ENTRAPMENT OF PETROLEUM UNDER HYDRODYNAMIC CONDITIONS

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ABSTRACT

Despite its effectiveness as a basis for petroleum exploration, the anticlinal theory represents but a special case of oil and gas accumulation and is valid only when the associated ground water is in hydrostatic equilibrium. Since ground water need not be at rest, a more general formulation valid for both hydrostatic and hydrodynamic conditions is required.

Oil and gas possess energy with respect to their positions and environment, which when referred to unit mass may be termed the potential at any given point of the fluid considered. When the potential of a specified fluid in a region of underground space is not constant an unbalanced force will act upon the fluid tending to drive it in the direction in which its potential decreases. Hence oil and gas in a dispersed state underground tend to migrate from regions of higher to those of lower energy levels, and come ultimately to rest in positions which constitute traps, where their potentials assume locally minimum or least values. Most often traps for petroleum are regions of low potential which are enclosed jointly by regions of higher potential and impermeable barriers.

Oil and gas migration occurs through a normally water-saturated environment. If the water is at rest, oil and gas equipotential surfaces will be horizontal, the impelling forces will be directed vertically upward, and the traps will be the familiar ones of the anticlinal theory. If the water is in motion in a nonvertical direction, the oil and gas equipotentials will be tilted downward in the flow direction with those for oil inclined at a greater angle than those for gas. The impelling forces for oil and for gas will not be parallel and the two fluids will migrate in divergent directions to traps which will not in general coincide and may, in fact, be separated entirely, a trap for oil being incapable of holding gas, and *vice versa*.

Under hydrodynamic conditions accumulations of oil or gas will invariably exhibit inclined oil- or gas-water interfaces with the angle of inclination given by

$$\tan \theta = \frac{dz}{dx} = \frac{\rho_w}{\rho_w - \rho_o} \frac{dh}{dx} ,$$

where dz/dx is the slope of the interface, ρ_w the density of the water and ρ_o that of the oil (or gas), and dh/dx the component of the hydraulic gradient of the water in the direction x. Stable oil and gas accumulations may be found in anticlines but they may equally well occur in structural terraces, noses, monoclines, and other unclosed structures entirely devoid of lithologic barriers to updip migration.

Not only are these effects theoretically expectable, but they occur, with tilts ranging from tens to hundreds of feet per mile, in almost every major oil-producing area. If many such accumulations are not to be overlooked, we are faced with the necessity of supplementing our customary knowledge of structure and stratigraphy with the three-dimensional ground-water hydrology of every petroliferous basin.