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GEOLOGY

Endogenous Factors of the Formation of Oil Fields in the Crystalline Basement of the Cuu Long Basin, South Vietnam Shelf

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The study of formation constraints of oil-and-gas (hereafter, petroleum) fields in the Precambrian–Mesozoic basement rocks of sedimentary basins or crystalline basement is of special importance in determining the regularities of naphthide genesis and petroleum accumulation. It is known that most oil fields in the basement are related to combined traps composed of outliers of the weathering crust, fractured zones in the basement, and diverse forms of basal bed wedging in the sedimentary cover of its inliers.

Data on oil geochemistry often suggest the probability of a common source of hydrocarbons (HC) during the formation of oil fields in the sedimentary and crystalline rocks. These data made it possible to interpret petroleum accumulation in the basement from the viewpoint of sedimentary-migration theory (SMT), which is a paradigm of petroleum geology of 20th (and 21st [1]) centuries.

The detection of a strong economic-grade oil flow from the Mesozoic basement in the South Vietnam sector of the South China shelf (Fig. 1) in 1988 led to the discovery of the unique White Tiger and other deposits (Dragon, Rang Dong, Black Lion, and others). Their giant HC resources are confined to the cavernous-fractured granitoid reservoirs [2–6]. These oil fields occur in the basement inliers (reverse faults, low-angle overthrusts, and torsion structures) and extend to depths of 4.6–5.0 km. Therefore, petroleum geologists believed that oil accumulation in the basement is related to the long-term continuous migration of HC from adjacent Oligocene (Chaku and Chatan) formations (Fig. 2).

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The Cuu Long Basin, which hosts the deposits mentioned above, is a complex tectonodynamic (subduction-riftogenic) petroleum basin (PB) [2]. This basin exhibits the highest oil potential of basement rocks among presently known PBs. Therefore, some researchers suggested that the granite layer of the Earth's crust is a new petroleum horizon of lithosphere [3].

More than 92% of explored oil reserves are concentrated in basement rocks of the White Tiger deposit. In this area, the coefficient of HC reservoir filling regularly decreases near the top of the section from 1.0 in basement granitoids to 0.6–0.7 in the Lower Oligocene reservoirs and 0.4–0.5 in the Upper Oligocene–Lower Miocene reservoirs. In addition, the formation pressure in oil-saturated basement zones is 0.5–0.7 MPa higher than that in the adjacent Lower Oligocene horizons. All these facts indicate a predominant role of vertical HC migration during formation of oil fields in the basement of the White Tiger deposit.

At the same time, oils in the basement inliers and surrounding Lower Oligocene rocks have similar compositions in terms of the typical physicochemical characteristics and other parameters, such as the pristane/phytane ratio equal to 2.31 (in the oil from basement) and 2.33 (in the oil from Lower Oligocene rocks); coefficients $Ki = (i\text{-}C_{19} + i\text{-}C_{20})/(n\text{-}C_{17} + n\text{-}C_{18})$ equal to 0.307 and 0.308, respectively; $CPI = (C_{15} + C_{16} + C_{17} + C_{18})/(C_{23} + C_{24} + C_{25} + C_{26})$ equal to 1.065 and 1.082, respectively; and $Kn = (n\text{-}C_{27} + n\text{-}C_{29})/2 \cdot n\text{-}C_{28}$ equal to 1.14 and 1.13, respectively.

In addition, oils from basement and Lower Oligocene fields, as well as HC extracts from mudstones of the Chaku Formation, contain identical porphyrines and some other chemofossils. Oils from the basement and Lower Oligocene fields have similar carbon isotopic composition ($\delta^{13}C$ from –25 to –26‰).

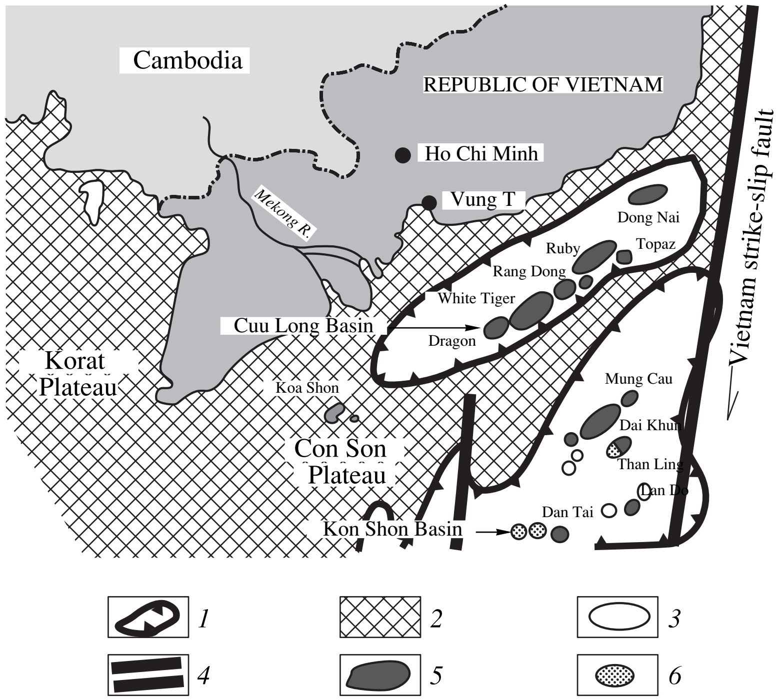

Fig. 1. Scheme of petroleum basins on the shelf of South Vietnam. (*1*) Basins; (*2*) rises; (*3*) local structures; (*4*) strike-slip faults; (*5, 6*) oil and gas deposits, respectively.

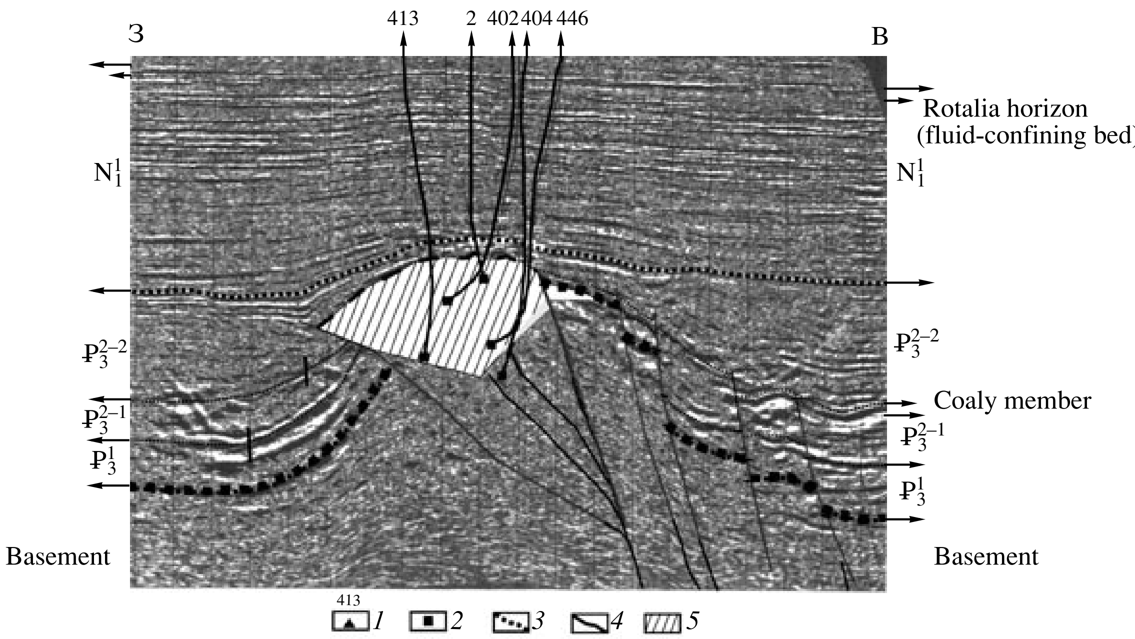

Fig. 2. Temporal seismic profile of the Central dome of the White Tiger deposit. (*1*) Well number; (*2*) bottomhole; (*3*) boundary of stratigraphic units; (*4*) deep-seated faults; (*5*) oil-saturated zone of the basement crystalline rocks.

The leading role in the formation of massive reservoirs in the basement belongs to the interrelated hydrothermal metasomatism [7] and adiabatic fracturing. The latter is represented by fractures of natural hydrorupture and seismic brecciation that are the main factors of the formation of dilatation zones. The intensity of chemical alteration in this process varied from weak hydrogen metasomatism to strong sodium metasomatism with intense zeolitization of feldspars. Hydrothermal processes occurred in several stages (before and