Sulfate Content of Formation Waters of the Productive Unit of the West Border of the South Caspian Depression

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Study of formation waters of the productive unit of the west border of the South Caspian depression - Apsheron Peninsula (15), Apsheron Archipelago, Southeast Kobystan, Baku Archipelago, Alyat Range, and Kura oil-gas area (See Table 1) - has disclosed a clear relationship between the $\text{SO}_4^{2-}$ (mg-equiv per 100 l) content and the hypsometric depth of the flow objectives. In all these regions the upper boundary of the zone of constant presence of sulfates in formation waters serves as a definite hypsometric surface that occurs at a depth of 2300-2500 m.

Higher concentrations of sulfate ions have been found in waters of the productive unit of West Apsheron and in the waters of the PK and KaS formations of East Apsheron; this indicates that the section is open and shows also the effect of surface waters (8). This is explained largely by the evaporite character of the lower division of the productive unit and by the presence of gypsum and anhydrite both in water-bearing rocks and in the underlying upper Pontian sediments, relicts of the waters of which are the waters of these formations (1, 4). In our opinion these are local phenomena not in accord with the functional relationship of sulfates to hypsometric depth, which appears to be regional and embrace the entire productive unit. Further, the presence of anhydrite and gypsum in the section of the Pontian and productive unit of East Apsheron has not yet been established (6, 19).

In Table 1, as a function of depth of occurrence of flow objectives, are given data on the distribution of $\text{SO}_4^{2-}$ in formation waters of most of the oil, gas, and condensate pools and also on tested but nonproductive intervals of the south border of the South Caspian depression occurring below this hypsometric level. As a result of a statistical analysis of data presented in the Table, a relationship was established between variations in the following parameters: coefficient of correlation + 0.823, error in coefficient of correlation with a probability of 0.997-±0.131, correlational ratio 0.

On a basis of the data in Table 1, a graph was constructed for the relationship of the $\text{SO}_4^{2-}$ content in water to the hypsometry of the objectives. See Fig. 1. The equation optimally approaches actual points and has the following form:

$$\text{SO}_4^{2-} = 0.0478 e^{0.001125 H}$$

where $\text{SO}_4^{2-}$ is the content of sulfate in the waters, mg-equiv/100 g; $H$ is hypsometric depth of flow of formation water, m.

This permits us to conclude that the content of sulfates in the formation waters of the productive unit of the west border of the South Caspian depression is a function of the hypsometry of the flow objectives and that it increases systematically with depth. See Fig. 1. It is also established that the content of sulfates in the marginal waters of gas pools is always higher than that of oil pools (all other things being equal).

A very important circumstance is the fact that the sulfates in most cases are associated with waters of the sodium bicarbonate type or with mixed formation waters in which alkali components prevail. It is evident from the Table that within each area there is a tendency toward a direct relationship between the content of sulfate ions in waters and their alkali content (A).

The relationship between $\text{SO}_4^{2-}$ concentration in waters and their depth of occurrence is manifest particularly well below a depth of 3000 m, i.e., in those intervals of the section where sulfate reduction takes place less intensively due to relatively high formation temperatures.

The problem of the sulfate content of the subsurface waters can be solved by determining the conditions favorable for preservation of this component in natural waters or by establishing its source of generation and entry into the formation waters.

As is well known, under the condition of primary presence of sulfates, the possibility and degree of their preservation in formation waters are determined largely by the presence and degree of intensity of processes of microbiol sulfate reduction, which are controlled by temperature conditions, salinity and composition of dissolved salts, the magnitude of Eh and pH, and the existence of organic source material.

From this point of view, the geologic conditions for the productive unit of the west border of the South Caspian depression, which is characterized by formation temperatures from 20 to 100°C, salinity of formation waters from 20 to 250 g/l, pH from 4.8 to 8.2, and