Numerical Modeling of Secondary Migration in Faults

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Numerical modeling using reservoir simulators has the potential to illuminate the processes by which hydrocarbons are emplaced during secondary migration. The modeling of secondary migration in faults provide insight into 1) possible bypassing mechanisms (i.e. why traps are underfilled) and 2) how column heights and composition may change through time. Two- and three-phase analytical and numerical models describing the relationship between secondary migration through fault zones and the concurrent charging of reservoirs in juxtaposition with these faults are presented. In these models the fault zone is assumed to behave as a porous medium with the flow governed by Darcy's Law.

The problem is illustrated in Figure 1. Oil and gas enter the bottom of the fault zone. At sufficiently high pressures all the gas would be in solution. The hydrocarbons migrate up through the fault zone due to buoyancy and when the pressure drops below the bubble point, a free gas phase is formed. As the hydrocarbons flow by sands juxtaposed against the fault zone the capillary pressure in the fault zone drives some of the oil and gas into the sands. The system modeled is isothermal, the geometry is fixed, and the porosity and permeability are constant.

Key results of the model are:

- Column height is a dynamic function of charge rate and not a static function of "capillary-entry pressure" as is often assumed,
- A fault can serve both as a migration pathway and as a seal,
- Hydrocarbons migrating along faults can backfill adjacent sands,
- Under-filled structures may result where reservoir sands pinch out away from the fault and hydrocarbons cannot displace the "perched" water that develops down dip,

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- In three-phase (oil, water and gas) cases hydrocarbon column heights significantly larger than the steady state values can form as the sand charges and
- Given similar petrophysical fault properties with depth and isotropic permeability, deeper sands will fill sequentially before shallower sands.

The hydrocarbon column heights that result from this process are controlled by the petrophysical properties of the fault zone, the flux of fluids into the fault zone, and the geometry of the reservoir. The degree of heterogeneity and anisotropy of the fault zone can have a significant effect on whether given reservoir sands are charged or bypassed. At steady state, the capillary pressures in the fault zone and the adjacent reservoir must be equal; the capillary pressures (which are a function of the hydrocarbon saturations in the fault) at this interface are the most important parameter in the determination the hydrocarbon column heights in an adjacent sand.

In summary, this work examines a physical model that provides insight into the secondary migration of hydrocarbons through faults and the subsequent charging of adjacent reservoir sands. The key parameters that control hydrocarbon column heights in the model are identified and observations are made about the charging of these reservoir sands.

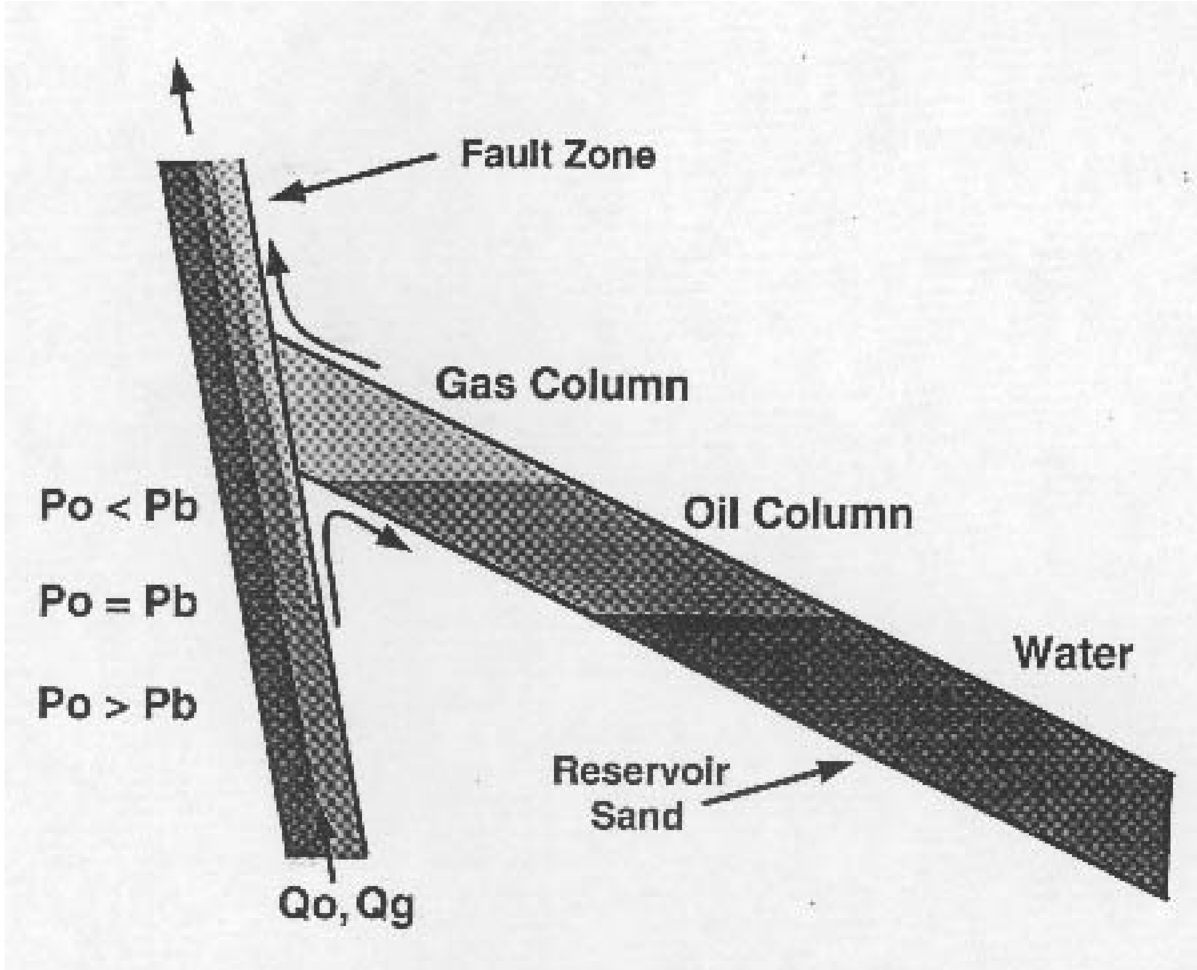

Figure 1 3-Phase migration schematic. Hydrocarbons enter the bottom of the fault zone and flow upwards due to buoyancy. As they flow up the fault zone some of the hydrocarbons will be driven into the sand by capillary forces. Po = oil phase pressure and Pb = bubble point pressure. At pressures below the bubble point pressure, a discrete gas phase is present