SOME NEW DATA ON ISOTOPE STRATIGRAPHY OF THE PERMIAN ROCKS AT THE EAST OF THE RUSSIAN PLATFORM

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ABSTRACT

Variations of $\delta^{13}C$, $\delta^{18}O$, and $^{87}Sr/^{86}Sr$ in carbonate rocks and shells of the Permian age at the east of the Russian platform have been regarded. Trends of these isotope ratios reflect the global regression and the increasing of regional environments isolation from the open sea and the arid climate challenges.

Keywords: the permian rocks, isotope ratios $\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$, the Russian platform.

1. INTRODUCTION

Carbon and oxygen isotope ratios variations in sedimentary carbonates are known as a tool to determine global changes in the relationship of the atmosphere-ocean-biosphere.

The Permian period is characterized by positive values of the $\delta^{13}C$ mainly about the value of +4‰ on global curve of the Late Paleozoic and Early Mesozoic [1]. A significant decrease (to ~+3‰ PDB) is observed at the boundary of the Sakmarian and Artinskian ages (~285 million years). Less decrease (to ~+3.5‰) is fixed at the end of Capitanian (~262 million years). A very sharp decrease of the $\delta^{13}C$ (to ~0‰ PDB) is determined at the end of the Permian during the ~2 million years. Sharp negative shifts in the values of the $\delta^{13}C$ at the Late Sakmarian and at the end of the Permian, in general, are explained by a sharp drop in sea level, and consequently, reduction of the cycled carbon reservoir [2].

The change of the $\delta^{18}O$ on global isotope curve is associated with the glacial concept [1]. A beginning of the Permian is characterized by the maximum of the $\delta^{18}O$ (~0‰ PDB). During the Asselian and Sakmarian it is observed at value 4‰ PDB, and at the end of the Sakmarian - at the value -6‰ PDB (for the period ~287-283 million years). During the Artinskian age (~283-277 million years the decreasing of the $\delta^{18}O$ from -4‰ to -7% PDB is fixed. Then the increasing up to ~- 3‰ PDB is mentioned. It corresponds to the boundary of the Kungurian and the Roadian. During the Roadian the decreasing of the $\delta^{18}O$ to ~-5‰ PDB is fixed. Then curve slightly deviates in the direction of increasing and stabilizes until the end of the Permian between ~-5 - -4.5‰ PDB. According to the described curve the ocean was cold (ice age) at the early Permian (the Asselian). Ice melting occurred in the Late Sakmarian and in the middle of the Artinskian. At the Middle and the Late Permian interglacial period continued and transferred to the warm early Triassic.

According to the isotope ratios values of carbon and oxygen in carbonate sediments of the Permian within the Volga-Kama region [3] Permian carbonates are characterized by increased values of the $\delta^{13}C$: ~6-7‰. This points, probably, on a high degree of organic matter fossilization under conditions of shallow-water carbonate platform. In the Lower Kazanian carbonates these values fall down to 2 ‰ PDB, and in the Upper Kazanian carbonates the values of the $\delta^{13}C$ reach up to 4 ‰ PDB.

Similar trends are observed for the carbonate sections of the Middle-Late Permian age in Iran, Pakistan, China, Nepal, Armenia, Turkey, and former Yugoslavia, which are characterized by high values of the $\delta^{13}C$ from 4 to 7 ‰ PDB [4]. About the same range of values observed for the Lower Permian carbonates of the North American basins [5] and Zechstein Western Europe [6].

In the Urzhumian and the Tatarian rocks the values of the $\delta^{13}C$ decrease up the section to -1 ‰ PDB (transitional and continental environments).

The Permian carbonates of the Volga-Kama rivers basin are characterized by the following values of the $\delta^{18}O$. At the Early Permian values of the $\delta^{18}O$ ~4-4, 5 ‰ PDB are fixed (regional data are increased). At the Early Kazanian values of the $\delta^{18}O$ decrease to ~-4‰ PDB (data are comparable with the global curve). At the Upper Kazanian substage and the Urzhumian stage values of the $\delta^{18}O$ increase to ~0-1‰ PDB (regional data are higher than global data). At the Tatarian the values of $\delta^{18}O$ are observed in the range of ~-6 ‰ PDB (Suite III) to ~-2 ‰ PDB (Suite IV) (data are comparable with the global curve) [3].

At the Urzhumian time the active isolation of sedimentary basins from the open sea is fixed by a sharp increase in strontium ratio [3].

Renewal of the database on the isotope ratios of carbon and oxygen through the analysis of new samples from standard section Monastyrskoe [7] has allowed to establish a stronger trend of the decreasing of isotope

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ratios of carbon and oxygen in the Tatarian sediments up the section.

This paper is devoted to a generalization of the previous and new data on the isotopic composition of carbon and oxygen on set of stratotype points representing different fragments of the Permian section in outcrops within the basins of the Volga, Kama, Belaya, Vyatka, Mezen and Sukhona rivers.

2. OBJECTS AND METHODS

The object is represented by set of data on carbon and oxygen isotope ratios, received in isotope geochemistry lab of Komi Scientific Centre (Ural Branch of the Russian Academy of Sciences) on more than 50 samples of carbonate rocks and fossils (carbonate material of shells) collected from a lot of outcrop sections at the East of the Russian platform (Figure-1, Table-1). Several samples from this collection were measured again in lab of isotope-analytical geochemistry of V.S. Sobolev Institute of Geology and Mineralogy (Siberian Branch of the Russian Academy of Sciences) to revise values $\delta^{13}C$, $\delta^{18}O$ and additionally to receive values on strontium ratio. Also set of data includes data on Kama river section from [8] (it is signed by symbol “s” in Figure-1 and Table-1). Data have been received by standard procedures.

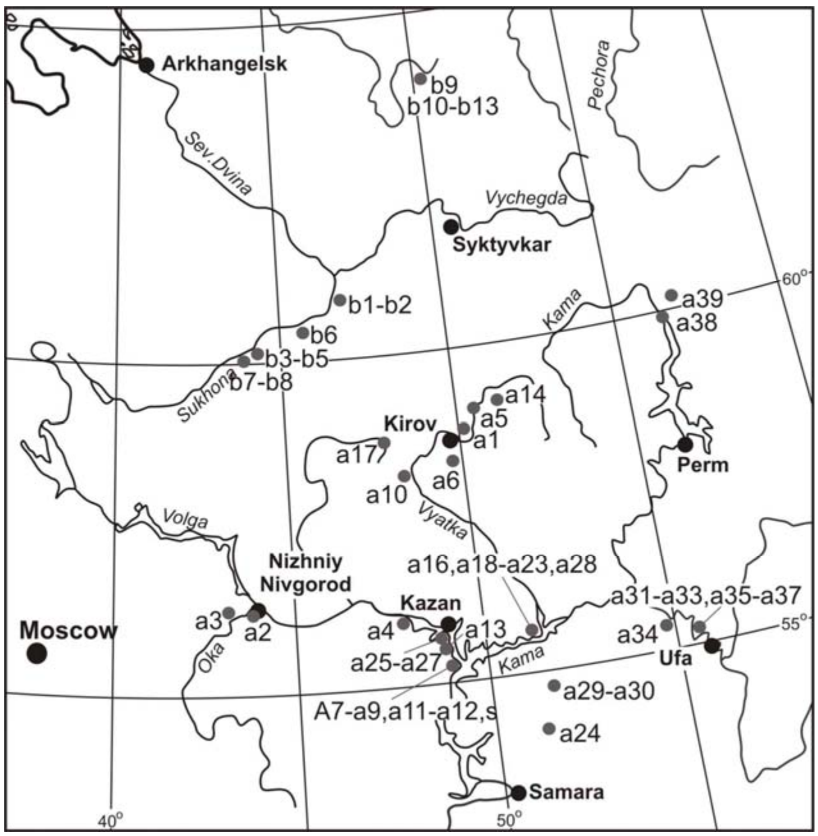

Figure-1. Map of probed sections of Permian rocks (series a, b, s; see Table-1).

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Table-1.

Strata	Section map point	$^{13}C^*$ PDB	$^{18}O^*$ PDB	$^{87}Sr/^{86}Sr^*$	$^{13}C^{rocks}$ PDB	$^{18}O^{rocks}$ PDB	$^{13}C^{shells}$ PDB	$^{18}O^{shells}$ PDB
Tatarian stage, suite IV	a1				-5,1	-9,6	-5,2	-8,7
Tatarian stage, suite IV	a2	-3,1	-12,1	0,70821	-1,9	-7,4	-2,4	-11,4
Tatarian stage, suite IV	b1	-2,9	-12,6	0,70789	-2,2	-12,0	-2,5	-12,8
Tatarian stage, suite IV	b2				-2,7	-12,4	-2,7	-12,7
Tatarian stage, suite IV	a3				-6,4	-10,4	-3,4	-7,9
Tatarian stage, suite IV	a4	-5,2	-9,4	0,70822	-3,8	-8,4	-3,9	-10,6
Tatarian stage, suite IV	b3				0,1	-10,1	-3,3	-12,0
Tatarian stage, suite IV	b4				-2,5	-12,9	-2,2	-14,3
Tatarian stage, suite IV	b5				0	-8,2	-1	-12,2
Tatarian stage, suite IV	a5	-2,6	-8,9	0,70807	-2,6	-11,0	-2,6	-11,3
Tatarian stage, suite IV	b6				1	-5,9	-5,3	-11,5
Tatarian stage, suite IV	b7				-1,5	-4,6	-5,6	-7,5
Tatarian stage, suite IV	a6				-10,5	-13,0	-4,9	-13,4
Tatarian stage, suite IV	b8				-0,5	-4,0	-2,6	-8,7
Tatarian stage , suite III	a7				-2,2	-9,3	-2,6	-9,7
Tatarian stage , suite III	a8				-3,5	-3,4	-2	-7,9
Tatarian stage , suite III	a9				-3,8	-7,5	-3,3	-11,2
Tatarian stage , suite III	a10				-3,8	-9,7	-3,9	-7,5
Tatarian stage , suite III	a11	-1	-8,7	0,70821	-4,45	-11,5	-4,1	-11,8
Urzhumian stage	a12						-7	-14,3
Urzhumian stage	a13				-2,8	-11,0	-5,2	-10,9
Urzhumian stage	b9	-2,3	-2,8	0,70815	0	-8,4	0,4	-10,7
Urzhumian stage	b10	-2,8			-8,1	-10,0	-9,5	-11,1
Urzhumian stage	b11	-3,8	-9,0	0,70813	-2,2	-7,8	-3,5	-9,2
Urzhumian stage	a14				-2	-10,1	-0,1	-10,5
Upper Kazanian substage	a16				-5,75	-6,4	-2,8	-3,3
Upper Kazanian substage	b13				2,5	-5,6	1,1	-5,5
Upper Kazanian substage	a17				-3,1	-9,0	-0,7	-6,0
Upper Kazanian substage	a18	-4,1	-7,6		-4,7	-12,1	-5,1	-13,2
Upper Kazanian substage	a19				0,6	-8,9	-0,3	-5,6
Upper Kazanian substage	a20				-0,1	-10,4	-0,4	-6,6
Upper Kazanian substage	a21				-2,9	-5,4	0,5	-6,2
Upper Kazanian substage	a22						-3,45	-12,5
Upper Kazanian substage	a23				-4,6	-9,4	-1,7	-4,0
Upper Kazanian substage	a24	-1,8	-1,2		-11,5	-13,3	-3,1	-4,0
Upper Kazanian substage	a25				4,1	-6,0	4,3	-4,6
Upper Kazanian substage	a26				4,8	-6,7	4,3	-5,1
Upper Kazanian substage	s[8]				4,3	0,4		

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Strata	Section map point	$^{13}C^{*}$ PDB	$^{18}O^{*}$ PDB	$^{87}Sr/^{86}Sr^{*}$	$^{13}C^{rocks}$ PDB	$^{18}O^{rocks}$ PDB	$^{13}C^{shells}$ PDB	$^{18}O^{shells}$ PDB
Lower Kazanian substage	s [8]				4,1	0,1		
Lower Kazanian substage	a27				4,5	-1,8	4,8	-3,0
Lower Kazanian substage	a28				-2,5	-8,9	-6,3	-11,7
Lower Kazanian substage	a29				-0,7	-6,0	3,75	-0,2
Lower Kazanian substage	a30				2,7	-2,9	4,2	0,1
Ufimian stage	a31				0,5	-10,6	-2,4	-15,2
Ufimian stage	a32				-1,7	-10,0	-5	-11,1
Ufimian stage	a33				-2,7	-11,1	-3,6	-9,6
Ufimian stage	a34				2,2	-13,2	-2,5	-14,7
Ufimian stage	a35				3,6	-12,1	-2,2	-3,1
Ufimian stage	a36				-0,8	-10,4	0,2	-7,0
Ufimian stage	a37				-0,2	-9,3	-0,6	-9,4
Ufimian stage	a38				1,9	-11,8	-2,1	-13,0
Ufimian stage	a39				1,9	-9,2	-0,6	-12,5
Sakmarian stage	s [8]				5,5	4,9		

^{rocks} - data from rocks, ^{shells} - data from shells (isotope geochemistry lab of Komi Scientific Centre (Ural Branch of the Russian Academy of Sciences)); * - data from rocks (revised points, lab of isotope-analytical geochemistry of V.S. Sobolev Institute of Geology and Mineralogy (Siberian Branch of the Russian Academy of Sciences)).

3. ISOTOPE RATIOS VARIATIONS: RESULTS AND DISCUSSION

Comparison of isotope ratios data from rocks and shell material shows similar trends (Figure-2).

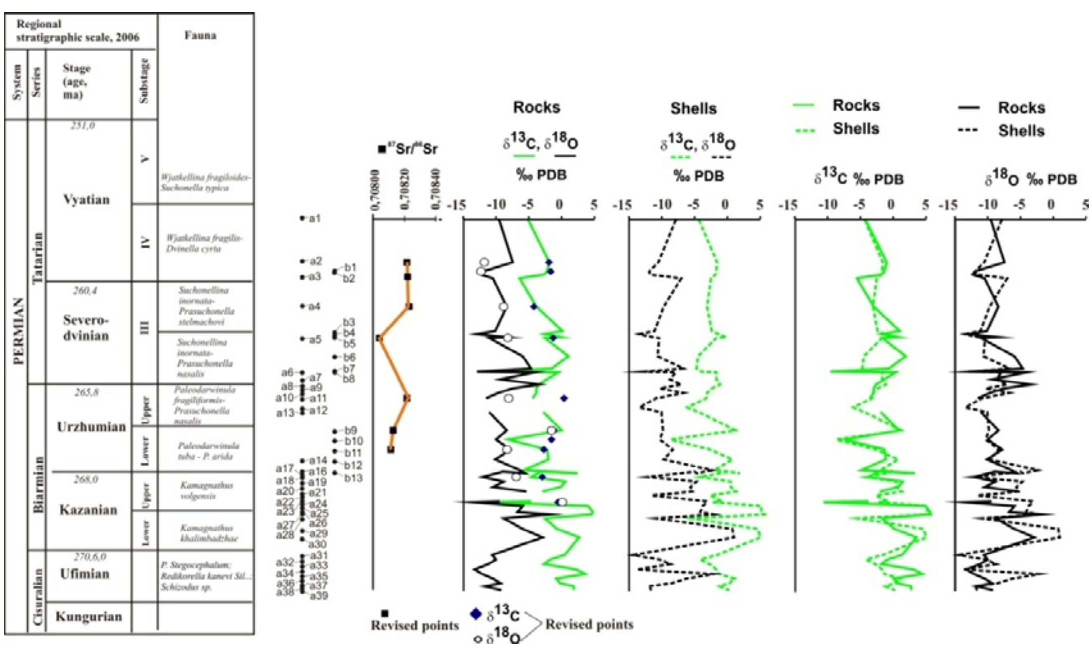

Figure-2. The scheme of $\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$ variations on summary section on fragments by Figure-1 and Table-1.

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Extending a database through greater geographic coverage of the Permian rocks field added graphics isotopic variations (Figure-3).

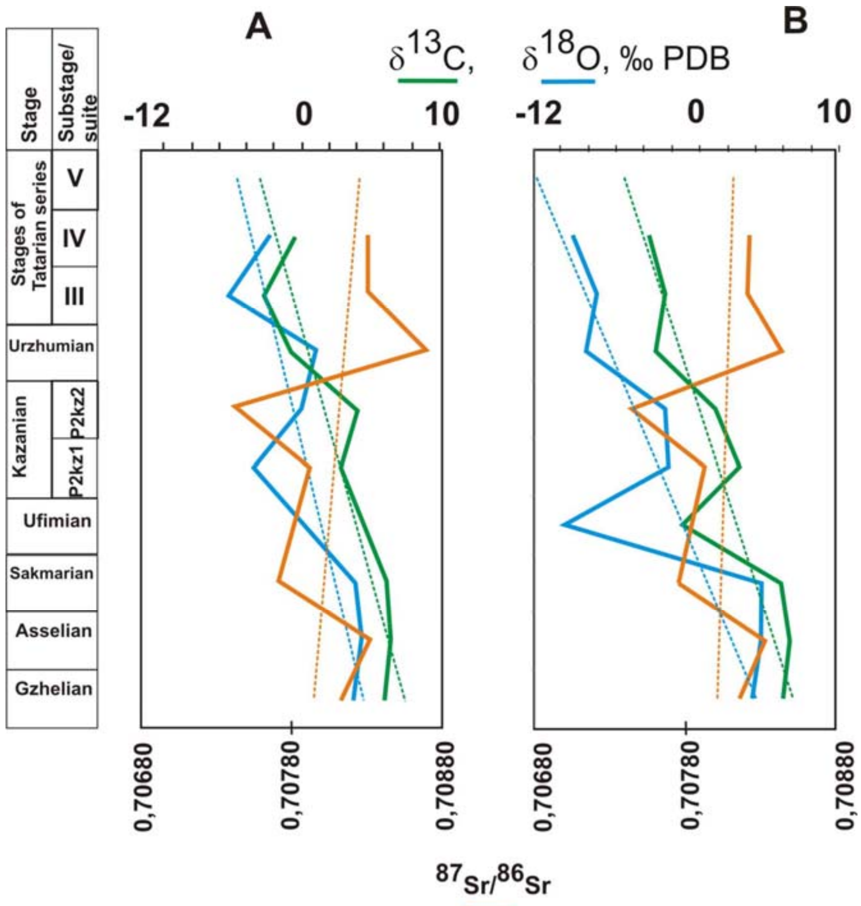

Figure-3. Scheme of $\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ variations in the Permian rocks at the east of the Russian platform: A - on data by [Nurgalieva, 2010], B - with adding of new data (byTable-1).

There is a significant local minimum of the $\delta^{18}O$ in the behavior of the isotopic ratios opposite of the Ufimian sediments (~-10‰ PDB) (Figure-4). The trends have kept its focus. At the Lower Permian sediments the values of the $\delta^{13}C$ and the $\delta^{18}O$ are 6.5 ‰ PDB and 4.4 ‰ PDB respectively. At the Upper Tatarian sediments the values of the $\delta^{13}C$ and the $\delta^{18}O$ are ~-4‰ PDB and ~-9 ‰ PDB respectively. Values of the $\delta^{13}C$ changed slightly in the Sakmarian, the Lower Kazanian and the Tatarian (Suite IV) sediments (the difference does not exceed 0.5 ‰). The noticeable negative shift (on the difference ~3‰) occurred in the Upper Kazanian, the Urzhumian and the Tatarian (Suite IV) sediments.

The values of the $\delta^{18}O$ decreased with noticeable difference for the Upper Kazanian (~2, 7 ‰), the Urzhumian (~9 ‰), and the Tatarian (Suites III and IV: on ~2, 3 ‰ and on ~ 6.9‰ respectively) sediments. In the Sakmarian and the Lower Kazanian sediments a slight increase in the values of the $\delta^{18}O$ (the difference is ~0.4 to 1.2 ‰) is observed.

The curve values of the ratio $^{87}Sr/^{86}Sr$ are corrected in the Tatarian rocks field with negative shift (on 0.0001-0.0003).

The Figure-4 shows the distribution of the data in the coordinates of the $\delta^{13}C$ - $\delta^{18}O$.

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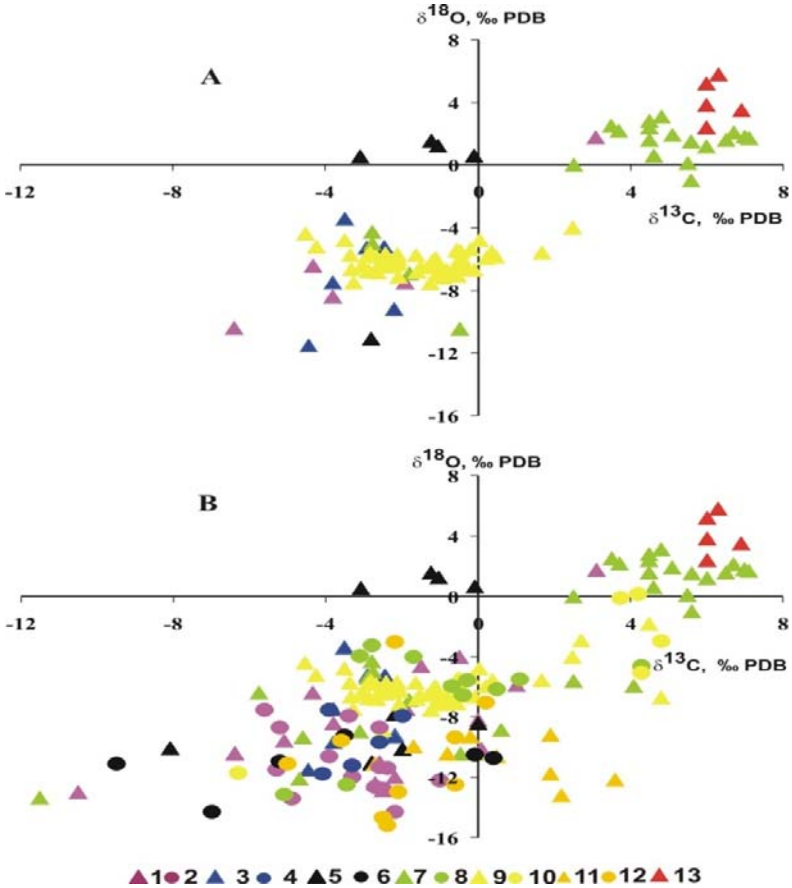

Figure-4. $\delta^{13}C$ - $\delta^{18}O$ graph for Permian rocks of the East of Russian platfirm.
A - data on [Nurgalieva, 2010]; B - with adding of new data.

Legends (triangles - data from rocks; circles - data from shells): 1, 2 - suite IV (Tatarian stage); 3, 4 - suite III (Tatarian stage); 5, 6 - the Urzhumian stage; 7, 8 - Upper Kazanian substage; 9, 10 - Lower Kazanian substage; 11, 12 - Ufimian stage; 13 - Lower Permian substage.

Points of the Early Permian and the Tatarian age localize in the first and third quarters of the coordinate plane, respectively. Points of the Ufimian age are observed in the second and third quarters. Points of the Kazanian age situate in the cloud, crossing all quarters, except the fourth one. Points of the Urzhumian age are observed in the third and fourth quarters of the coordinate plane.

Variations of the $\delta^{13}C$ and the $\delta^{18}O$ values can be explained by the factor of the open sea influence and the climatic factor. The first factor is confirmed, first of all, by the $^{87}Sr/^{86}Sr$ behavior. The values of the $^{87}Sr/^{86}Sr$ reach a local minimum opposite of the Kazanian sediments (maximum link with the open sea), and then the values increase dramatically in the Urzhumian and the Tatarian rocks, indicating a rapid isolation of sedimentary basins from the open sea. Decreasing of $\delta^{13}C$ and $\delta^{18}O$ can be result of this isolation.

Arid climate factor could call the increase of water salinity, which may lead to reduction of isotopically light carbon in the system water-biota-organic matter-carbonate because of reducing the content of organic matter in this system and, accordingly, reducing the amount of carbon dioxide with isotopically light carbon, oxidized and utilized by depressed photosynthetic biota and bacteria-reducents [9, 10].

The Early Permian paleobasin was characterized by higher values of the $\delta^{13}C$ that can indicate the sedimentation in the environments of carbonate platforms with a high degree of organic matter fossilization. In the Ufimian time there was a significant negative shift in values of the $\delta^{13}C$. This indicates the falling sea level and the increasing of organic carbon, coming out from the biological cycle between the sedimentary basin and the atmosphere. In the Kazanian time the values of the $\delta^{13}C$ increase (the Kazanian Paleosea formed [11]). The role of a marine biota in the biological cycle becomes greater. In the Urzhumian time the role of the evaporate processes increase (the values of the $\delta^{13}C$ decrease), and in the

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Tatarian time there is a small increase in the values of the $\delta^{13}C$ with subsequent decrease (isolation from the open sea, factors of continental water streams and terrestrial biota).

The obtained values of the $\delta^{18}O$ for the Early Permian positively shifted relative to the global oxygen curve that can be explained by the combination of global glacial effect and regional evaporate processes. The trend of the $\delta^{18}O$ in the Ufimian time proves the decrease of the $\delta^{18}O$ on the global curve, interpreted as a period of warming and melting of glaciers.

In the Kazanian time there is an increase of the $\delta^{18}O$, explained by the marine transgression at the beginning of the Kazanian time (Kazanian paleosea [11]). Then open sea regression called decreasing of the $\delta^{18}O$ in the Urzhumian and the Tatarian sediments.

4. CONCLUSIONS

Variations of the $\delta^{13}C$, $\delta^{18}O$, and $^{87}Sr/^{86}Sr$ reflect the changes in the environmental history during the Permian period at the east of the Russian platform and can be used as tool to develop the stratigraphic frame of the Permian system.

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