«Methodology for express definition of water inflow source in high water cut wells operating multi-layer deposits basing on high-precision studies of fluid produced composition»

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Introduction

An important problem in field development is the high water cut of the production. This problem is very important in fields at a late stage of development, when the number of water-flooded wells increases while oil production decreases.

Determination of the source of water incoming to production wells and possible problems in the well bore due to annular circulation or breakthroughs of water from aquifers or from injection well, is one of the most important tasks in the development of multilayer deposits. Today, many methods are used to detect these problems, but all of them require shutting down the well and launching special equipment, which is sometimes a time-consuming process in view of the construction features of the wells and is characterized by a significant delay in detection time.

The approach proposed in the work is based on the analysis of the results of a study of the geochemical composition of produced water, which is unique for horizons of different age. Reference wells operating on one formation are initially investigated, a statistical sampling of unique values is performed, then the obtained results are applied to water-flooded wells producing from several formation and wells in which completion problems are expected or there is a mismatch with the behavior planned.

The relevance of the work is caused by the lack of available operational methods for obtaining information about the water inflow sources, which prevents the effective development of multilayer deposits.

Method

At the level of the geochemical composition of formation water, it is possible to attach it to a particular development object [1]. The physical and chemical properties of produced water vary widely depending on the geologic age, depth, and geochemistry of the hydrocarbon-bearing formation, as well as the chemical composition of the oil and gas phases in the reservoir, and production chemicals added to the production [2]. For this, certain characteristics of each object are distinguished using wells operating on the same formation, called reference (Fig. 1, well 1, well 2). Further, in wells operating on several formations (Fig. 1, well 3), or in wells with cross-flows behind the casing (Fig. 1, well 4), the source of water inflow is determined.

The approach includes studies:

- isotopic composition of water, including the determination of isotopes of hydrogen and oxygen [1].
- full chemical composition, including determination of associated components: iodine, bromine, boron, lithium and other elements.

To determine the isotopic composition of hydrogen in water samples, a Delta V Plus isotope mass spectrometer (ThermoFisher Scientific, Germany) with a GasBench II attachment in constant flow mode is used. This device allows to determine the ratio of stable isotopes of light elements: H / D, 13C / 12C, 15N / 14N, 18O / 16O, 34S / 32S. For the elemental composition of formation water, an inductively coupled plasma mass spectrometer iCAP Qc (Thermo Fisher Scientific, Germany) is used.

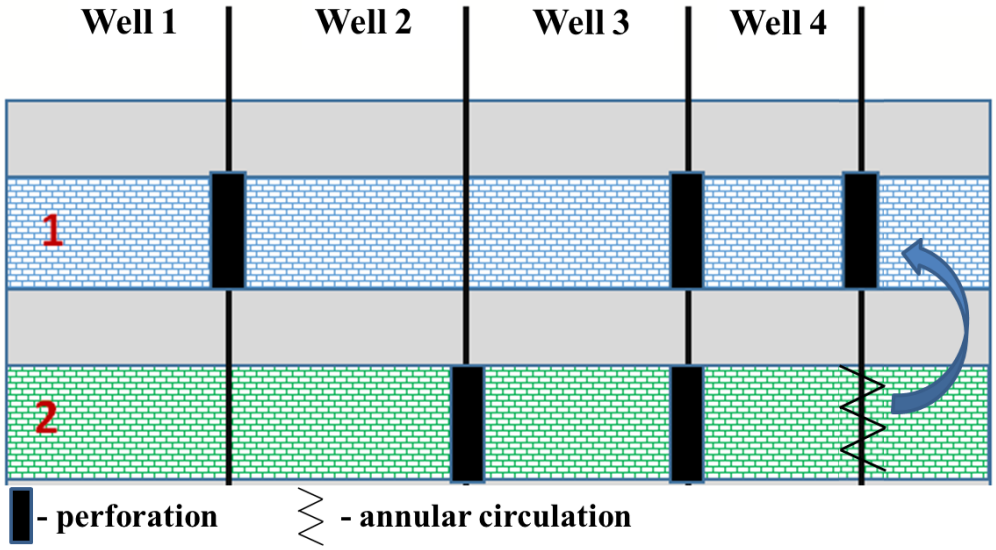


Figure 1 *Type of wells. Theoretical approach*

Examples

The object of the study was one of the multilayer deposits of the Republic of Tatarstan. As reference wells, 26 water-flooded wells operating on the Tula, Bobrikovian, Tournaisian and Bashkirian reservoirs separately were considered as reference wells and interpretation was done for 8 wells operating simultaneously on two of formations mentioned of the deposit of study.

The survey methodology includes express water samples purification to remove oil fraction, study of samples on high-precision equipment, processing of the results and establishment of layer-by-layer characteristic features (creation of a Water Atlas).

After studying 26 reference wells for the content of isotopes and chemical elements, the elements Ba, Ge, Mn, as well as the ratio of isotopes d 18O / 16O and d H / D, were selected as characteristic of the studied formations. It should be noticed that the use of several indicators affects the greater reliability of the method of water determination. For determination of the unique parameters of water inflow into the wells of reservoirs, discriminant analysis is most preferable [3].

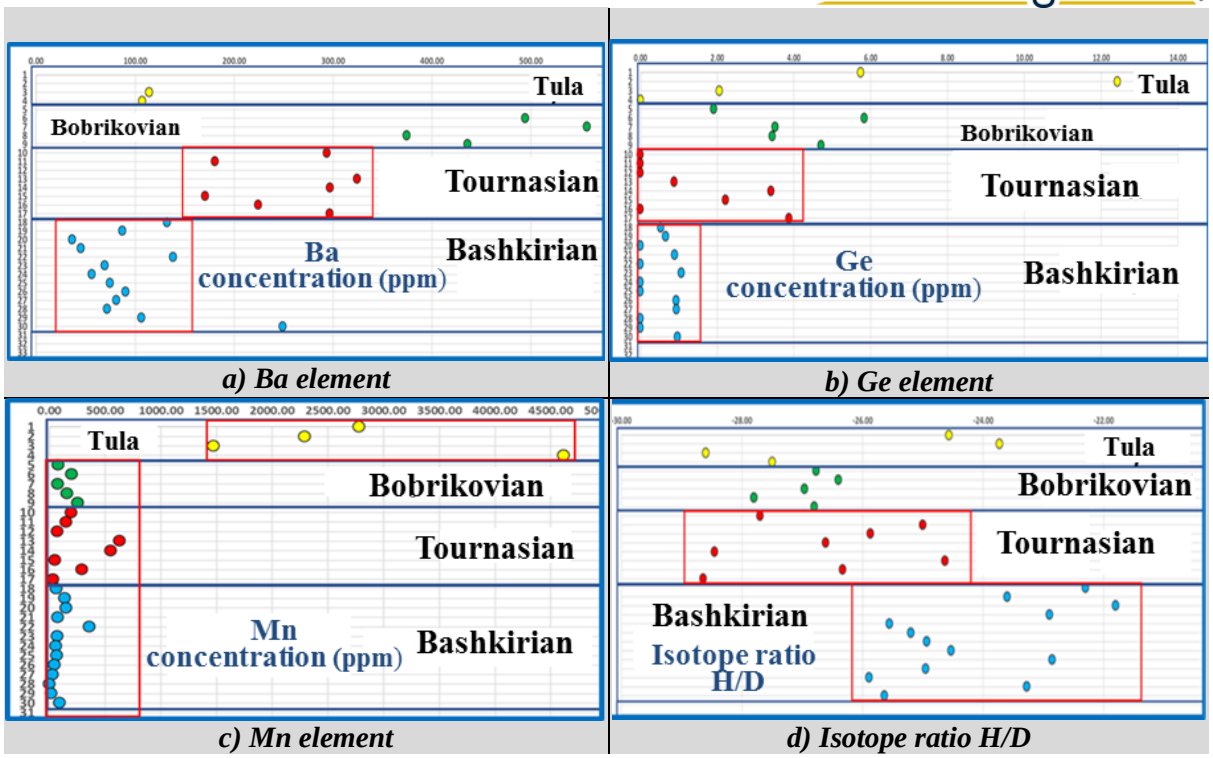
As a result of research, the following patterns were identified (Fig. 2):

1) by the Ba concentration (Fig. 2a), the water of the Bashkirian stage is uniquely separated from the water of the Tournaisian and Bobrikovian ages. The boundary values do not intersect, which makes this element very indicative;

2) according to the Ge content (Fig. 2b), the water of the Bashkirian stage is characterized by a lower concentration of this element;

3) water from Tula deposits differs in the Mn content increased by tens and hundreds of times (Fig. 2c);

4) according to the ratio of H / D isotopes (Fig.2d), the water of the Bashkirian stage is uniquely separated from the waters from the Bobrikovian and partially Tournaisian horizons (there are border crossings with the waters of the Tournaisian stage), while the waters of the Tournaisian stage clearly differ from the Bashkirian stage by a reduced ratio of these isotopes.



a) Ba element *b) Ge element*

c) Mn element *d) Isotope ratio H/D*

Figure 2 Characteristic features of formations. Reference wells

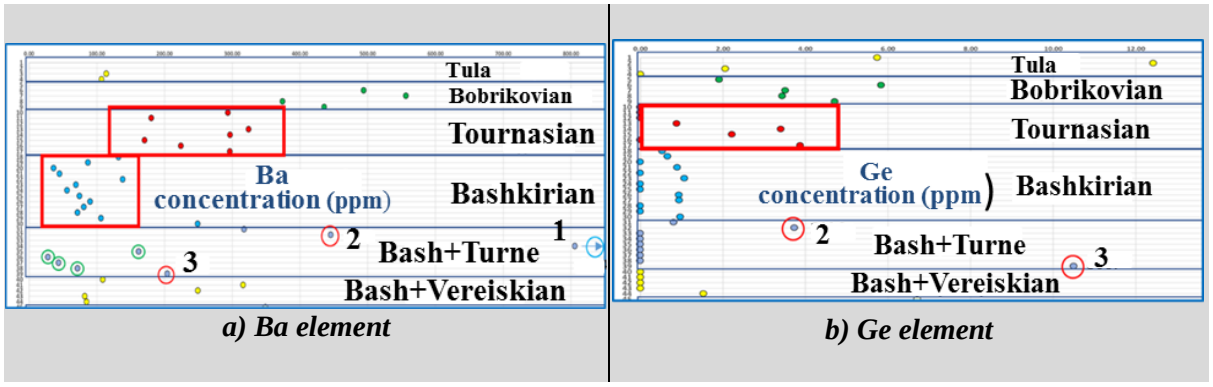
The next stage of research was to establish the main source of water inflow in wells producing several formations simultaneously. These wells were considered in groups depending on the perforation; in this paper, we consider highly flooded wells operating simultaneously on the Bashkirian and Tournaisian ages. Thus, based on three different measurements (Fig. 3) of the composition of water of the Bashkirian and Tournaisian ages, wells №№3, 2 and 1 do not correspond to all other values:

1) increased content of Ba (Fig. 3a);

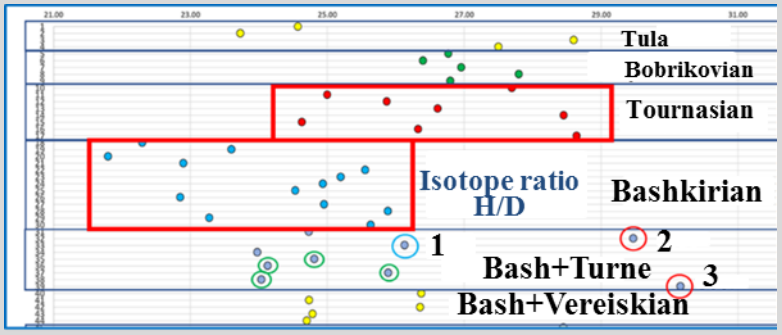
2) increased Ge content (Fig. 3b);

3) the ratio of isotopes is close to the values of the Tournaisian layer (Fig. 3c).

By these indicators, the main contribution to the water inflow to these wells is made by the Tournaisian layer. The remaining wells are almost unambiguously belonging to the Bashkir layer (highlighted in green in Fig. 3). This confirms the low Ba content, the ratio of isotopes that fit mainly within the boundaries of the Bashkirian tier, and zero Ge indicators.



a) Ba element *b) Ge element*



c) Isotope ratio H/D

Figure 3 Characteristic features of formations. Reference wells

Conclusions

As a result of studies of the geochemical composition of produced formation water it was possible to establish the characteristic features of each formation and determine the main source of water inflow in the wells operating several formations. Indicative elements are: the content of barium (Ba), germanium (Ge), manganese (Mn) and the ratio of water isotopes (H / D). A source of water was identified for 3 out of 8 studied wells operating in the Bashkirian and Tournaisian strata. According to the detected indicators, the Tournaisian layer makes a significant contribution to the water cut. It is recommended to carry out water shut-off treatment in these wells. In the remaining studied wells, both formations contribute to the water inflow of production.

The research methodology provided can be easily implemented on multilayer reservoirs, where water cut problems experienced in view of the simplicity of sampling, clear and direct research methods, and the possibility of effective processing of the results by mathematical statistics. The research results allow us to timely determine the source of water flow into the wells and quickly take the necessary measures to eliminate the identified complications.

References

1. Alekseev F.A., Gottih R.P., Saakov S.A., Sokolovsky E.V. [1975] Radiokhimicheskiye i izotopnyye issledovaniya podzemnykh vod neftegazonosnykh oblastey SSSR. Nedra, P.271.
2. Jerry M. Neff, Kenneth Lee, Elisabeth M. DeBlois. [2011]. Produced Water: Overview of Composition, Fates, and Effects. DOI: 10.1007/978-1-4614-0046-2_1
3. Kudryashova D. A. [2018]. Use of probabilistic and statistical methods for determination of the sources of water flow in candidate wells for water shut-off works (on example of the Visean reservoir of the Perm region field). Bulletin of PNRPU. Geology. Oil & gas engineering & mining Volume 17/№1 p.26-36.