IJABR

International Journal of Advanced Biotechnology and Research (IJABR)
ISSN 0976-2612, Online ISSN 2278–599X,
Special Issue-1, 2019, pp342-349
http://www.bipublication.com

Research Article

Hydrogeology Peculiarities of the Juncion Zone of the Urals and West Siberia

Zinaida UFELMAN[1, a *], Linar KHABIBULLIN[1, b], Marsel KADYROV[1, c] and Denis DRUGOV[1, d]

[1]Industrial University of Tyumen, Tyumen, Russia
[a]ufelmanza@tyuiu.ru, [b]linarkh@bk.ru, [c]kadyrovma@tyuiu.ru, [d]drugovda@tyuiu.ru

ABSTRACT.
The article presents the results of studying one of the most difficult regions of the West Siberian megabasin in regards to geodynamics – the near-edge eastern part of the megabasin, namely the junction zone of the Urals and West Siberia. The purpose of the paper is to identify features of hydrogeological conditions of the near-edge part of the West Siberian megabasin. This part of the West Siberian megabasin includes the Cis-Ural megablock, the western part of the western megablock, and the East-Urals marginal suture that separates them. The article briefly describes the history of the Urals geodynamic development. The interaction between the Ural margins and the West Siberian megabasin resulted in geohydrodynamic anomalies (presence of alternation of linearly elongated areas of super-hydrostatic reservoir pressures (+4-5 MPa) with areas of low-hydrostatic reservoir pressures (pressure deficit of 6.0-9.0 MPa)), severe hydrogeothermal conditions, elevated levels of hydrocarbonates and carbon dioxide in waters. The complex copper-sulphide composition of Ural rocks is reflected in the microelement complex of natural waters of the West Siberian megabasin, and this affects, first of all, the composition of groundwater of the Cis-Ural region, both surface watercourses and deep oil and gas bearing horizons. In the underground waters of the basin’s eastern part, elevated values of vanadium, cobalt, nickel, copper, zinc, molybdenum, and other elements are recorded, which is associated with the ablation of terrigenous material from the Ural margins as the West Siberian geosyneclise is filled.

Keywords: Microelements in groundwater, Geofluidic system, Hydrocarbonates, West Siberian megabasin, Carbon dioxide in groundwater.

INTRODUCTION

This article presents the results of studying one of the most difficult regions of the West Siberian megabasin (WSMB) in regards to geodynamics – the near-edge eastern part of the megabasin, namely the junction zone of the Urals and West Siberia. This part of the WSMB includes the Cis-Ural megablock of WSMB, the western part of the western megablock, and the East-Ural marginal suture that separates them. We analyzed this area from the standpoint of the geofluidic systems theory. The first ideas about geofluidic systems were laid down in Vernadsky’s equilibrium system theory [1]. A "geofluidic system" [2-4] is a complex block-hierarchical (matrix-fluidic) structure, the elements of which are structural and lithological blocks or their complexes (stratigraphic, tectonic, morphostructural) and marginal dynamically stressed zones (DSZ) which connect them [5]. At the same time, on the scale of the earth crust, geofluidic systems are a "pie" (rock) with a "filling" (fluids: liquids, gases, hydrotherms, melts, etc.). The direction and character of DSZ make a significant impact on the structure of hydrogeodynamic field, determining, along with processes of squeezing sedimentation water out, the formation of zones with pre-hydrostatic and super-hydrostatic reservoir pressures.

At the current stage of development, shifts occur along the East-Ural marginal suture, thanks to which the basement of West Siberia continues shifting under more ancient Archean-Proterozoic Ural rocks at an angle of about 30° [6]. The marginal suture had the greatest impact on such oil and gas provinces of West Siberia as: East-Ural, Cis-Ural, and Krasnoleninsk.

It is the geodynamic approach that allowed Matusevich and Bakuev to publish a new hydrogeological stratification of WSMB [3] (1986) at the XXVII session of the International Geophysical Committee, and also to create a more complete classification of groundwater reservoirs and justify their relationship with oil and gas formation and accumulation in collaboration with Kartsev and Vagin. In 2013, the authors published the basics of the new dual geodynamic concept in hydrogeology using the example of WSMB [2]. The dual nature is associated with the presence of both lateral and vertical movements of water in underground reservoirs. This can be clearly seen in the example of unique WSMB, where processes of oil and gas formation and accumulation are controlled by the significant scale of the revitalization of groundwater.

METHODS

The Ural deep structure was thoroughly studied using the largest geological and geophysical profiles, with particular attention paid to the near-edge part of WSMB with a large number of hydrogeodynamic and hydrogeochemical anomalies (reservoir pressure difference, high carbon dioxide in waters). Main features of the gravitational field of this area, geothermal gradients were analyzed. The trace element composition of groundwater in the near-edge part of WSMB was compared with the composition of Ural rocks. The contents of such water microcomponents as lead, copper, zinc, titanium, and nickel were analyzed, which made it possible to show the reflection of the Ural metallogeny in the groundwater of WSMB formed as a result of the ablation of terrigenous material from the Urals as the West Siberian geosyneclise was filled.

RESULTS AND DISCUSSION

Geological Structure Peculiarities of the Junction Zone of the Urals and West Siberia. The article by Rylkov et al. [7] examines the deep structure of the Urals using the three largest complex new-generation geological and geophysical profiles intersecting the Urals: URSEIS, ESRU, PUT. These profiles, intersecting all Ural geological structures, are currently the most important sources of comprehensive geological and geophysical information about the deep structure of the Ural mobile belt and the nature of its junction with surrounding platforms. Below are some data from this study that are directly related to understanding the nature of the hydrogeological field of the territory under consideration.

The Urals, as a linear folded orogen, underwent a full cycle of geodynamic development [7, 8], including the following stages: prerifting (Riphean – Vendian); continental rifting (Cambrian – Lower Ordovician); oceanic spreading (Middle – Upper Ordovician); island-arc (Upper Ordovician – Upper Devonian); collision (Upper Devonian – Perm); limited post-orogenic stretching (Triassic) and sub-platform stage. The East Urals (paleo-island-arc) consist of two main uneven-age island-arc terrains: Tagil (located in the Middle Urals and to the north, formed from the Ordovician to the Lower Devonian) and Magnitogorsk (the Southern Urals, the Lower Devonian – Carboniferous). Both of these terrains form the so-called main volcanogenic axis (megazone) of the Urals with a strongly pronounced gravitational super maximum.

The East-Ural marginal suture is an active margin of the continent with a wide development of sublatitudinal lineaments, arc and annular elements, back arc basins. The schematic geological and geophysical profile through the Urals and the West Siberian geosyneclise, compiled by Zhero, Zaitsev, Kramnik, and Surkov, is given in Fig. 1. In this diagram, Vorobieva [9] has highlighted the area of the deep Proterozoic trough; its western edge is the area of the Main Ural fault dividing the Central Urals and the eugeosynclinal area of the eastern slope.

In the Southern and Middle Urals, there is a suture zone, plunging into the mantle under the Main Ural fault zone or slightly to the east, and traced in varying degrees under the Central Ural lifted block or the Pre-Urals fore deep down to depths of 75-80 km. The Urals are characterized by such unique features as the presence of deep "mountain roots", the presence of well-preserved ophiolite and island-arc andesitoid complexes, a high-pressure metamorphite belt, a granite-metamorphic belt, and the presence of the largest and diverse ore fields, etc.

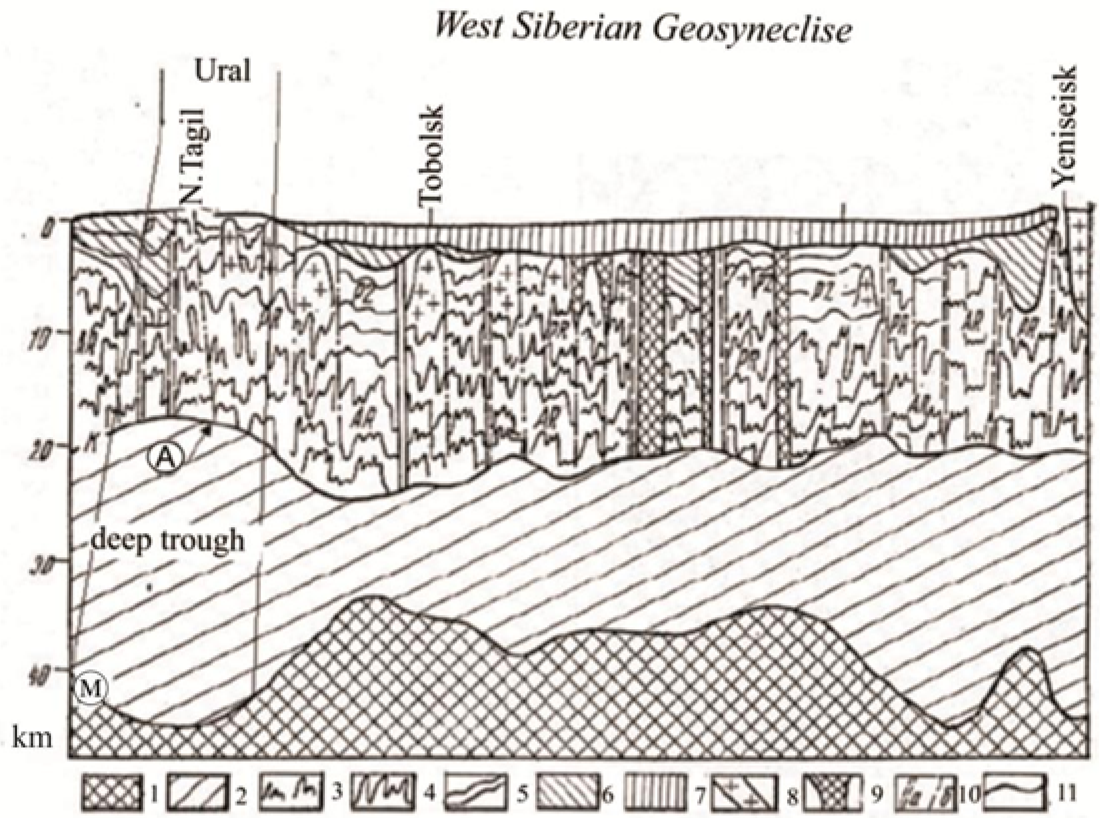

Fig.1. Geological and geophysical profile through the Urals and the West Siberian geosyneclise.

Compiled by Zhero, Zaitsev, Kramnik, Surkov, with annexes of Vorobieva. 1 – upper mantle: 2 – granulite-basite layer of the earth crust (thickening of this layer fixes deep graben-like structures, and under the Urals – the area of the deepest graben covered by a thick Proterozoic stratum); metamorphic complexes: 3 – Archean (AR). 4 – Proterozoic (PR); 5 – Paleozoic folded deposits (PZ); 6 – Permian-Triassic deposits of marginal troughs; 7 – Mesozoic and Cenozoic sedimentary deposits, overlying the Epi-Paleozoic platforms ("plate complex" – p): 8 – granite batholites: 9 – basic and ultrabasic rocks; 10 – deep faults (a – dividing tectonic blocks; b – dividing different structure-facies zones).

Hydrogeological Field of the Junction Zone of the Urals and West Siberia. The study of the hydrogeological field on the basis of the geodynamic concept should be comprehensive and include its components: gravitational, electromagnetic, thermal, concentration, hydrogeodynamic and technogenic fields.

The hydrogeological field of the Eastern slope of the Urals is extremely contrasting and dynamically active. Hydrocarbonate magnesium waters are mainly developed among ultrabasic massifs; hydrocarbonate calcium-magnesium waters dominate among carbonate, especially dolomitic limestones; acid sulfate waters dominate in copper deposits. In tectonically reduced zones of Paleozoic rocks, the mineralization of fracture-vein waters is somewhat higher than in fracture and fracture-karst waters drained by them. Under conditions of slow circulation or stagnation, salt water and even brines with mineralization of up to 52 g/l are sometimes formed in such zones [10].

Briefly note that the structure of hydrogeological field of this territory was primarily determined by its development history: the closure of the Riphean-Early Paleozoic Siberian Ocean and the formation of the corresponding water-pressure systems within West Siberia with sharply different geodynamic regimes. The history of the formation of WSMB water-pressure systems is discussed in detail in [3, 4].

The maximum values of the positive gravitational field are concentrated along the axial part of the Urals [11]. In the junction zone of the Urals and West Siberia, local gravitational maxima appear, which are subparallel to the main line of the gravitational maxima of the Ural orogen. The intensity of a positive anomaly can reach 150 mGal. Local gravitational minima are also noted here, for example, in the Berezovsky oil and gas bearing area. Negative field intensity values are sometimes less than 10 mGal.

The extremely high locality of tectonic processes in the junction zone of the Urals and West Siberia took here the form of the alternation of minima and maxima of the gravitational field. It is interesting, that such locality is not observed in the junction area of the Russian platform and the Urals, which is associated with the well-known asymmetry of the Urals (climatic, geological and tectonic, hydrogeological).

It is the junction zone of the Urals and West Siberia that is also characterized by one of the most contrasting parameters of hydrogeothermal field. Areas with the highest geothermal gradients (up to 4-6.5 °C/100 m) are controlled by the gravitational field maxima. Here, waters with high temperatures lie relatively shallow. For example, water with a temperature of 70-90 °C is common in the Shaim region at a depth of 1,500-1,600 m, while in the Surgut region, waters with such a temperature are found at depths of 2,400-2,500 m.

Gravitation-tectonic stresses in the crust of the Urals led to the formation of elongated heterogeneous hydrogeodynamic and hydrogeochemical fields along the East Ural marginal suture. Groundwater here is often characterized by high concentrations of carbon dioxide and trace elements, intense hydrogeothermal field. Geodynamic alternating stresses led to changes in the stress state of rocks of these megablocks, in particular, to a change in the void space of rocks (during compression – a decrease in porosity and fracturing, and during tension – an increase in porosity and fracturing). In this case, consequently, super-hydrostatic reservoir pressures or, conversely, pre-hydrostatic reservoir pressures occur. The mechanism of formation of such water-pressure systems is associated with an increase in the fracture-pore volume of rocks under tension (expansion) and "sucking" of water from surrounding rocks into these near-fault areas, which leads to a sharp decrease in reservoir pressures below the nominal hydrostatic pressure and to the activation of horizontal and vertical migrations within the junction area.

For example, within the Cis-Ural part of West Siberia, which belongs to the elision lithostatic water-pressure system with geodynamic elements in lower parts of the section, the following anomalies were formed: linearly elongated areas of super-hydrostatic pressures (+ 4-5 MPa) alternate with areas of low-hydrostatic reservoir pressures (pressure deficit of 6.0-9.0 MPa). At the same time, there is a clear connection between hydrogeodynamic, hydrogeothermal and hydrogeochemical zonalities. The main distinctive feature of the hydrogeothermal field here is the presence of severe geothermal conditions. Thus, temperatures from 60 to 70 °C were recorded at a depth of 1.4-1.5 km in Em-Egovskaya, Inginskaya, and Palyanovskaya areas, which is not observed in almost any other part of West Siberia. Elevated values of the geothermal gradient of 4.6 °C/100 m were recorded in Cretaceous sediments of the region, which are inherent in lower parts of the section: at a depth of 2.5 km, they are usually above 120 °C.

The content of hydrocarbonates in lower parts of the section of the Cis-Ural megablock and the western part of the WSMB western megablock is large everywhere. Here, hydrocarbonate-sodium type of groundwater according to Sulin prevails. One of the reasons for this is the large-scale redistribution of substance in the WSMB western megablock, associated with elision water exchange, squeezing out of a huge amount of recovered water from the "Frolovsk barrier" clay. But deep fluids coming from basement faults also have been playing a significant role. Kovalchuk et al. [12, 19] note that soda waters with a sum of salts of 5-20 g/l, widespread in lower hydrogeological complexes of the territory under consideration, were formed as a result of the reverse metamorphization of calcium chloride waters under the influence of endogenous (metamorphogenic) carbon dioxide. According to their origin, these waters can be called sedimentation-endogenous (metamorphogenic). The main part of carbon dioxide in the junction zone of the Urals and West Siberia comes to sedimentary deposits from faults of the Paleozoic basement (only a small part of CO_2 has a biogenic origin). Its formation is associated with thermometamorphic processes occurring mainly in carbonate-containing rocks. For example, on such areas as Shaimskaya, Samutnelskaya, Mezhevskaya, etc. of the Cis-Ural area [10, 12-15], the saturation of soda waters with carbon dioxide reaches 80% or more. By studying pore solutions and conducting isotope analyses of water and gas, researchers dealt with the Shadrinsk carbonate water field [6] found that the source of carbon dioxide fluid is carbonate-containing Devonian and Carboniferous rocks, composing the WSMB basement. The content of CO_2 here reaches 3.20-3.25 g/l. At the longitude of Shadrinsk, the depth of immersion of carbonate-containing rocks of West Siberia under more ancient rocks of the Urals reaches 20-330 km, and the temperature reaches 300-450 °C. Famous hydrogeologist A.M. Ovchinnikov noted that it is in this temperature range (360-400 °C) where the greatest amount of CO_2 is released during thermometamorphism. The movement of vapor-gas-water fluid from a depth of 20-30 km can occur only along local reduced zones of ruptures, which form a kind of knot in the Shadrinsk area.

Maxima of the gravitational field of the Urals [11] indicate a deep connection between the roots of the Urals and plume tectonics. The high density of matter inside these plumes is the main cause of increased values of the gravitational field in the orogenic part. Probably, they and the associated periodic activation of movements of deep fluids are one of the reasons for the contrast and mosaic nature of the hydrogeochemical field in the junction zone of the Urals and West Siberia and in adjacent areas. For example, Kovalchuk et al. [12] note the presence of groundwater within the Eastern slope of the Urals with both mineralization of up to 5 g/l and mineralization of up to 85 g/l (in slope depressions).

At present, taking into account the latest data on hydrogeochemistry, geotemperatures, mineral composition and hydrothermal processing of rocks, attention should also be paid to the influence of deep fluids, primarily on the hydrogeodynamic field of lower parts of the section. Channels of vertical cross flows are faults of the basement and the path of their "translation" into the sedimentary cover. There are studies confirming the "translation" of faults within West Siberia almost up to the surface through the entire sedimentary cover [6, 7, 15, 18]. In some cases, they serve as active fluid migration channels, in others – as hydrodynamic screens due to authigenic mineral formation. The zone of contact between the sedimentary cover and the basement is the zone of active flow of ascending and descending migration processes, since it is here where the pore permeability of sedimentary rocks is replaced by the fracture permeability of crystalline formations. Moreover, the closer to the East-Ural marginal suture, the greater the number of migration channels.

One more of the most important aspects of the interaction between the Ural margins and the West Siberian megabasin is noteworthy – the ablation of terrigenous material from the Urals. The Urals throughout the development of the West Siberian sedimentation basin was one of the sources of terrigenous material, and its metallogeny permeated the composition of groundwater and surface waters of the WSMB, especially in the near-edge part of the basin (Table 1).

Table 1: The average concentrations of some trace elements (in [μg/l]) in groundwater of the Shaim region and in the condensation water of the Berezovo-Igrimskaya cluster of fields

Territory	V	Co	Ni	Cu	Zn	Mo	Ti	Hg
Shaim region	9.8	7.1	34	23.6	731.0	4.5	ND	ND
Berezovo-Igrimskaya cluster of fields	ND	6.8	7.4	6.7	2.3	0.9	0.5	8.7

The metallogenic profile of the Urals is defined by the presence of a deep trough (Fig. 1). Characteristic fields for the Urals are fields of chromite ores, platinum group metals, iron and manganese ores, and vanadium mineralization. Large deposits of gold are associated with granite batholites. Copper-porphyry and copper-molybdenum-porphyry ores are discovered in the Urals. The linear zone of the Tagil-Magnitogorsk downfold is a concentration of large-scale (in terms of reserves) deposits of copper-pyrite and pyrite-copper-zinc ores [9].

For example, the Krasnoleninsk oil and gas province, for which the eastern slope of the Urals is a feeding province, is characterized by structure-metallogenic zones of initial and early stages of development (Ti, Cu, Cr, P, Mo, Au, Ni, etc.) according to Bilibin [16]. Even at a distance from the Urals, the complex copper-pyrite mineralization of this region is reflected in the complex of trace elements of the WSMB natural waters, and this affects, first of all, the composition of underground waters of the Cis-Ural region (Table 2). With depth, the concentration of trace elements increases, which can be explained by the long-time contact of water with the mineral part of rocks.

Table 2: The average content of trace elements (in [μg/l]) in surface watercourses, in waters of Oligocene-Quaternary and Jurassic complexes of different WSMB areas [2, 4, 13, 16]

Element	Surface watercourses				Waters of the Oligocene-Quaternary complex				Waters of the Lower-Middle Jurassic complex
	Area of WSMB				Area of WSMB				
	E	CU	C	SW	E	CU	C	SW	CU
Pb	0.6	0.75	0.60	0.12	0.30	0.40	0.99	0.40	ND
Cu	1.12	4.20	0.90	1.60	1.50	6.70	4.50	2.90	112.20
Zn	20.00	29.00	6.90	2.20	18.70	26.70	33.30	5.90	ND
Ti	10.30	14.20	3.10	5.20	2.52	11.60	6.40	3.30	450.00
Ni	1.80	3.30	Traces	3.10	0.80	24.00	14.00	14.00	30.00

Note: Areas of WSMB: E – East, CU – Cis-Ural, C – Central, SW – South-West.

The concentration of trace elements in waters is significantly affected by carbon dioxide. In the Shaim region, the high content of trace elements is associated (in addition to the temperature factor) with a huge amount of carbon dioxide (up to 18 ml/l) of thermometamorphic origin, probably coming through zones of ruptures and faults. For example, the content of mercury in waters of the Shaim region reaches 100-180 μg/l. A certain part of mercury is juvenile in nature: here, along the axial part of the Shaim swell, a fault is detected, to which the thermal and gas anomalies are confined (groundwater is gassed with carbon dioxide). Throughout this fault (Tolumskaya, Trekhozernaya, Teterevskaya, Ubinskaya areas), a high content of mercury (up to 60 μg/l) and cadmium (up to 57 μg/l) is observed [4, 9, 17].

CONCLUSION

Studying the hydrogeological field of the junction zone of the Urals and West Siberia is a complex multifactorial task. At this stage of the study, the authors have concluded that the hydrogeological field of this zone is a self-organizing open system, which is characterized by a complex structure of the matter and energy distribution. It has continuous flows of heat, gravitational, electrical energy, various substances (liquid, solid, gaseous). The substance can be represented by infiltration and elision water, gas flows from the basement, etc.

Also, the nature and structure of the hydrogeological field of the zone under consideration are affected by technogenic processes. All its components are changing. The transformation of the concentration field under the influence of technogenesis is expressed primarily in the contamination of intervals of the hydrogeological section that occurs as a result of drilling, the operation of reservoir pressure maintenance systems and the disposal of industrial wastewater. The technogenic component affects, besides the concentration field, and more precisely, through it, the hydrogeodynamic field by clogging the reservoir rocks during the interaction of "alien waters" with reservoir waters, which leads to a deterioration of parameters of their filtration-capacitive properties.

Currently, intensive 3D exploration and detailed interpretation allow opening the fundamentally new features of structure and life of plicative and disjunctive structures of the junction zone of the Urals and West Siberia, and substantially refining the geological models of fields. The authors see further development of the research as the synthesis of sufficient hydrogeological information and recent advances in geology, tectonics, geodynamics, geochemistry, thermodynamics, etc., that is, as the use of the interdisciplinary approach. This approach will allow identifying the structure and nature of the territorial hydrogeological field, taking into account directions and power of matter and energy flows, determining the level of matter organization in the hydrogeological field under study.

REFERENCES

[1] V.I. Vernadsky, The History of Natural Waters, Nauka, Moscow, 2003.

[2] V.M. Matusevich, R.N. Abdrashitova, Geodynamic concept in modern hydrogeology on the example of the West Siberian megabasin, Basic Research 4 (2013) (Part 5) 1157-1160. Information on www.rae.ru/fs/?section=content&op=show_article&article_id=10000591

[3] V.M. Matusevich, O.V. Bakuev, Geodynamics of water-pressure systems of the West Siberian oil and gas bearing basin, Soviet Geology 2 (1986) 117-122.

[4] V.M. Matusevich, A.V. Rylkov, I.N. Ushatinsky, Geofluid Systems and Oil and Gas Bearing Issues of the West Siberian Megabasin, TIU, Tyumen, 2005.

[5] A.V. Radchenko, O.S. Martynov, V.M. Matusevich, Dynamically Stressed Zones of the Lithosphere – active Channels of Energy-Mass Transfer, Tyumen Printing House, Tyumen, 2009.

[6] A.I. Vishnyak, I.A. Chetverkin, V.P. Novikov, R.I. Plotnikova, Hydrogeological model of the Shadrinsk carbonate mineral water field as a basis for assessing its reserves, Exploration and Protection of Mineral Resources 11 (2011) 35-43.

[7] S.A. Rylkov, A.A. Rybalka, K.S. Ivanov, The deep structure and metallogeny of the Urals: comparison of the deep structure of the Southern, Middle and Polar Urals, Lithosphere 1 (2013) 3-16.

[8] A.V. Zubkov, The stress state of the Ural crust, Lithosphere 3 (2002) 3-18.

[9] S.V. Vorobieva, The formation of tectonic structure and metallogenic profile of the Urals, Bulletin of TSU 14(3) (2009) 628-631.

[10] A.V. Sidorenko (Ed.), Hydrogeology of the Urals, Nedra, Moscow, 1972.

[11] R.M. Bembel, V.M. Megerya, S.R. Bembel, Geosolitons: Functional System of Earth, the Concept of Exploration and Development of Hydrocarbon Fields, Vector Book, Tyumen, 2003.

[12] A.I. Kovalchuk, Yu.P. Vdovin, A.V. Kozlov, Formation of the Chemical Composition of Transural Groundwater, Nauka, Moscow, 1980.

[13] V.M. Matusevich, Geochemistry of the West Siberian Artesian Basin Groundwater, Nedra, Moscow, 1976.

[14] A.A. Rozin, Groundwater of the West Siberian Artesian Basin and Its Formation, Nauka, Novosibirsk, 1977.

[15] G.A. Tolstikov, Conditions for the formation of hydrocarbonate-chloride sodium waters in the Jurassic sediments of the West Siberian Lowland, P. 1, Proceedings of SNIIGGiMS 32 (1964) 50-58.

[16] Yu.A. Bilibin, Metallogenetic Provinces and Metallogenetic Epochs, Gosgeoltekhizdat, Moscow, 1955.

[17] Takzare, A., Goudarzi, M., Maleki, A., Soltani, A. E., Kaheh, F., Arab, S., & Espahbodi, E. (2018). Paediatric sedation during upper gastrointestinal endoscopy: Comparison of propofol+ ketamine vs sodium thiopental+ fentanyl. *Electronic Journal of General Medicine*, *15*(6).

[18] Günay T, Yardımcı OD, Polat M, Sandal K, Şeneldir H. Evaluation of Malignancy Risk in Patients Who Underwent Hysteroscopy for Preliminary Diagnosis of Endometrial Polyp. J Clin Exp Invest. 2018;9(2):95-9. https://doi.org/10.5799/jcei.433819

[19] KHEIRY, M. V., HAFEZI, A. M., & Hesaraki, S. (2013). Bone Regeneration Using Nanotechnology–Calcium Silicate Nano-Composites, UCT Journal of Research in Science, Engineering and Technology, 1(1): 1-3.