Relationship between Primary Migration and Compaction of Rocks

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The clays, being apparently the principal oil-source rocks, have the property of changing their volume considerably under the action of gravitational and tectonic pressure. Rocks that are capable of shrinking as a result of diagenetic changes pass through several stages of compaction, which may lead to a decrease in their porosity to 10-12%.

During the process of compaction, water is expelled first from the rocks. The hydrocarbons composing oil remain up until such time as the ratio of water to hydrocarbons reaches a value where oil hydrocarbons are squeezed out together with the water. At this last stage there remains in the subcapillary pores of the rock both combined water and disseminated droplets and films of oil as well as bubbles of gas. Further, the bubbles are expelled from the small pores and into the larger (1).

In connection with the shrinkage of rocks (due to compaction) in the absence of expelling of water and oil hydrocarbons from the pores, the liquid and gas-forming matter moves and forms larger pores occupied by oil, water, and gas.

During the process of compaction the volume of the various rocks changes differently due to several causes, particularly the dimensions of the particles composing the rock. Thus, the volume of sandy rocks changes less than does that of clays.

During compaction of clays, the contents of the pores, being expelled, will travel into rocks having a high permeability and a low intra-pore pressure. The intra-pore pressure in clayey rocks is higher than the formation pressure of sandstones and is close to the rock pressure—even exceeding it. In those cases where the intra-pore pressure is beyond the elastic limit of the rock, fractures should form.

The practice of artificial separation of rocks (hydrofracture) shows that the pressure at which parting takes place is 1.4 to 2.4 times greater than the hydrostatic pressure.

Rocks that are impermeable under some conditions become permeable due to rupturing and to opening of the fractures, which can serve as paths for transfer of oil hydrocarbons from the oil source rocks into permeable strata.

Taking into account the difference in phase permeability of water and oil, during the earlier stages of compaction largely water should be expelled. Then at a particular ratio of oil and water in the micropores, water and hydrocarbons are expelled together. In the latter stage of compaction, largely oil is expelled from the oil source rocks.

The migration of oil from the oil source rock must be regarded as a discontinuous process governed by the necessity for an increase in the intra-pore pressure to a value at which the rock can rupture, opening fractures that connect the place of accumulation of the oil and gas droplets with porous and permeable rocks having less pressure.

At the final stage the source rocks contain only those organic deposits which are not capable of migration due to the mechanical properties that are governed by the molecular state.

The main cause of the primary migration apparently is an increase in the intra-pore pressure to a value at which paths of migration can form (2).

An oil source formation with oil, gas, and water can be regarded as a stratum or formation bounded on all sides and not connected hydrodynamically with the enclosing rocks.

The problem of increasing the pressure of a closed stratum with respect to increasing the rock pressure can be examined in the area of elastic deformation, using the following formula proposed by E. B. Chekalyuk (3):

$$\Delta P_{zhg} = (\beta_{zh} - \beta_M)\Delta P_g/[(\beta_{zh} - \beta_M) + t(\beta_{zh} - \beta_M)]$$

where $\Delta P_{zhg}$ and $\Delta P_g$ are the increases in formation and rock pressures; $\beta_{zh}$, $\beta_{zh}$, and $\beta_M$ are coefficients of the volume elasticity of water, of the skeleton of the formation, and of the minerals; and $t$ is the thickness of the stratum.

The increase in the formation pressure due to an increase in temperature can be determined according to the formula:

$$\Delta P_{zh} = (C_{zh} - C_M) \Delta T/\beta_{zh}$$