Features of the Formation and Distribution of Oil and Gas Pools in the Lower Permian Sub-Salt Sediments of the Ural-Volga Area

Yu. Ya. Bol’shakov

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More than 70 oil and gas fields have been discovered in Lower Permian sediments of the Volga-Ural oil-gas province. They are located principally in the Cis-Ural downwarp and in the southern part of the platform portion of the province.

The Lower Permian Assel-Sakmar-Artinsk sediments on the platform are organoclastic limestones. Their intergranular porosity is 10-12%, and in places is as high as 22-25%. In the Cis-Ural downwarp these sediments are reefs on the west and molasse on the east. Reservoirs are reef carbonates and sandstones. Open porosity ranges from 2 to 30% and more.

In the Kungur stage, sediments of the Filippov horizon are oil-gas-bearing; these consist largely of dolomites and anhydrites. Oil and gas pools occur here in dolomite, where open porosity ranges from 4-10 to 18-25%.

The Lower Permian carbonate and sulfate sediments are extensively fractured, and this increases their filtration capacity significantly. Fracture permeability of the carbonate rocks ranges from 1.7 to 29 md, increasing in places to 330-1090 md.

The main factors that control the retention of hydrocarbon accumulations are initial pressure, gradients, capillary forces, and formation pressures that are higher in the covering rocks than in the reservoirs. The effect on formation pressure caused by osmotic processes is examined here. Solutions diffuse through semi-permeable membranes (clays and marls here) from low salinity reservoirs into high salinity reservoirs, producing higher formation pressures in the latter. This process was discussed with respect to oil fields by F. A. Berry and B. B. Hanshaw.

Fig. 1 is a diagram showing osmotic difference in pressures on both sides of an ideal semi-permeable membrane as a function of concentration of NaCl in the system NaCl-water. The osmotic pressure of a saturated solution with respect to that of distilled water is about 470 kgs per cm$^2$.

Mineralization of the formation waters of the Lower Permian sediments is as low as 22 g/l and as high as 314 g/l. Formation pressures also have a great range. In the Kungur rocks the formation pressure is 20-30 kgs/cm$^2$ higher than in the Artinsk rocks. In well 73 on the Sol’-Iletsa projection a formation pressure of 165.6 kgs per cm$^2$ was measured at a depth of 885 m in Kungur carbonate rocks; this is almost double the hydrostatic pressure. Such pressures certainly reflect osmotic processes.

All the Lower Permian fields can be put into three categories: 1) oil-gas-bearing Sakmar-Artinsk sediments and no pools in Kungur reservoirs, 2) oil-gas-bearing Kungur and no pools in the Sakmar-Artinsk sediments, and 3) pools in both Kungur and Sakmar-Artinsk reservoirs. See Table 1.

A field of the first group is shown in Fig. 2A. The difference in formation pressures in the Kungur and Artinsk sediments exceeds the excess pressure in the pool. At the boundary between the reservoirs and the shielding rocks there is a jump in mineralization of the formation water with higher values in the Kungur rocks. The relationships of formation energies prevent entry of hydrocarbons into the Filippov (Kungur) reservoirs. In other fields of this group there is an opposite relationship of excess and osmotic pressures. Preservation of the Sakmar-Artinsk pools is governed by the high shielding properties of the covering rocks.

Fields of the second type, where pools occur only in Filippov (Kungur) reservoirs, are located in regions where mineralization of Kungur and Sakmar-Artinsk rocks is more or less the same. Osmotic processes were not a factor here. See Fig. 2B.

Two fields are of the third type. See Fig. 2C for the Orenburg field, which is located in a region with a great difference between the mineralizations of the formation waters of the Kungur and Artinsk sediments. A massive pool more than 500 m high is present in the Artinsk-Middle Carboniferous rocks, and a blanket pool occurs in the Artinsk reservoir. Total mineralization of the waters of the Kungur stage is on an average 56 g/l greater than that of the Artinsk waters. Consequently, formation pressure in the Kungur reservoirs could have been increased by 37 kgs/cm$^2$ due to osmotic processes. The present excess pressure in the Artinsk-Middle Carboniferous pool is 60.8 kgs/cm$^2$. Its excess over the formation energy of the Kungur horizon in connection with the presence of