are currently poorly understood, but numerical models of fracture widening amid precipitating cements can replicate observed size-scaling patterns. Synkinematic fracture-bridging cements can also potentially account for irregular fracture spacing in stratabound fracture arrays.