Primary Migration of Petroleum: A Phenomenon Revisited

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ABSTRACT

Primary migration is the expulsion-driven movement of the generated hydrocarbons through and out of the fine-grained source rock. It is fundamentally different from the buoyancy-driven movement of expelled hydrocarbons through porous and permeable rocks, which is denoted by secondary migration. This phenomenon was revisited through a combination of analytical, experimental and applied studies, which were conducted on a variety of organic-rich shales around the globe. The studies revealed that the process of primary migration of petroleum is sequential. It is a “cause-effect” relationship between petroleum generation and expulsion. Petroleum migrates out of the source unit in three stages: 1) initial bitumen impregnation, 2) internal hydrocarbon expulsion and 3) external hydrocarbon migration. The initial stage takes place during bitumen generation. Kerogen volume reduction creates void space within the kerogen particle, around the kerogen particle and along bedding planes. Bitumen occupies the created void space before internal expulsion can begin. As the thermal conditions continue to satisfy certain kinetic requirements, hydrocarbons are generated (e.g., oil), internal expulsion stage starts as a consequence of significant volume increase, and followed by pressure increase. Pressure increase due to volume expansion can cause fracturing and can locally open existing ones facilitating internal expulsion. Fracturing favors the horizontal direction for internal expulsion and migration mimicking the horizontal laminations. Bedding parallel partings and fractures may interconnect with near vertical or vertical pressure induced fractures. Ultimately, they act as migration pathways allowing upward and/or downward external migration into carrier beds. After the external migration stage, the transient pressure decreases, causing the bedding parallel partings and fractures to heal. This can generate episodic pressure build-up/release cycles as more generation and fracturing occur. This also can be repeated until it declines to a level where pressure does not increase sufficiently to re-open or create fractures. The studies, addressed here, have documented the physical and chemical factors controlling the initial movement of petroleum in the subsurface. They explain fracturing of mature source rocks as an indispensable prior to significant petroleum expulsion. This impacts our understanding of the formation of unconventional petroleum systems in organic-rich shales.