WELL DRILLING

Concerning the issue of mudding permeable beds when using clayless drilling fluids

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In conditions of multi-zone hydrocarbons deposits non-uniform in depth and strike the use of carbonate blockers of the same type is ineffective due to the low reliability of the data on the size of collector pores. The problem can be solved by using composite blockers containing both rigid and elastic materials. The paper shows the results of laboratory studies and examples of practical application of the composite blockers in Biokar clayless mud system.

According to modern concepts [1, 2], among drilling fluid water-based, only clayless biopolymer systems provide top quality disclosure of productive horizons. Unlike clay or polymer clay drilling fluid, which filtration is accompanied by deep penetration of colloidal particles into the porous medium and the formation of the inner zone mudding, biopolymer fluids with negligibly low content of colloidal phase, form a crust on the surface of the filtration layer, which plays role of the impermeable occluding screen (Fig. 1). This is achieved through the use of special reagents blockers, particle size of which is adjusted according to the pore size of the collector.

During formation of interior mudding, cleaning of the natural reservoir is extremely difficult, which leads to a partial or a complete loss of well productivity. When clayless fluids are used, the thin surface crust can be easily destroyed by the flow of reservoir fluid during the flood and operating of wells. The natural permeability of the reservoir is almost completely restored in this case.

To create an insulating layer on the surface of the productive, fractionated, finely ground carbonate fillers are used, such as limestone, dolomite and marble, more often belonging to the class of so-called hard colmatants [3]. These substances seem almost ideal blockers because they are characterized by high degree of homogeneity, acid-solubility, resistance to dispersion, low abrasiveness and inertia to the reservoir fluids. In case of the proper selection, colmatants are split in the openings of pores between grains of rock, creating unique arched bridges, which act as the foundation for future filtration surface crust. The strength of the blocking layer is comparable to the strength of reservoir bed. This allows avoiding acquisitions and providing high quality disclosure of permeable horizons by excessive repressions, which, in particular, occur during drilling in areas of abnormally low reservoir pressure.

However, the effective blocking of filtration channels of the collectors occurs only in a narrow range of size relations with the size of colmatant particles. Even in case of minor deviations, as in one or the other side, arched lintels formation does not occur, and the permeability of the occluding layer and the amount of filtered fluid increase dramatically [4]. The result is a deep penetration of the components of the drilling fluid and increase in the thickness of the contaminated zone. There are real examples where the quality of disclosure of productive horizons was worse than in case of use of obsolete clay systems, because of a bad selection of the fractional composition of the solid phase of drilling fluids.

Therefore, the application of rigid blockers requires complete and accurate information about the pore structure of the reservoir, since wrong choice of a colmatant can negate all the benefits of the use clayless drilling fluids. The situation is further complicated by the presence of cracks in the reservoir, which can change their size depending on the pressure in the borehole. In addition, the rate of formation of occluding layer and its permeability is affected by dispersion of blocker particles during drilling, inflow of sludge formed by drilled rock into the solution, presence and concentration of dense media solids and more. Thus, as most of fields in Ukraine are multihorizon fields, which are characterized by heterogeneity in the depth and strike, determining of the optimal particle size of a hard blocker reagent for each particular hole is an extremely complex technological challenge. There is an opinion, which is gaining more and more popularity in Ukraine, that the much advertised approach aiming to bring mathematical analysis methods and computer simulation process to solve the problem of mudding [5] is "inefficient and unreasonable from either an economic or a technological point of view". [6]

In our view, a necessary condition for the solution of this problem is a complete rejection from false practice of the use of hard colmatants of the same type and transition to composite blockers, containing as tough and elastic material.

The class of elastic colmatants includes organic materials that are prone to elastic deformation under pressure within the pore space of the reservoir. Due to it, elastic colmatants are characterized by better splitting and formation bond. The inconsistency of their size with the size of collector pores affects the formation of the insulating layer, which is also characterized by greater resistance to pressure fluctuations, to a lesser extent. But its strength is significantly inferior to the layer of hard colmatants [3].

In case of combined use of elastic and rigid colmatants they complement each other, which makes it possible to get a blocker, largely devoid of these shortcomings.

Composite blockers help create a flexible insulating layer of high strength. During its formation elastic material fills the voids between the hard colmatant particles and grains of hard rocks which are formed as a result of discrepancies between their dimensions. In this case, due to elastic deformation under pressure, elastic materials are able to act as an elastic sealant, regardless of the size of the voids and their configuration (Fig. 2). Thus, there is no need for a detailed study of the characteristics of the collector for the effective application of composite blockers.

Clayless biopolymer solution Polymeric mud drilling fluid

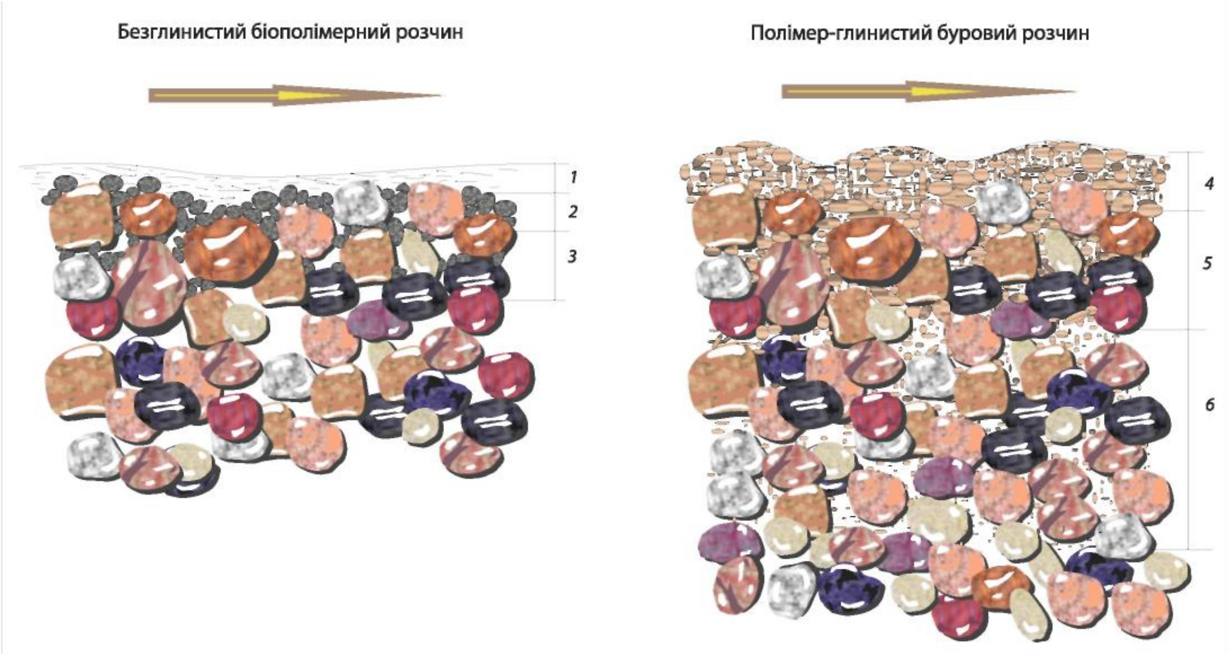

Fig. 1. Formation of zones of lowered permeability in the reservoir pore environment during opening with different solution types: 1 - outer polymer layer, 2 - outer colmatage layer 3 - internal colmatage layer (zone of penetration), 4 - clay coating, 5 – colmatage zone, 6 - penetration zone

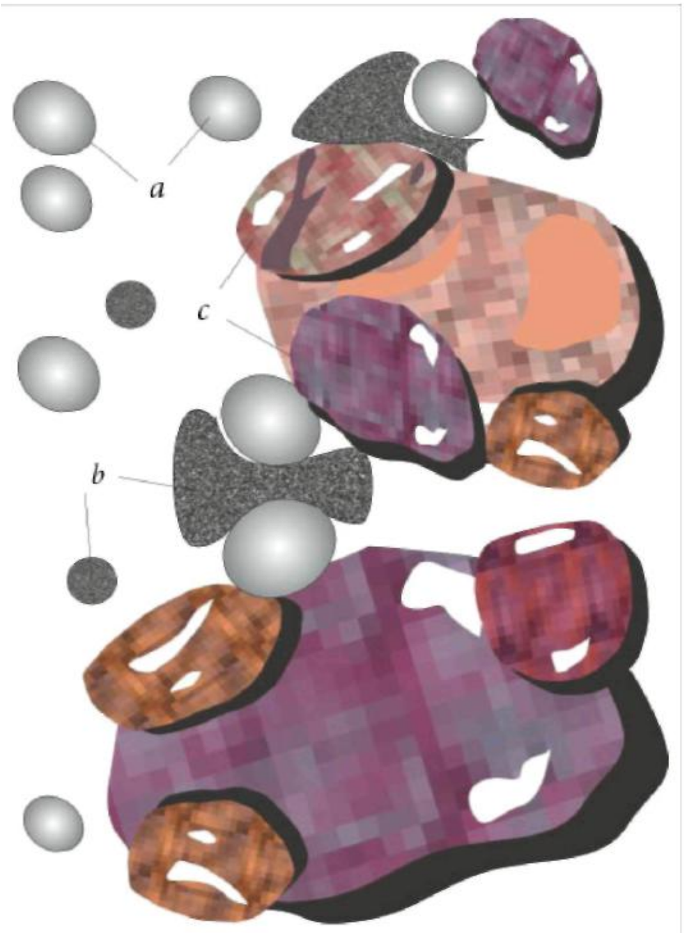

Fig. 2. Colmatage of a reservoir pore space by a composite blocker: a - hard blocker particles; b - elastic blocker particles; c – rock grains

Table 1 Use of Biokar flushing fluid for the opening of production horizons

Well No., field	Customer	Operation particulars

Well No. 545, Bugruvativske	Ukrnafta PJSC	horizontal well
Well No. 97, Yablunovske	Karpatigaz PJSC	horizontal well
Well No. 301, 303, 304, 306, 307, Lelyakivska	SP Kashtan Petroleum Ltd.	inclined controlled and horizontal wells, abnormally low formational pressure, carbonate reservoir with cracks
Well No. 10, Olhivske	Kub-gaz Ltd.	abnormally low formational pressure
Well No. 22, 23, 24, 62, Ostroverkhivske	Ukrgazovydobutok PJSC	inclined controlled wells
Well No. 10, Krasnozayarske	Ukristgaz Ltd.	hydrostatic pressures
Well No. 53, Sviridivske	Regal Petroleum Corporation Ltd.	abnormally high formational pressure
Well No. 2, Roganske	Esko-Pivnitch Ltd.	abnormally low formational pressure
Well No. 20, 21, Ostroverkhivske	Ukrgazovydobutok PJSC	for perforation, damping and repairs
Well No. 14, Sakhalinske	DK Ukrnaftoburinna CJSC	for perforation, damping and repairs

Theoretical notions were confirmed during laboratory tests of clayless filtering liquids containing colmatants of different types, with the use of the sand filter model [1]. Granulometric composition of filters was selected according to the size of the particles, typical for large- , medium- and fine-grained sand and coarse aleurite. [7] For mudding filters carbonate reagent blockers were used, that are applied for well drilling in Ukraine. Efficacy was assessed by an insulating layer of fluid that was filtered for 30 min. through the sand filter under pressure of 0.7 MPa.

As is evident from the research results (Fig. 3), hard colmatants show selective efficacy in all cases. That is to say, that there is no carbonate or any other hard blocker with equal efficiency in the entire range of pore sizes of collectors. For optimal size ratio of pores and blocker particles, solution filtration level is low, but the change in pore size leads to its increase, and therefore an adjustment of the blocker fractional structure is required. Determination of the need for such adjustment is only possible in case of additional introduction of elastic organic filler into the drilling fluid. In this case, the formation of an impermeable insulating barrier is independent of the reservoir porosity, and filtration remains minimal in all experiments.

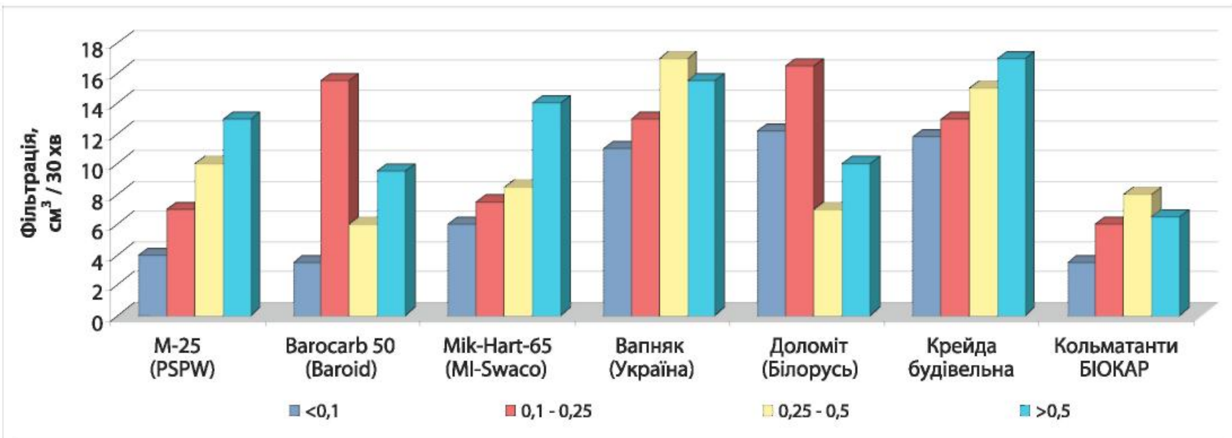

Fig. 3. Insulating properties of different colmatants after pumping of biopolymer solution through sand filters of different granulometric composition.

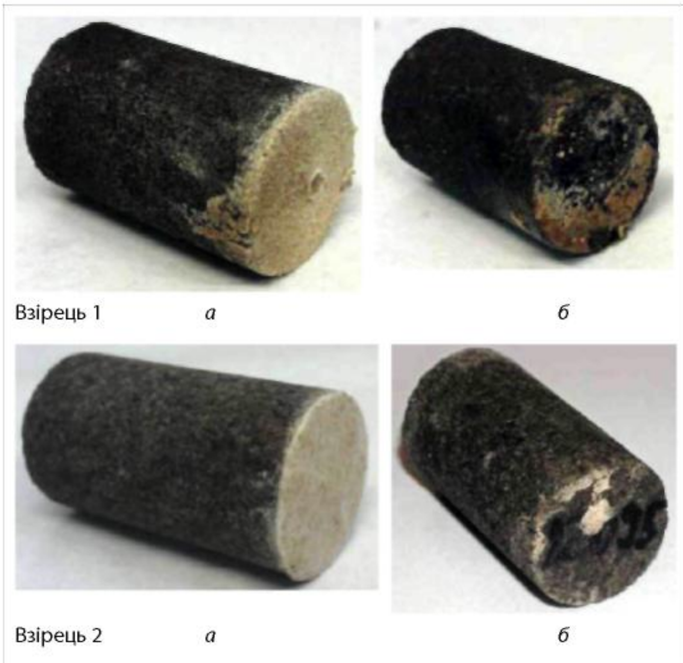

Fig. 4. Samples after the pumping of the flushing fluid (*а*) and final permeability detection (*б*)

Past studies have helped to define the types and optimal concentrations of organic materials that can be used as fillers for clayless drilling fluids. It was established that the optimal content of hard colmatants in clayless drilling fluid is about 10%, and its relation with the content of elastic colmatant must be maintained at 10:1-1,5. The obtained results formed the basis for the development of composite reagents-blockers for Biokar biopolymer clayless drilling fluid, which is successfully used to disclose productive horizons in the fields of Ukraine (Table 1).

The high insulating properties of Biokar drilling fluid and its positive influence on quality of disclosure of productive horizons is demonstrated by research results obtained in the Oil and Gas Institute in Cracow. During the research with the methodology of the American Petroleum Institute the following items were used:

Filter press for determining filtration in static and dynamic conditions and temperatures (High Pressure High Temperatur Filter Press: $\Delta P_{max} = 2,8$ MPa, $T_{max} = 150$ °C, OFI, USA);

Permeability meter to determine corn permeability in situ (Universal Permeability Meter – Core flooding System: $\Delta P_{max} = 2,1$ MPa, $T_{max} = 150$ °C, Temco, USA);

unit for determine the thickness of the inner and outer filter cake (RVG Kodak 2000).

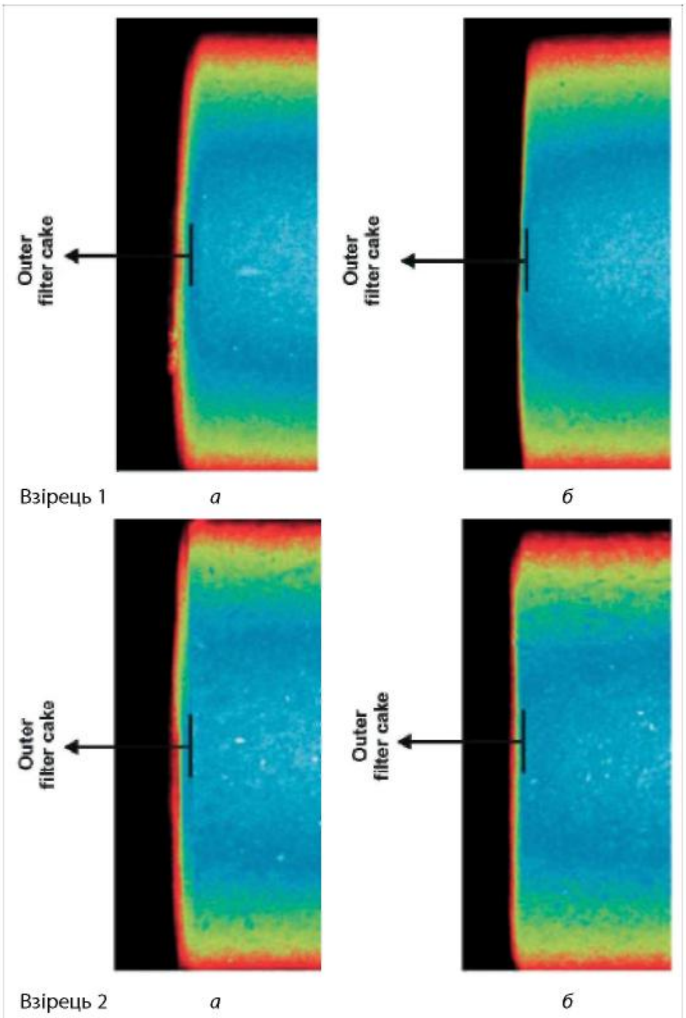

Fig. 5. Radiographs of samples after pumping of drilling fluid (a) and the final determination of permeability (*б*)

Experiments were performed in the cores productive layers of Starosambirskyi field using oil of Polish Carpathians collectors at the temperature 80 °C (Table 2).

Table 2

The measurement results of the Institute of Oil and Gas (Cracow)

Sample porosity, %	Filtration rate, cm^3/30 min		Sample permeability, mD			Permeability recovery rate, %
	dynamical	static	oil-field water model	Oil		
				start	End	
11.3	0.9	0.5	3.40	1.47	1.36	92.5
9.4	1.1	0.4	0.48	0.33	0.31	93.9

As shown in Fig. 4, after pumping of the drilling fluid a dense filtration cake is formed on the surface of samples, which is a layer of colmatant particles that block the pore space, forming arched bridges between grains of rock. Filtration cake is easily destroyed during reverse oil flow because of minimal penetration depth of colmatant particles into the rock. Lack of internal colmatage of the samples is also confirmed by their X-ray examination (Fig. 5). The results of determining of the thickness of the inner and outer filter cake are shown in Table . 3.

Table 3 Filter cake thickness after mudding and cleaning of corn samples

Filter cake thickness after mudding of the sample (drilling fluid pumping), mm		Filter cake thickness after cleaning of the sample (reverse oil pumping), mm	
External	Internal	External	Internal
1.4	0	0.7	0
1.2	0	0.5	0

Thus, studies have confirmed that Biokar drilling fluid ensures efficient maintenance of filtration properties of reservoir with permeability recovery rate amounting to 92.5 - 93.9%. Two or more times decrease in the thickness of the outer filter cake upon cleaning of samples and almost complete lack of interior colmatage zone indicate a high insulating capacity of composite blockers, which guarantees high quality of disclosure of productive horizons.

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