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FRACTURED RESERVOIR ANALYSIS WITH EXAMPLES FROM THE CRETACEOUS CARBONATES OF LAKE MARACAIBO, VENEZUELA

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Exploration and development in fractured reservoirs required that we address the following technical sequence or work flow:

1. Determine fracture system origin(s),
2. Quantify fractured rock properties that affect reservoir performance,
3. Document fracture and matrix porosity interaction,
4. Characterize and/or classify the reservoir system, and
5. Locate optimum exploration or development locations and well paths.

To accomplish this evaluation we must integrate outcrop and core observations, rock mechanics tests, core analyses, well test data, log response, seismic interpretations, and drilling records. Results indicate whether or not the reserves and production rates expected are economic to develop. An example of such a study is shown from the deep Cretaceous La Luna and Cogollo Reservoirs of primarily Block 1 in Lake Maracaibo, Venezuela.

Characteristics of these fractured reservoirs have been previously published in, among others, Bueno and Avila (1987), Franseen and Others (1992), and Willemse and others (1990). In our current study, observations from about 5,000' of core from 13,000' to 15,000' depths support the general deformation sequence of Franseen and others (1992) involving burial and tectonic stylolites, vertical extension fractures, thrust stress state fracture sets, and wrench stress state fracture sets. In addition to these, we also define: (1) A system of regional orthogonal fractures especially prevalent in the La Luna and Maraca Formations, (2) Normal fault stress state fractures, and (3) Discreet zones of high intensity fault zone fractures as opposed to the more homogeneous or facies controlled fracture distributions implied in Franseen and Others (1992).

Quantification of the reservoir properties of the fractures present is difficult due to a lack of availability of large sample or whole-core analyses and laboratory compressibility tests for both fractures and matrix. However, observed fracture plane morphologies display a variety of textures and fills that must be quite conducive to fluid flow. These include: open vertical fractures, slickensided fractures (many of which display horizontal or wrench-like slickensides regardless of their original motions inferred from geometry), and partially mineralized fractures. The partially filled fractures are perhaps the least compressible and most conducive to fluid flow and are often saturated with hydrocadrbons. These can occur along one direction of the regional orthogonal fracture set (filled with Eocene dead oil?), along isolated vertical extension fractures, and as unloading partings overprinting previously filled fractures and stylolites. Analysis of the fracture planes indicate no pervasive inhibition to cross-flow between the fractures and the low porosity rock matrix (generally less than 3%).

Core and log observations indicate reservoir zones of fracture porosity, matrix porosity, and fracture plus matrix porosity. However, most porosities are relatively low and display a weak control by lithology and stratigraphic sequences. A general lack of production surveys in the deep Cretaceous wellbores makes estimates of the relative contribution of each porosity system to total flow speculative. Nevertheless, it is probable that the section exposed in these 1000'-plus open hole completions responds as a mixed Type I and Type II fractured reservoir as defined in Nelson (1985). In Type I sections, fractures provide essential permeability and storage, while in Type II sections fractures provide essential permeability, and matrix provides essential storage. While the section may be of a mixed behavior, preliminary results indicate that Type I behavior may dominate in the current wells.

The choice of optimum well locations and well paths is dependent, therefore, primarily on encountering the greatest number of fractures per linear foot of wellbore completion. Because we interpret the greatest fracture intensity in core to be related to fracture 'halos' surrounding faults, optimum well paths should maximize their travel within these narrow zones and communicate as many isolated matrix porosity zones as possible through these zones. Optimum positioning is made possible by detailed analysis and interpretation of normal, reverse, and wrench faults, especially at the La Luna/Maraca level, on a recent 3D seismic survey in Block 1 in Lake Maracaibo.

References

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