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Seal Bypass Systems in Deep Water Fold Belts

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We present an interpretational framework for the analysis of a diverse set of geological structures that breach sealing sequences and allow fluids to flow vertically or subvertically across the seal. In so doing they act as seal bypass systems (SBS). We define SBS as seismically resolvable geological features embedded within sealing sequences that promote cross-stratal fluid migration and allow fluids to bypass the pore network. We classify SBS into three main groups based on seismic interpretational criteria: (1) fault related, (2) intrusion-related, and (3) pipe-related. We show how each group exhibits different modes of behaviour with different scaling relationships between flux and dimensions, and different short and long-term impacts on seal behaviour. If such bypass systems exist within a given seal sequence, then predictions of sealing capacity based exclusively on the flow properties (capillary entry pressure/hydraulic conductivity) of the bulk rock can potentially be negated by the capacity of the bypass system to breach the grain and pore network.

We present a range of examples of SBS affecting contrasting types of sealing sequences within deepwater fold belt settings using 3D seismic data. These examples show direct evidence of highly focused vertical or sub-vertical fluid flow from subsurface reservoirs up through the seal sequence with leakage internally at higher levels or to the surface as seeps and/or as pockmarks. Our examples come from regions of active deepwater exploration including offshore Nigeria, offshore Borneo, and the Levant Basin (eastern Mediterranean). We show examples of leakage through pipe-like vents, through mud volcano conduits and along thrust faults. We examine the likely hydrodynamic conditions leading to the formation of these leakage pathways, and in particular examine the interplay between degradation of folded topography, submarine slope failure and rapid unloading of sealing sequences as a means of promoting seal failure and leakage. The possible role of hydrate dissociation in preconditioning seals for later failure under higher effective stress conditions is examined. We also highlight the critical role of stratigraphic leakage routes, whereby juxtaposition of coarse-prone units allows fluids to move laterally towards suitable vertical escape structures, to give a combined multi-storey mode of fluid venting. Consideration of these examples may assist in seal prediction in deepwater exploration campaigns, where more classical methods of sample based analysis might lead to erroneous confidence in seal integrity.