Inversion Tectonics: Overrated in Exploration and Underreported in Production?

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Abstract

Albert W. Bally provided the first description of structural inversion in the early 1980s. By definition, an inversion structure forms when a pre-existing extensional (or transtensional) fault controlling a hangingwall basin containing a syn-rift or passive fill sequence subsequently undergoes compression (or transpression) producing partial (or total) extrusion of the basin fill. Inverted structures provide traps for petroleum exploration, typically four-way structural closures. As to the degree of inversion, based on large number of worldwide examples seen in various basins, the most preferred petroleum exploration targets are mild to moderate inversional structures, defined by the location of the null-points. In these instances, the closures have relatively small vertical amplitude, but simple in a map-view sense and well imaged on seismic reflection data. Also, the closures typically cluster above the extensional depocentres which tend to contain source rocks sequences providing petroleum charge even after the inversion. Cases for strong or total inversion are generally not that common and typically are not considered as ideal exploration prospects, mostly due to breaching and seismic imaging challenges associated with the trap(s) formed early on in the process of inversion. Also, migration may become tortuous due to the structural complexity or the source rock units may be uplifted above the hydrocarbon generation window effectively terminating the charge once the inversion occurred. For any particular structure the evidence for inversion is typically provided by subsurface data sets such as reflection seismic and well data. However, in many cases the deeper segments of the structure are either poorly imaged by the seismic data and/or have not been penetrated by exploration wells. In these cases the interpretation of any given structure in terms of inversion has to rely on

the regional understanding of the basin evolution with evidence for an early phase of substantial crustal extension by normal faulting. In some cases, the simple reactivation of pre-existing structures related to earlier episodes of shortening in the area have been erroneously classified as inversion. Listing of “reverse” or “thrust” faults under “trap form type” of hydrocarbon fields in a very large worldwide data base (but excluding US/Canada) provided 2242 matches. Interestingly, only 28 of these fields (about 1.2%) were classified under the “trap forming mechanism” as inversion! Therefore we believe that during the life-cycle of many E&P projects the term inversion is often used quite loosely during the exploration phase. In contrast, during the production phase the exact meaning of inversion as a trap forming mechanism is typically lost and replaced by the more generic "compression" or "overthrusting" descriptors.