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Research Article

Hydrogeodynamic and Hydrogeochemical Conditions of the Aptian-Albian-Cenomanian Complex of the Kamennoye Oil Field

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ABSTRACT.
The article gives a hydrogeological characteristic of the Aptian-Albian-Cenomanian deposits of the Kamennoye oil field, which is a part of the Krasnoleninsky group of fields in Western Siberia. Based on the interpretation of the geophysical field research on the exploration wells and the stratigraphic arrangements, the geological and structural characteristics of the field are given. The structure, composition, and thickness of the Uvat, Khanty-Mansi, and Vikulov suites are described, which belong to the Aptian-Albian-Cenomanian hydrogeological complex. Their hydrogeochemical characteristic is given. The particular attention is paid to the Vikulovsuite, since it obtains the main oil reserves of the field. It is calculated that super-hydrostatic pressures are fixed on the most part of the field, the excess reaches 1.6 MPa. The relationship between the value of reservoir pressure and the mineralization is analyzed. The hydrogeological conditions of the Aptian-Albian-Cenomanian and the Lower–Middle Jurassic complexes are compared. It is shown that within the Kamennoye field, the regional lateral directionality of the groundwater flows of the Aptian-Albian-Cenomanian complex is maintained – from the periphery, where the regional alimentation areas are located, to the central regions of the basin.

Keywords: Aptian-Albian-Cenomanian hydrogeological complex, Reservoir pressure, West Siberian megabasin, Ion-salt composition of waters, Oil and gas hydrogeology.

INTRODUCTION

Understanding the nature of the hydrogeological conditions of oil fields is closely related to the formation of oil deposits. According to the classical concepts of oil and gas hydrogeology of the Russian and Soviet scientists (Kartsev, Vagin, Matusevich,and others), the zones of maximum reservoir pressure correspond to the zones of oil and gas formation, and the zones of minimal reservoir pressure – to the zones of oil and gas accumulation. The study of the hydrogeological conditions of oil fields often complements the understanding of the conditions of the formation of hydrocarbons [1-3] and makes it possible to amend the development model.

The Kamennoye oil field is a part of the Krasnoleninsky group of the Frolovsk oil and gas bearing region. The main oil reserves are confined to the Aptian deposits of the Mesozoic;thus the main attention of the authors is paid to the hydrogeological conditions of the sediments of this particular age [6, 7].

METHODS

The geological and hydrogeological characteristics of the object of research are based on the results of the interpretation of the geophysical field researchon the exploration wells and stratigraphic arrangements of the Kamennoye oil field. The hydrogeochemical

data was systematized, the type of waters and the formula of the ion-salt composition were determined. The values of temperatures and reservoir pressures were analyzed, which made it possible to makethe conclusions regarding the lateral directionality of the groundwater flows.

RESULTS

The analysis of the hydrogeological features of the Aptian-Albian-Cenomanian complex within the Kamennoye oil field (the study of the lithological composition of the rocks of the complex, the chemical composition of waters, current temperatures, reservoir pressures and correlation of these parameters) allowedmakingthe conclusion that the regional lateral directionality of the groundwater flow of the complex is maintained from the periphery, where the regional alimentation regions of the West Siberian megabasin are located, to its central regions. The main factors for the formation of groundwater of the Aptian-Albian-Cenomanian complex are the interaction processes in the system "buried sedimentary water – rock –expelled waters".

Towards the Jurassic deposits of the Mesozoic, the pattern of the directionality of the flow dramatically changes: due to the development of a large number of fractures of the foundation that continue in the sedimentary cover, the vertical directionality of the groundwater flows prevails.

DISCUSSION

The Kamennoye oil field is located in the western part of Western Siberia and is a part of the Krasnoleninsky group of fields. The deposits of the Cenozoic, Mesozoic, and Paleozoic are traced in the section of the field. This paper examines in more detail the sediments of the Mesozoic group, in particular, the Aptian-Albian-Cenomanian one, due to the fact that it obtains the main oil reserves.

The examined territory is located in the western part of the Western Siberian hydrogeological megabasin. The hydrogeological stratification is represented as three hydrogeologicalbasins (Paleozoic, Mesozoic, and Cenozoic) and seven independent hydrogeological complexes Oligocene-quaternary, Turonian-Oligocene, Aptian-Albian-Cenomanian, Neocomian, UpperJurassic, Lower-Middle Jurassic, and Triassic Paleozoic.

In terms of oil and gas hydrogeology, the Aptian-Albian-Cenomanian and Lower-Middle Jurassic hydrogeological complexes are of particular interest. The authors have previously considered the nature of the hydrogeochemical and hydrogeodynamic anomalies of the Lower-Middle Jurassic complex of the examined area [4]. It is revealed that within the limits of the Lower-Middle Jurassic complex there is a conjugate ascending-descending movement of groundwater, which is possible due to numerous fractures. The groundwater of the complex is a result of mixing sedimentary, expelled (squeezed from clay sediments) waters and deep fluids.

The Aptian-Albian-Cenomanian hydrogeological complex within the field is composed mainly of the sandy-aleuritic difference of rocks, which are dominated by the reservoirs of I-III classes (in accordance with the classification; Khanin) [5, 8] and represented by the sediments of Uvat (Cenomanian) Khanty-Mansi (Albian) and Vikulov (Aptian) suites. In the Aptian-Albian-Cenomanian time, the entire territory of the Krasnoleninsky region was occupied by the sea and a small part of the shelf.

The depth of the occurrence of the roof of the Aptian-Albian-Cenomanian hydrogeological complex (the roof of the Uvat suite) within the field varies from 956 to 1008 m, the base (the roof of the Koshay suite) is 1712-1780 m. The total thickness of the complex in the area of the Kamennoye oil field varies from 716 (well 5668) to 785 m (well 69r), increasing to the center of the field (Fig. 1). The figure shows the isolines of the thickness of the Aptian-Albian-Cenomanian hydrogeological complex.

The Uvat suite is composed mainly of powerful permeable rocks with rare interlayers of clay rocks of low thickness. The sediments are represented by sands, sandstones, siltstones,and clays. The coefficient of sandiness of the suite on average amounts to 92.7%.

Within the field, the suite has a total thickness (according to GIS) from 248-250 m (on average

249.2 m), represented mainly by permeable rocks. The effective thickness ranges from 225 m to 244 m (on average 231.1 m). The sediments of the Uvat suite were accumulated in the desalinated shallow sea basin [3].

By the chemical composition, the groundwater of the Uvat sediments has sodium chloride composition (Table 1); they belong to the calcium chloride type (according to Sulin). The waters are salty with the salinity of 12.61 to 12.86 g/dm^3, very hard, with a total hardness of 14.75-15.58 meq/dm^3, neutral in terms of pH (pH=7.3-7.4). The concentration of sulfate ion is 0.25-0.6 meq/dm^3, iron ions 11.4-14.2 mg/dm^3.

The Khanty-Mansi suite is mainly represented by argillite-like clays with sparse layers of permeable rocks (the sandiness coefficient is 10.9%). Within the limits of the examined field, it has the total thickness of 98-108 m (on average 104.1 m), the effective one – on average 27.2 m. The permeable rocks make up 26.1% of the suite.

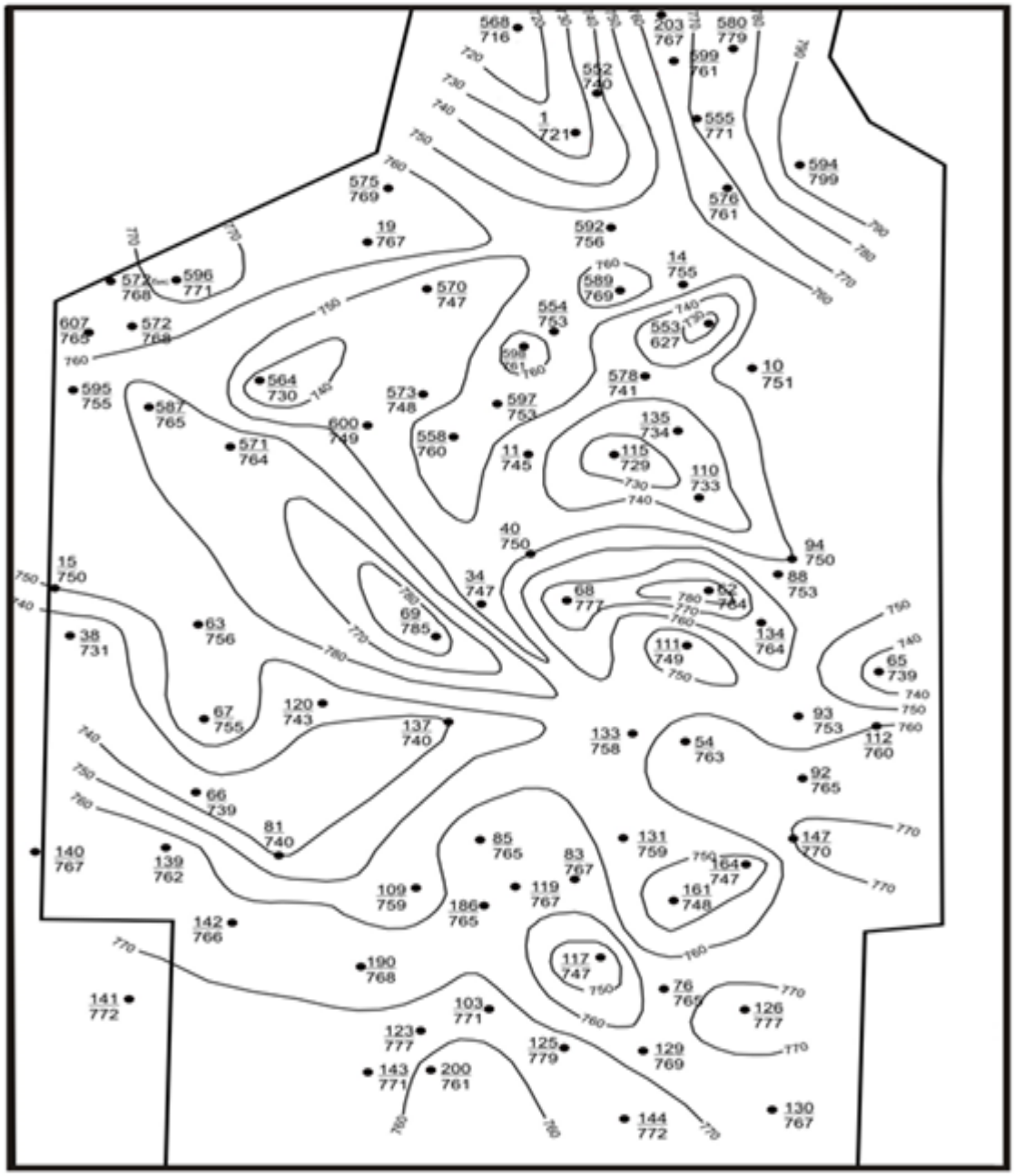

Fig. 1 The map of the isopachytes of the Aptian-Albian-Cenomanian hydrogeological complex of the Kamennoye oil field [2].Type codes: $\frac{594}{799}$ –oil exploratory well, the numerator contains its number, the denominator – the thickness of the Aptian-Albian-Cenomanian hydrogeological complex, [m].

Table1: Results of the chemical analysis of water samples from the Aptian-Albian-Cenomanian hydrogeological complex (Uvat suite)

Well No.	[pH]	Macro components: mg/dm^3; meq/dm^3							Total hardness, [meq/dm^3]	Mineralization, [g/dm^3]
		HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+		
9305	7.40	348	7553	12	210	62	4,677.51		15.58	12.86
		5.70	213.00	0.25	10.48	5.10	203.37			
9305	7.30	354	7376	29	205	55	4,592.18		14.75	12.61
		5.80	208.01	0.60	10.23	4.52	199.66			

In accordance with the lithological features, the suite is also divided into two parts. The lower part is composed of dark gray argillites, thin layers of aleurolites of chalkstone and siderite. The upper part is represented by coastal-marine gray-colored aleurolites and clays with rare sandstone interlayers.

The value of the geothermal gradient in the sediments of the Khanty-Mansi suite ranges from 3 to 40 °C per 100 m.

The number ofcontinuous formations of sandstones, alternating with clays and dense rocks, increases markedly in the *Vikulov suite*. Permeable rocks are represented by sandstones, aleurites,and sandy-aleuritic rocks. The coefficient of sandiness is 37.3% on average.

The depth of the occurrence of the roof of the Vikulov suite varies from 1,446 to 1,490 m; the total thickness within the considered field is 180-260 m. However, the total reservoir capacity according to geographic information system (GIS) is only a small part of it, an average of 82.1 m.

The Vikulov suite is divided into two sub-suites, the lower of which is more clayey. The deposits of the Vikulov suite were formed in coastal-marine conditions, given the wide distribution of small lakes.

The temperature of the rocks of the Vikulov suite varies from 56 to 77 °C (Fig. 2). The increase in temperature occurs in an easterly direction. The magnitude of the geothermal gradient in the deposits of the Vikulovsuite varies from 1.5 to 2 °C per 100 m.

The considered features of the lithological composition of rocks and the structure of the Aptian-Albian-Cenomanian hydrogeological complex as a reservoir of groundwater within the Kamennoye oil field are typical of this complex in the territory of the West Siberian megabasin.

The groundwater of the Vikulov deposits of the Aptian-Albian-Cenomanian hydrogeological complex has sodium chloride composition. The type of water, according to Sulin, issodium bicarbonate:

The formula of ion-salt composition

$$M_{10.5}\frac{Cl86HCO_3 13SO_4 1}{(Na+K)95Ca4Mg1}$$

Limits of change in ion-salt composition

$$\frac{Cl(80-92)HCO_3(8-20)SO_4(0-1)}{(Na+K)(92-96)Ca(2-4)Mg(0-2)}$$

Magnesium-chlorate type is less frequent:

$$M_{14.6}\frac{Cl94HCO_3 6}{(Na+K)94Ca4Mg2}$$

$$\frac{Cl(93-94)HCO_3(6-7)}{(Na+K)(93-94)Ca4Mg(2-3)}$$

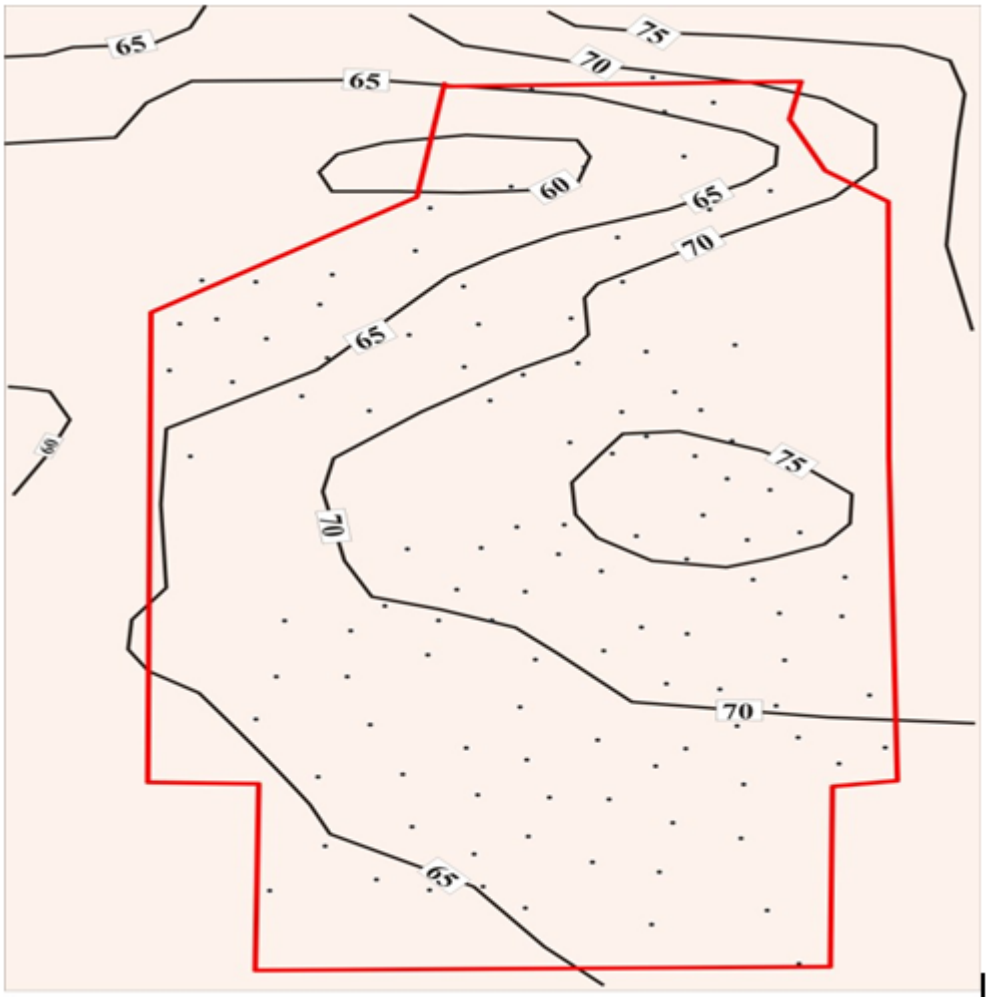

Fig. 2 Map of current temperatures in the roof of the Vikulov deposits.

The interval of change in the mineralization of sodium bicarbonate type of water is from 7.9- 8.6 to 12.1-13.8 g/l (on average 10.5 g/l), magnesium-chlorate type – from 13 g/l to 15.5 g/l (on average 14.6 g/l). The content of chloride ions varies from 4,042 to 8,662 mg/l (5,932 mg/l on average), which is on average 1.65 times higher than in the Lower-Middle Jurassic complex. The concentration of bicarbonate ions varies from 695 to 2,044 mg/l (1,079 mg/l on average), i.e. there is an increase in the concentration on average by 1.5 times towards the Lower-Middle Jurassic complex. Sodium with potassium dominates in the cationic composition of groundwater of the Vikulov deposits (the minimum content is 2,951 mg/l, the maximum is 5,592 mg/l, the average is 4,037 g/l), the concentration of these cations is approximately 1.4 times higher than in the Lower-Middle Jurassic complex. The concentration of calcium ions (~117 mg/l) and magnesium (~16 mg/l) in the groundwater of the Vikulov deposits exceeds those in the Lower-Middle Jurassic complex by 1.1 and 1.7 times, respectively.

The sodium-chloride ratio in the groundwater of the Vikulov deposits reaches 1.2 for the sodium bicarbonate type of water of the Vikulov deposits, and does not exceed 1 for the magnesium-chlorate one. The boron-bromine coefficient is 0.2 on average.

Under the conditions of the suite, the watersare predominantly saturated with gas ofmethane type (according to Zorkin) with a methane concentration of 85-95%, nitrogen content up to 8%, carbon dioxide about 2%, hydrogen sulfide as part of water-dissolved gases is absent. The maximum gas saturation of the formation waters at the water-oil contact boundary reaches 1.8 m^3/m^3. The content of the main micro components is given in Table 2.

Table2: The content of micro components in the groundwater of the Vikulov deposits of the Aptian-Albian-Cenomanian (Kamennaya and Em-Egovskaya area) and the Lower-Middle Jurassic (Talinskaya area) hydrogeological complexes

Name	Average values (range)	
	Aptian-Albian-Cenomanian complex	Lower-Middle Jurassic complex
NH_4	76(17-105)	
J^-	11 (3-22)	6.6 (0.8-16.6)
B^-	8 (4-13)	12.9 (2.1-60.8)
Br^-	25 (0.7-151)	26.9 (10.3-64.4)
SiO_2	20 (9-72)	37.5 (10-100)
rNa/rCl	~ 1	1.41 (0.9-3.6)
B/Br	0.2 (0.13-0.32)	~ 0.59(0.3-1.1)
Number of examined samples (wells)	34 (28)	

Thus, from the Aptian-Albian-Cenomanian complex to the Lower-Middle Jurassic one [1], inverse hydrogeochemical zonality is observed. With the depth (from the studied complex below), the content of such micro components as iodine and bromine decreases, and the contents of boron and silicon dioxide, sodium-chloride and boron-bromine coefficients increase, which indicates that there are different conditions for the formation of groundwater of the Aptian-Albian-Cenomanian and Lower-Middle Jurassic hydrogeological complexes of the Krasnoleninsky oil and gas bearing region and that there is the absence of the influence of deep fluids and the diverse directionality of groundwater movement within the Aptian-Albian-Cenomanian hydrogeological complex.

Over the most part of the field, super-hydrostatic pressure is observed, the excess reaches 1.6 MPa. Between the value of mineralization and the given reservoir pressure, a positive relationship rM– P = 0.22 is fixed, although it is not very pronounced (Table 3). The graph of the dependence of the data of hydrogeological field parameters is presented in Fig. 3.

The increase in reservoir pressure may be associated with the squeezing of expelled waters from the clay deposits of the Aptian and Albian (down) and Neocomian (up).

The results of the previously conductedpaleohydrogeological studies [2] unequivocally indicate that the cause of the development of super-hydrostatic reservoir pressures is the expulsion water exchange.

There is the correlation between the value of reservoir pressure and the depth of the occurrence of the Aptian-Albian-Cenomanian hydrogeological complex r = 0.44. An interesting fact is that as the depth of the occurrence of the Aptian-Albian-Cenomanian hydrogeological complex increases, the reservoir pressure drops.

Table 3: Values of mineralization and reservoir pressures in the Vikulov suite of the Aptian-Albian-Cenomanian hydrogeological complex

Well No.	Mineralization, [g/l]	Given reservoir pressure, [MPa]
594	10.7	15.2
50	8	16.6
92	13.4	16.4
47	8.6	16.2
73	10.62	15.8
81	15.48	15.2
63	12	15.2
551	12.2	15.8
555	13.87	15
1718	10.4	16.08
1648	11.7	16
1548	11.36	15.42
1670	12.81	15.94
1520	13.12	15.38
1580	12.3	15.18
1580	14.29	15
1644	13.6	15.78
1547	14.78	15.6
1511	15.1	15.42
1508	15.6	15.38
1696	15.9	15.8
1621	16.1	15.22
1693	16.3	15.06

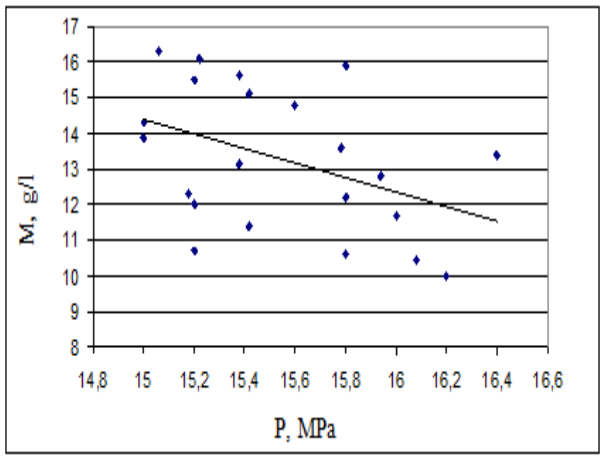

Fig. 3 Graph of the dependence of mineralization on the value of reservoir pressure in the Aptian-Albian-Cenomanian hydrogeological complex.

CONCLUSION

The structure of the geohydrodynamic and hydrogeochemical fields within the Aptian-Albian-Cenomanian hydrogeological complex differs significantly from that within the Lower-Middle Jurassic complex, primarily by greater uniformity. The main factors for the formation of groundwater of the Aptian-Albian-Cenomanian complex are the interaction processes in the system "buried sedimentary water – rock – expelled waters". Within the Kamennoye field, the regional lateral directionality of the groundwater flow from the Aptian-Albian-Cenomanian complex is maintained – from the periphery, where the regional alimentation areas are located, to the central regions of the basin.

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