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ISOTOPE-GEOCHEMICAL PROGNOSIS OF THE STRATIGRAPHIC ORIGIN OF THE OIL SEEPAGE SOURCE IN THE SOUTH CASPIAN BASIN

Husseynov D. A.; Guliyev I. S.; and Feizullayev A.A
Institute of Geology, Baku, Azerbaijan

One of the peculiarities of the South Caspian basin (SCB) is a wide spread of the surface oil and gas seepage, most of which is confined to the mud volcanoes. The latter are spread in many oil and gas structures in the Caspian Sea, Absheron Peninsula, the Shamakhy-Gobustan and the Lower Kura depressions. Conduits of these volcanoes are favorable ways for the upward migration of hydrocarbons from deep subsurface and that is why their study is of a considerable interest. According to the petrographic and paleontologic studies of the ejectas and breccia of mud volcanoes the age varies within a wide range from the Cretaceous to Pliocene. This considerably complicates determination of the stratigraphic and deep confinement of the centre of the hydrocarbon fluids released by mud volcanoes.

The problem can be solved on the base of isotopic-geochemical study of the hydrocarbon fluids released by mud volcanoes with consideration of the most important isotopic-geochemical regularities previously resealed for petroleum fields in the SCB. One of the most important regularities is the determined by the authors' differentiation of carbon isotop ratios for oil in the stratigraphic section expressed in the ^{13}C enrichment in successive order, from older reservoirs to younger. This tendency allows identifying 2 oil groups: 1) the isotopically light ($\delta^{13}C$=-28.2‰ – 27.8‰) oils contained in the Lower Cretaceous. Eocene, Maikop and Chokrak reservoirs; 2) the isotopically heavy oils ($\delta^{13}C$=-24.8‰ –25.0‰) from the Diatom reservoir.

Determination of the delimination values for carbon isotopic composition in the oils from reservoirs of different age made it possible to calculate the share of the Paleogene-Lower Miocene and Diatom deposits in the formation of oil deposits in the Pliocene reservoir the most important oil and gas bearing complex in the SCB.

Presence of both mixed oils produced by the Paleogene-Lower Miocene and Diatom (Middle and Upper Miocene) deposits and oils sourced by single stratigraphic complex is characteristic of the Pliocene reservoirs. Isotopic-geochemical study of oil seeps associated to mud volcanoes allowed two oil groups to be differentiated: oils with typical Paleogene-Lower Miocene carbon isotopic signature, and those representing mixture of oils generated in Paleogene-Lower Miocene and Diatom deposits. Figure 1 illustrates the correlation of mud volcanic seepage according to the isotopic composition of carbon in the saturated fraction. It is inferred from the figure that about 50% of mud volcanoes release exclusively the Paleogene-Lower Miocene oils. Around 17% of the mud volcanoes largely release oils from the Diatom complex of deposits and 33% of them release a mixture having approximately equal share of oils from the Paleogene-Lower Miocene and Diatom complexes.

Regular pattern in spatial location of mud volcanic oil seepages is of interest. According to it the objects with dominant Diatom component in oils are located in remote west part of the South-Caspian depression in the zone of the conjugation zone of the Lower Kura and Shamakhy-Gobustan depressions. In tectonic terms the margin of these structures is deep Ajichay-Alyat fault, over which the Paleogene-Lower Miocene deposits in the south-west flank of the Shamakhy-Gobustan tectonic stage are overthrust the Middle-Upper-Miocene and Pliocene complexes in the north-east part of the Lower Kura stage. Identity of the carbon isotopic composition of oils in the plate moved upon and in the covered stage shows that the oil generation interval supplying mud volcanoes is chiefly within the Diatom complex in the Lower Kura depression.

This conclusion is confirmed by identical low maturity of oils from group of mud volcanic seepage. Assessment of the maturity of oils in mud volcanic seepage according to vitrinite reflectance equivalence (R_o) calculated on sterane aromatization level (C_{28}triaromatic/C_{28}triaromatic+C_{28}monoaromatic) indicates low level of their transformation (R_o=0.46-0.64%). Application of other maturity parameters of the maturity, like hopanes and steranes isomerization ratios, etc. is not possible due to very high biodegradation and oxidation extent of oils. It should be noted that the analogous low maturity is typical for the oils of the fields in the studied region and the Caspian Sea that very rarely is 0.68% (R_o) and on average is 0.61% (R_o).

Quantitative calculations based on the dependence of the carbon isotopic composition of the hydrocarbon gases upon the level of their catagenetic maturity (Faber, 1987) show that for ethane from 8 mud volcanoes located in different parts of the west flank of the South-Caspian depression they are 1.3-1.79% (R_o). On the basis of the measurements of R_o in the SCB down to depth of 5300 m and extrapolation of R_o values to the deep-seated horizons, the hypsometric depth of confinement of ethane of the studied mud volcanoes in the region is within 7-8 km. These depths in the north and the north-west flanks of the depression correspond to the Jurassic-Cretaceous sedimentary complex. In the central deeper part of the basin the ethane formation interval is located at depths corresponding to the Paleogene-Miocene complex.

It should be emphasized that the results are corroborated the correlation of the inert components (He/Ar_r) in the gases of mud volcanoes. Maximum values of He/Ar_r around 2.5 typical for the Mesozoic structural stage were detected in the gases of mud volcanic oil seepages of the remote north and north-west zones of the SCB confined to the Cretaceous deposits. In the mud volcanoes releasing isotopically light oils with the Paleogene-Lower Miocene isotopic signature, He/Ar_r ratio at 0.5 is also typical for the gases generated in this complex of sediments. Gases of volcanoes with the isotopically heavy diatom oils are characterized by He/Ar_r between 0.13 and 0.17.

The above stated gives evidence on the existence of several stratigraphically isolated intervals of hydrocarbon formations in the Mesozoic, Paleogene-Lower Miocene and Diatom deposits. Thus, the oil and gas formation “kitchens” are replaced relatively each other and are confined to different hypsometrical and stratigraphic levels. According to the vertical zonation scheme of oil and gas formation (Fig. 2) all of the oils in the known fields and mud volcanoes correspond to the early stage of oil window. The gases in the fields and mud volcanoes correspond to the zone of wet gas and methane formation. This points to the fact that hydrocarbons lagerly of oil range with the level of maturity 0.64-1.3% (R_o) in the SCB remain undiscovered. This data presented suggest high prospects for discovery of considerable accumulations of mature oils up to condensates in the South Caspian region.

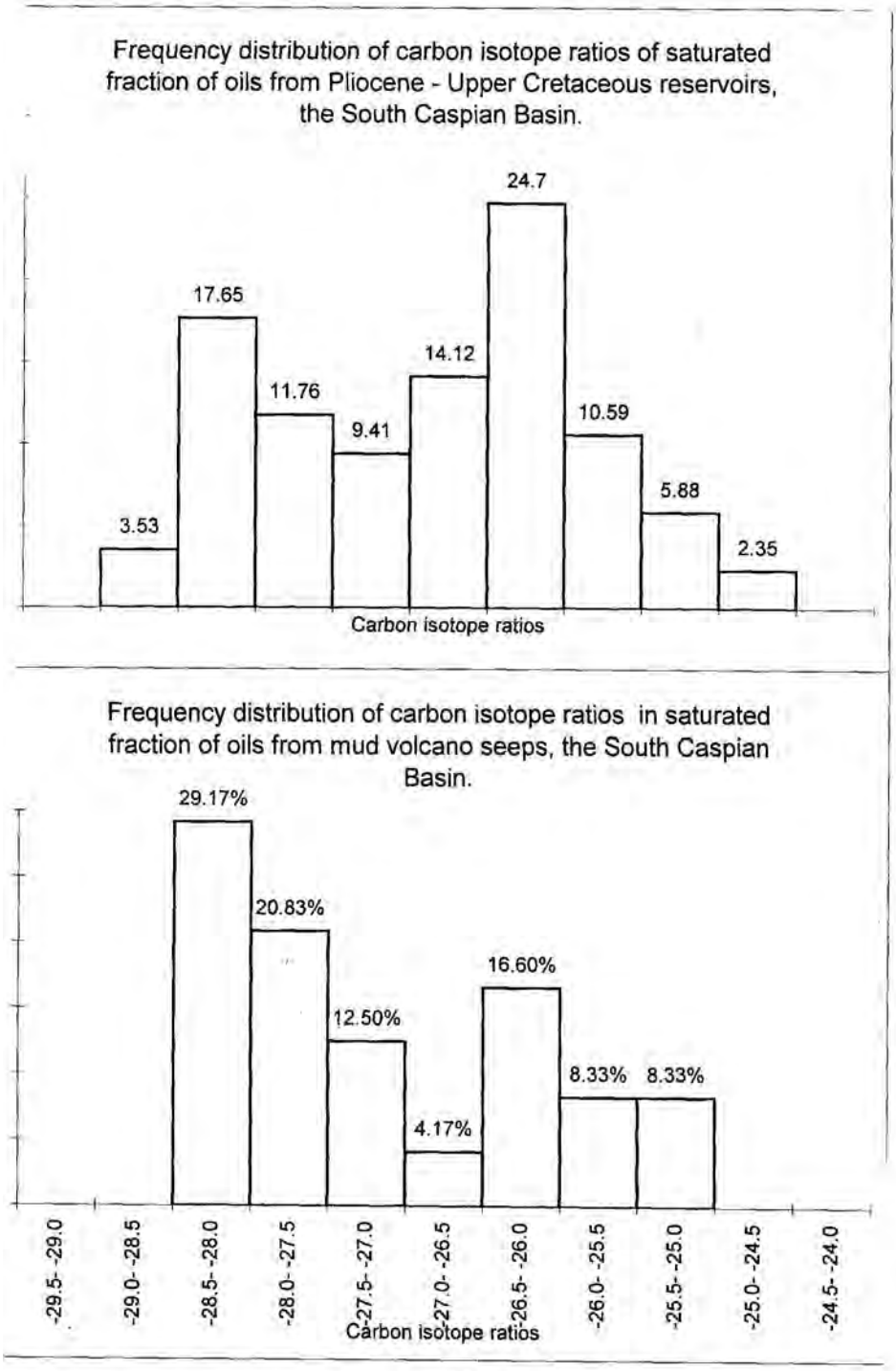
Frequency distribution of carbon isotope ratios of saturated fraction of oils from Pliocene - Upper Cretaceous reservoirs, the South Caspian Basin.
3.53
17.65
11.76
9.41
14.12
24.7
10.59
5.88
2.35
Carbon isotope ratios
Frequency distribution of carbon isotope ratios in saturated fraction of oils from mud volcano seeps, the South Caspian Basin.
29.17%
20.83%
12.50%
4.17%
16.60%
8.33%
8.33%
-29.5- -29.0
-29.0- -28.5
-28.5- -28.0
-28.0- -27.5
-27.5- -27.0
-27.0- -26.5
-26.5- -26.0
-26.0- -25.5
-25.5- -25.0
-25.0- -24.5
-24.5- -24.0
Carbon isotope ratios

Figure 1

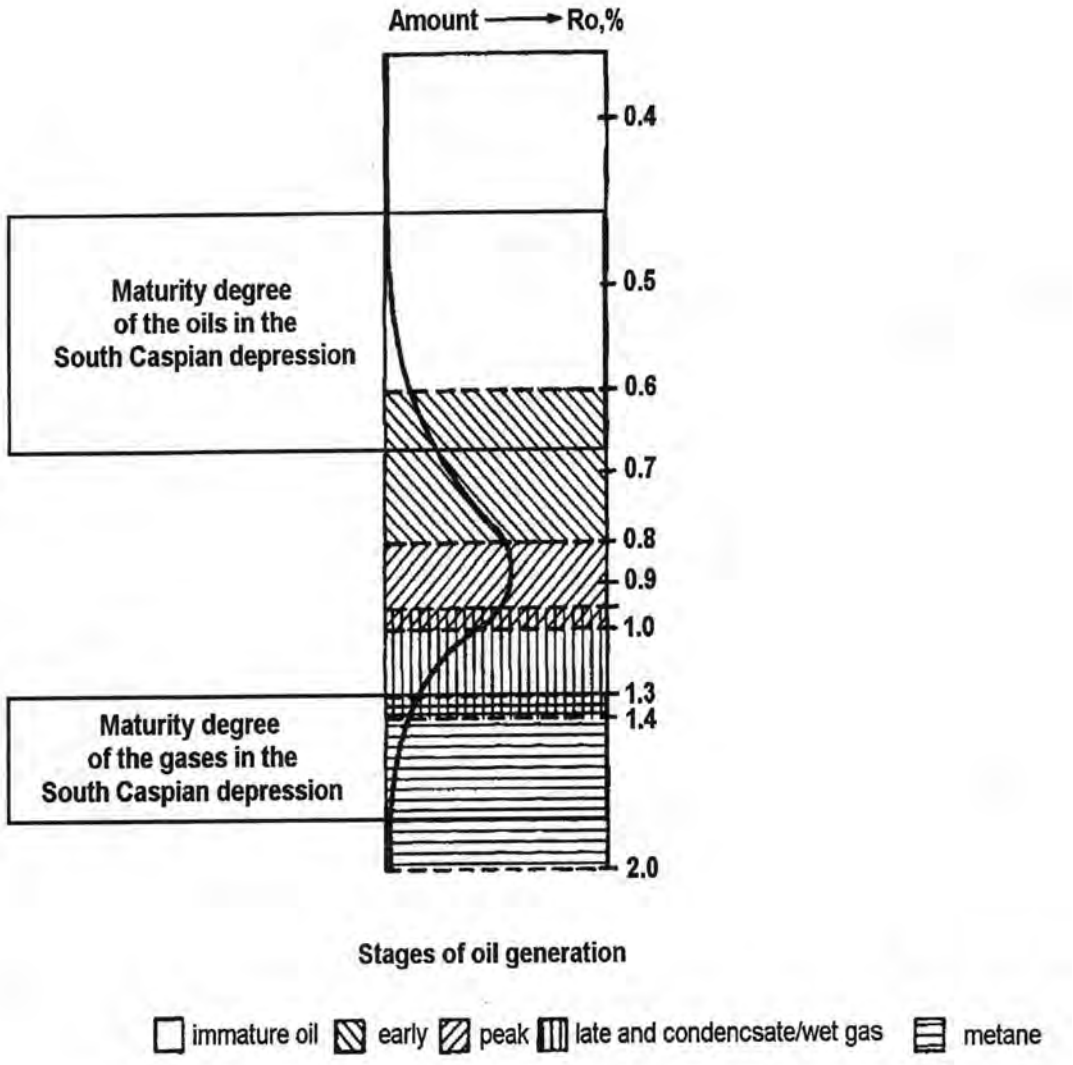
Amount → Ro,%
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.3
1.4
2.0
Maturity degree of the oils in the South Caspian depression
Maturity degree of the gases in the South Caspian depression
Stages of oil generation
immature oil
early
peak
late and condencsate/wet gas
metane

Figure 2