https://doi.org/10.33271/nvngu/2023-1/010

E. Yu. Seitmuratova[1],
orcid.org/0000-0001-8403-4635,
R. T. Baratov[1],
orcid.org/0000-0002-0627-1536,
Ya. K. Arshamov*[1],
orcid.org/0000-0003-0527-6797,
D. O. Dautbekov[1],
orcid.org/0000-0002-8220-5450,
Sh. A. Seytzhanov[2],
orcid.org/0000-0003-4807-8571

1 – Satbayev University, Almaty, the Republic of Kazakhstan
2 – TOO "Yildirim Holding Kazakhstan", Astana, the Republic of Kazakhstan
* Corresponding author e-mail: y.arshamov@satbayev.university

LITHIUM AND GOLD CONTENT IN SALT DOMES AND SALINE LANDS OF WESTERN AND SOUTHERN KAZAKHSTAN

Purpose. To identify the lithium content of mineralized saline lands in the lower reaches of the Chu and Sarysu Rivers and the gold content of the Inder and Shalkar salt domes, and to give a predictive estimate of their industrial prospects.

Methodology. The basis of the research methodology is a classic combination of prospecting and surveying: collection of precursor materials, field work, including object mapping, hydro- and lithochemical sampling, analytical studies and analysis of laboratory data.

Findings. We carried out the whole complex of the planned works on the sites under study. As a result, in 76 % of the analyzed water samples lithium content was found to be higher than clarkee in seawater (0.17 mg/l) by 1.2–2.4–4.12 times. Lithium content in salts and soils is noted in significantly lower values of lithium clarkee in the Earth's crust, in rare cases lithium values in samples are 1.5–2 times higher than clarkee. Out of 25 samples of the Shalkar salt dome area, Au was found in 9 samples with grades from 1.36 to 6.02 g/t. The percentage of significant samples is 36 %. The average Au content in the Shalkar salt dome taking into account all other "empty" samples is 1.2 g/t. According to these data, taking into account modern technologies of extraction of Au at its low content, the Shalkar salt dome may well be classified as a large-volume deposit of poor ores. The results of quantitative analysis by atomic absorption of samples from the Inder salt dome also indicate the presence of significant Au content in seven samples – from 1.6 to 3.9 g/t. The average gold content for the entire volume of samples taken would be 0.78 g/t, which can be considered commercially significant under current conditions. The given results of hydromineral raw materials research for possible extraction of lithium and noble metals, despite their preliminary character and insignificant volumes, unequivocally indicate the necessity of large-scale exploration works for final evaluation of the described objects and identification of new ones similar to them.

Originality. The originality of the study is that such work has been carried out for the first time. Quantitative assessment of lithium and gold content in saline lands and salt domes of Kazakhstan showed an excess of their clarkee and the prospects of these objects for further research.

Practical value. significance lies in the identification of lithium content of hydromineral raw materials and gold content of salt domes of Kazakhstan as possible cost-effective new sources of lithium and gold.

Keywords: *Kazakhstan, hydromineral raw materials, salt domes, mineralized waters, lithium content, gold content*

Introduction. Recognition of the climate impact of anthropogenic greenhouse gas emissions has led to development of sustainable energy technologies requiring unconventional ores, defined as 'critical' or 'strategic' based on their importance for clean energy and economic viability. Lithium (Li) is classified in several countries as a critical energy element because of the growing demand for lithium-ion batteries, which have a high power density and relatively low cost, making them optimal for energy storage in portable electric devices, electric power grids and the growing fleet of hybrid and electric vehicles [1].

Literature review. Experts estimate that demand for lithium by 2028 could triple to around 550–600 thousand tons per year [2], with lithium carbonate prices as high as $28,600 per ton in 2021 [3]. According to some experts [1, 4–6], identified raw resources of lithium in the world are estimated at 13 million tons with world consumption estimated at 65 thousand tons. At the same time, 22 % of confirmed reserves of lithium are concentrated in pegmatite ores, and 78 % in various kinds of hydromineral raw materials [1]. Discovery and development in the 1990s of the richest deposit of lithium brine in the intermountain troughs of Andes (Chile, Bolivia, Argentina) revolutionized the market of lithium products. Underground brines are becoming the dominating raw material for the Li_2CO_3 production all over the world because of the lower cost in comparison with lithium carbonate production from solid ore [2, 5–7]. Currently, the world production of lithium is less than 0.2 % of the known world reserves (102 million tons). Currently, the world production of lithium is less than 0.2 % of the known world reserves (102 million tons).

The high demand for lithium has challenged geologists to discover new sources of this alkali metal. During most of the *20th* century, the main sources of lithium were pegmatite-type deposits. Because of the widespread occurrence of endogenous pegmatite deposits and their high lithium content, approximately half of the world's lithium production was of this type. At that, most of the lithium was produced from pegmatites of Australia.

Latin American countries, particularly Chile, as well as Australia and China are the main producers of lithium at the present stage (Fig. 1) [1]. While the Australia's main source of lithium remains pegmatite type deposits, the breakthrough of Latin America and China to the leading producers of lithium was due to the involvement of hydro-mineral deposits (Salar de Atacama, Chile; Salar de Uyuni, Bolivia; Salar del Hombre Muerto, Argentina; the series of lithium-bearing sors in Qinghai of the Tibet plateau in China [1, 2].

Unsolved aspects of the problem. Thus, the main source of Li at the present stage is so called hydromineral raw material, which is intensively mineralized brines (rapa) accumulated in separate salt-bearing basins, most often in their marginal parts, in downstream salt marshes of drainless rivers, and also in salt, subsalt, inter-salt and suprasalt strata of the areas of wide occurrence of salt domes. Priority of this type of deposits for lithium mining is determined by very low cost of extracted

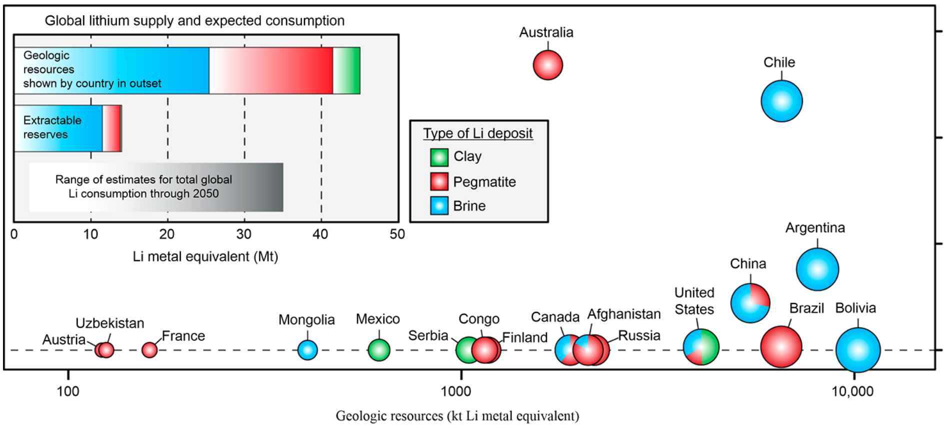

Fig. 1. The global lithium resources and the 2015–2050 total estimated consumption [1]

raw materials. In light of the above, Kazakhstan appears to be a very promising region.

First of all, the whole Caspian province in Kazakhstan belongs to such areas, where for a long time the salt deposits have been developed for extraction of halite, sylvin, gypsum, boron, magnesite and calcite. The spectrum of extractable useful components from mineralized water of salt fields in Kazakhstan remains at the basic level. Though in the middle of the last century much research was carried out, showing exceptional polycomponence of mineralized waters. At present, the components contained in brines are of particular interest: Li, Ru, Cs, Sr, I, Br and others, and in salt domes, in addition to the above elements, also noble metals Au, Ag, Pt, Pd, Ro, Ir, Os. At the currently developed Inder salt deposit, halite, sylvin, anhydrite, calcite, borates and native sulphur were found to contain Ag, Au and Pt in amounts from 1 to 5 g/t [8]. According to preliminary data, the insoluble residual salts of another salt dome – the Satimola giant – contain hurricane concentrations of gold up to 500 g/t and osmium up to 300 g/t [9]. There are many similar cases.

In recent decades, commercial Au and Pt concentrations in potassium salt deposits have also been established in Russia (Verkhnekamskoye deposit), Uzbekistan, Turkmenistan, Belarus, Prikarpatiye [10, 11].

This small share of information on a new, extremely valuable, type of mineral raw material of salt deposits and mineralized brines quite justifies the idea of a possible reversal to extraction of noble and rare-earth metals, very much in demand nowadays, especially of lithium, also in Kazakhstan. And that was the reason for short-term reconnaissance works to determine the lithium- and gold-bearing capacity of a number of salt marshes and salt domes of Southern and Western Kazakhstan.

Purpose. To determine the lithium-bearing capacity of mineralized solonchaks of the lower drainless rivers Chu and Sarysu and gold-bearing capacity of the Inder and Shalkar salt domes, to give the prognosis of their commercial prospects.

Methodology and the survey objects. In Kazakhstan, the previous geological work was not targeted on identification of lithium-bearing mineralized brines, and salt deposits were evaluated against rare-earth and noble metal extraction only in isolated laboratory studies [8, 12].

In light of the above, in the autumn of 2015, the authors of the present paper, at the request and with small funding from the mining industry, compiled a project [12] and, for the first time, carried out the short-term field work to determine the lithium and gold content in solonetz and sors of the lower reaches of the Talas and Chu rivers, and in the Shalkar and Inder salt domes (Fig. 2).

The main tasks of the project were:

- geological survey and sampling of salt-marshes and sors of the downstream drainless rivers Talas and Chu by taking water and soil samples to determine Li;
- geological survey and sampling of waste rock dumps of salt domes and the Shalkar and Inder lakes located in the Caspian region, also to determine their lithium and gold content;
- analytical studies on the sampling material and interpretation of the results.

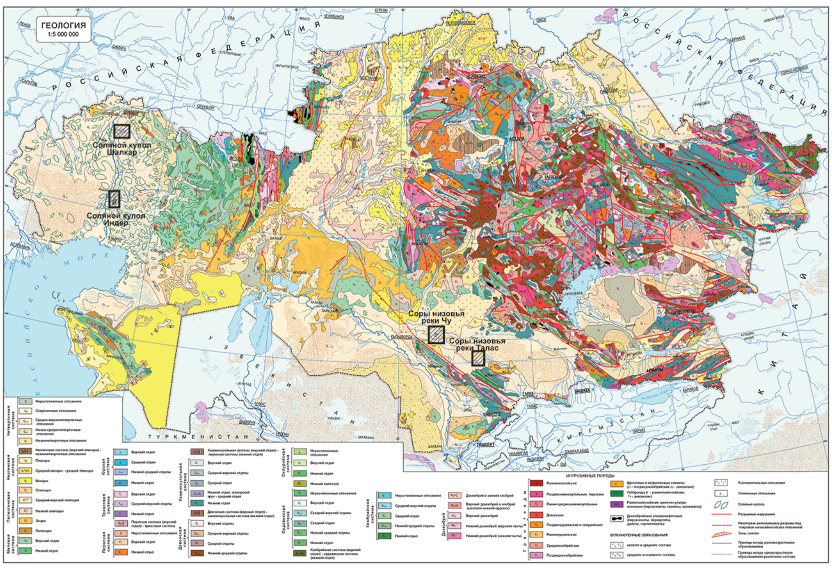

Fig. 2. Layout of the 2015 field season objects [13]

The project work was carried out in two phases: the fieldwork and the desk work, including analytical studies.

Specific sampling locations were not included in the fieldwork survey and sampling programme as it was a field trip to an understudied area with marshy lands.

Initially, several lakes and solonchaks without names were sampled in the lower Talas River (Fig. 3). In the lower Talas River, the first route was taken along the north-eastern part of the solonetz area where the Talas riverbed disappears. The route then continued into the central part of the downstream Talas River saltmarsh area, where many of the lakes were dried up. Even the largest lake, Akjar, marked on the map, was completely dry. Its bottom is clayey, saltish takyr, whose soil was sampled (several). The saline lake Kyzylkol, to south-west of the Talas salt marsh, was also sampled (four water samples). In total, *13* water (500 ml), *6* soil (0.3 kg) and *2* (0.2 kg) salt samples were collected from the Talas lowland solonchaks.

In the lower reaches of the Chu River (Fig. 4), the sors, found to be more extensive, waterlogged and saltish compared to the Talas sors, were sampled in the northern and north-eastern parts of the area, the lower Chu River, within the Kapkansor solonchak and in the central, southern and western parts of the huge solonchak valley. The solonchaks and takyrs within this vast area differed from each other: some of them were covered with salt crust, some had a muddy clay surface and some had crystals of gypsum and anhydride on the surface (Kapkansor and the nearest sors). Waterlogged sors as lakes have only been encountered in the southern part. In these lakes a rather thick crust of salt covers the bottom. The salt has a pink, sometimes light pink, hue which is probably due to the predominance of potassium salts in these lakes. The sampling was conducted almost to the centre of these small lakes, with a depth not exceeding 20–30 cm. Thus, *50* water samples of 500 ml, *11* soil samples of ~0.3 kg and *7* salt samples (0.2 kg) were collected.

Further explored were the Shalkar and Inder salt domes with salt lakes of the same name which were formed, according to B. S. Zeylik, as a result of watering of possible meteorite sinkholes [13]. The detailed research of the Shalkar salt dome conducted in the 1970s by Oshakpaev T. A. (1974) at the Institute of Geological Sciences has not included the Li and Au determinations.

Therefore, geochemical samples were taken from recultivated mine workings and residuals of core samples at the magnesium and boric salts deposits of Shalkar lake and its flanks (Fig. 5).

Next, the southern boundary of the outcrop was sampled where it was possible somehow to trap debris, as there are no bedrock outcrops in the area. Along the route, sandstone debris, dense blocks of siliceous siltstones and organogenic limestones (shell) were encountered. To the north-east, layered outcrops of the same siliceous siltstones and occasional borates were found. Along the Shalkar Lake framing, a total of *25* grab samples weighing ~0.3 kg and *2* water samples (500 ml) were taken from the lake.

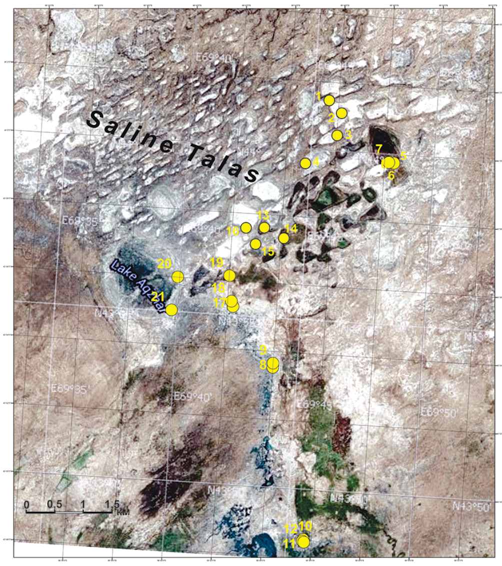

Fig. 3. The satellite image (1 : 50,000) *of the downstream Talas River sors area with sampling points* [13]

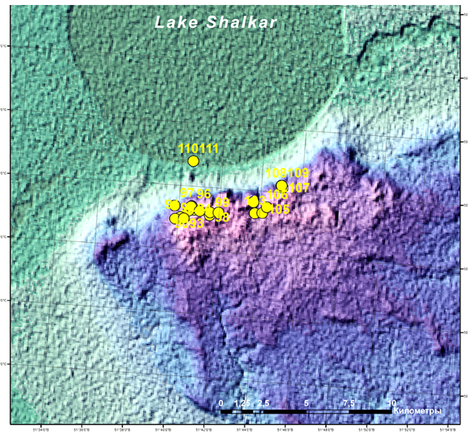

Fig. 5. The sampling at the Shalkar salt dome (*radarsat 1, scale* 1 : 50,000) [13]

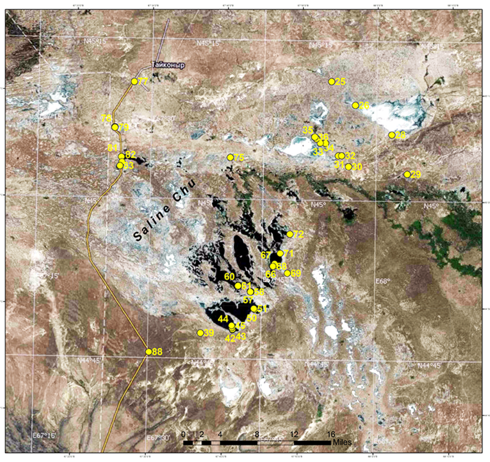

Fig. 4. The satellite image of the downstream Chu River sor area with sampling points [13]

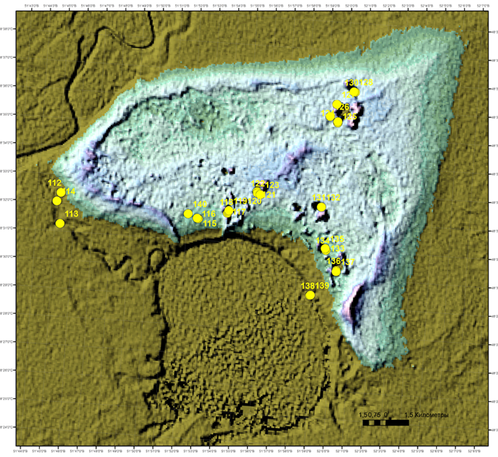

Fig. 6. The sampling at the Inder salt dome (*radiolocation satellite image, scale* 1 : 50,000) [13]

The final objective of the field season was to survey and sample the Inder Lake. Noteworthy, there are many quarries (~10–15) in the bedrock of the northern side of the Inder Lake, some of which are still under development. The quarries are used to produce gypsum, anhydride and boric salts. Chalk is also observed in the waste dumps of the quarries. The bottoms of all of the mined out pits are flooded with groundwater, from which water samples were taken for lithium analysis.

A further seven water samples for lithium were taken from the Inder Lake in its north-eastern part. The lake bed is covered with a thick crust of halite, and the lake water is salty-bitter. In total, *7* water samples (0.5 l) and *22* grab samples (0.3 kg) were taken in the area of the Inder Lake (Fig. 6).

Survey results. The 2015 field season covered 357 km of geological traverses with sampling in the following amounts (Table 1).

Table 1

Summary of water, salt and grab sampling of surveyed soils and salts of downstream drainless Talas and Chu rivers of the Inder and Shalkar salt domes

sample ID	Sampling location	Coordinates			Sample type	Sample weight
		X	*Y*	*Z*, m		
1	2	3	4	5	6	7
1	Talas	70.7448056	43.40875	396	water	500 ml
2	Talas	70.7233056	43.395833	401	water	500 ml
3	Talas	70.64975	43.498611	368	soil	~0.25–0.3 kg
4	Talas	70.6086111	43.537444	–	salt	~0.25–0.3 kg
5	Talas	70.61025	43.536806	–	cloudy water	500 ml
6	Talas	69.8065278	43.995917	294	soil	~0.25–0.3 kg
7	Talas	69.8030278	43.996056	292	wet soil	~0.25–0.3 kg
8	Talas	69.7334722	43.892333	297	wet soil	~0.25–0.3 kg
9	Talas	69.7334444	43.894389	299	salt	~0.2 kg
10	Talas	69.7613611	43.809222	301	water	500 ml
11	Talas	69.7608333	43.808361	300	water	500 ml
12	Talas	69.7618333	43.807889	301	water	500 ml
13	Talas	69.52325	43.760694	321	water	500 ml
14	Talas	69.5220556	43.76	–	water	500 ml
15	Talas	69.52025	43.760306	–	water	500 ml
16	Talas	69.5176111	43.759389	–	water	500 ml
17	Talas	69.7039722	43.920833	302	clay	~0.25–0.3 kg
18	Talas	69.7027222	43.923417	302	water	500 ml
19	Talas	69.7003333	43.935778	298	water	500 ml
20	Talas	69.6654444	43.933556	298	soil	~0.25–0.3 kg
21	Talas	69.6626667	43.917222	293	soil	~0.25–0.3 kg
22	Chu	67.7326111	45.209889	–	water	500 ml
23	Chu	67.87075	45.207111	–	water	500 ml
24	Chu	67.8693889	45.205444	–	clay	~0.25–0.3 kg
25	Chu	67.8985833	45.186722	128	clay	~0.25–0.3 kg
26	Chu	67.9520556	45.149806	121	clay	~0.25–0.3 kg
27	Chu	67.9591667	45.147222	–	gypsum	~0.2 kg
28	Chu	68.0335	45.104167	123	water	500 ml
29	Chu	68.0686389	45.042722	128	salt	~0.2 kg
30	Chu	67.9383333	45.053583	133	water	500 ml
31	Chu	67.9156944	45.070417	119	water	500 ml
32	Chu	67.9229444	45.070611	122	water	500 ml
33	Chu	67.8865833	45.089917	124	clay	~0.25–0.3 kg
34	Chu	67.8753611	45.090194	121	clay	~0.25–0.3 kg
35	Chu	67.8668333	45.096861	123	salt	~0.2 kg
36	Chu	67.8627222	45.099389	124	cloudy water	500 ml
37	Chu	67.8382222	45.119917	–	water (brine)	500 ml
38	Chu	67.865	45.165278	–	water (brine)	500 ml
39	Chu	67.6165833	44.790056	21	water (brine)	500 ml
40	Chu	67.6830833	44.797556	–	pink water	500 ml
41	Chu	67.6811944	44.798389	–	dark gray water	500 ml
42	Chu	67.6870556	44.795778	122	salt	~0.2 kg
43	Chu	67.6871111	44.796528	122	water	500 ml
44	Chu	67.6858889	44.799194	122	pink water	500 ml
45	Chu	67.6852778	44.80225	120	pink water	500 ml
46	Chu	67.7445278	44.822917	–	pink salt	~0.2 kg
47	Chu	67.7415	44.827944	–	White salt with clay	~0.25–0.3 kg
48	Chu	67.7430833	44.830278	–	salt	~0.2 kg

Continue of Table 1

1	2	3	4	5	6	7
49	Chu	67.7372778	44.826833	–	water	500 ml
50	Chu	67.7356944	44.828278	116	water	500 ml
51	Chu	67.7337222	44.829222	117	water	500 ml
52	Chu	67.7353889	44.830889	–	water	500 ml
53	Chu	67.7311111	44.831083	–	water	500 ml
54	Chu	67.7665833	44.832722	–	salt	~ 0.2 kg
55	Chu	67.7637778	44.832556	–	water	500 ml
56	Chu	67.7267778	44.855722	121	water	500 ml
57	Chu	67.7250833	44.8565	118	salt	~0.2 kg
58	Chu	67.7255278	44.855361	118	cloudy water	500 ml
59	Chu	67.7002778	44.864111	–	water	500 ml
60	Chu	67.6983611	44.865583	119	cloudy water	500 ml
61	Chu	67.6979722	44.864722	118	salt	~0.2 kg
62	Chu	67.7419444	44.859	–	salt	~0.2 kg
63	Chu	67.7856111	44.86775	–	salt	~0.2 kg
64	Chu	67.7824167	44.899722	–	wet clay	~0.25–0.3 kg
65	Chu	67.7816944	44.902111	–	pink salt with mud	~0.25–0.3 kg
66	Chu	67.7806111	44.897278	117	clay	~0.25–0.3 kg
67	Chu	67.778	44.900111	115	salt	~0.2 kg
68	Chu	67.7745278	44.895972	113	salt	~0.2 kg
69	Chu	67.8064722	44.885556	117	water	500 ml
70	Chu	67.7910833	44.913917	–	clay with salt	~0.25–0.3 kg
71	Chu	67.79	44.916444	116	water	500 ml
72	Chu	67.811	44.946722	117	water	500 ml
73	Chu	67.7914194	44.966194	–	water	500 ml
74	Chu	67.7235556	45.009306	–	water	500 ml
75	Chu	67.6764444	45.065444	121	water	500 ml
76	Chu	67.6399167	45.095389	–	water	500 ml
77	Chu	67.4608889	45.181972	124	water	500 ml
78	Chu	67.4196944	45.110194	118	water	500 ml
79	Chu	67.4196944	45.109389	119	water	500 ml
80	Chu	67.4383889	45.064139	–	water	500 ml
81	Chu	67.4350833	45.063917	123	water	500 ml
82	Chu	67.4366944	45.055667	119	water	500 ml
83	Chu	67.4323333	45.04975	119	water	500 ml
84	Chu	67.4329167	45.035556	–	water	500 ml
85	Chu	67.4244444	45.025611	–	water	500 ml
86	Chu	67.3655833	44.966028	–	water	500 ml
87	Chu	67.3637778	44.964139	–	clay	~0.25–0.3 kg
88	Chu	67.5036389	44.759028	160	water	500 ml
89	Shalkar	51.6794444	50.454528	88	sandstone	~0.25–0.3 kg
90	Shalkar	51.6750833	50.453917	76	loam	~0.25–0.3 kg
91	Shalkar	51.6684444	50.450167	71	rubbish	~0.25–0.3 kg
92	Shalkar	51.6644444	50.449194	68	limestone/shell rock	~0.25–0.3 kg
93	Shalkar	51.6715556	50.449667	72	siliceous gruss	~0.25–0.3 kg
94	Shalkar	51.6773056	50.456361	74	magnesium salts	~0.25–0.3 kg
95	Shalkar	5.67816667	50.456278	76	siliceous siltstone	~0.25–0.3 kg
96	Shalkar	51.6767778	50.456111	72	salt	~0.2 kg
97	Shalkar	51.6632222	50.456	58	limestone	~0.25–0.3 kg
98	Shalkar	51.6925556	50.452306	84	limestone	~0.25–0.3 kg
99	Shalkar	51.6925556	50.452306	84	limestone	~0.25–0.3 kg
100	Shalkar	51.69275	50.453722	85	limestone	~0.25–0.3 kg
101	Shalkar	51.6996667	50.454	86	limestone	~0.25–0.3 kg
102	Shalkar	51.7276389	50.460833	75	soil	~0.25–0.3 kg
103	Shalkar	51.7294444	50.454917	72	rubbish	~0.25–0.3 kg

Continue of Table 1

1	2	3	4	5	6	7
104	Shalkar	51.6841389	50.454139	71	limestone gravel	~0.25–0.3 kg
105	Shalkar	51.7356389	50.455361	74	limestone	~0.25–0.3 kg
106	Shalkar	51.739	50.458583	88	limestone	~0.25–0.3 kg
107	Shalkar	51.7508889	50.469361	69	salt	~0.2 kg
108	Shalkar	51.7495833	50.470389	68	salt	~0.2 kg
109	Shalkar	51.7499722	50.470444	70	salt	~0.2 kg
110	Shalkar	51.6760556	50.479972	13	water	500 ml
111	Shalkar	51.6760556	50.479972	13	water	501 ml
112	Inder	51.7538056	48.539389	–5	chalk	~0.2 kg
113	Inder	51.7548056	48.521167	–4	chalk	~0.2 kg
114	Inder	51.7506944	48.53425	–2	chalk	~0.2 kg
115	Inder	51.8765556	48.5295	15	salt	~0.2 kg
116	Inder	51.8756667	48.529694	12	salt	~0.2 kg
117	Inder	51.9021944	48.533917	6	gypsum	~0.2 kg
118	Inder	51.9027778	48.534667	–1	salt	~0.2 kg
119	Inder	51.9031944	48.535417	–24	water	~0.2 kg
120	Inder	51.9270833	48.547611	–25	water	~0.2 kg
121	Inder	51.9270833	48.547611	–25	gypsum	~0.2 kg
122	Inder	51.9274722	48.546778	–28	limestone	~0.25–0.3 kg
123	Inder	51.9301111	48.545972	–27	salt	~0.2 kg
124	Inder	51.9945	48.591111	16	borate salts	~0.25–0.3 kg
125	Inder	51.9944167	48.59175	16	borate salts	~0.25–0.3 kg
126	Inder	51.9874167	48.594528	17	salts/anhydride	~0.2 kg
127	Inder	51.9926389	48.601889	9	gypsum	~0.2 kg
128	Inder	52.0070556	48.609806	–	water	500 ml
129	Inder	52.0070556	48.609806	–	gypsum	~0.2 kg
130	Inder	52.0081389	48.609694	–29	borate salts	~0.25–0.3 kg
131	Inder	51.9848889	48.541056	–26	gypsum	~0.2 kg
132	Inder	51.9848889	48.541056	–26	water	500 ml
133	Inder	51.99125	48.515944	–23	water	500 ml
134	Inder	51.99125	48.515944	–23	gypsum	~0.2 kg
135	Inder	51.9906389	48.516917	–26	boric salts	~0.25–0.3 kg
136	Inder	52.0016389	48.504361	–30	water	500 ml
137	Inder	52.0015556	48.503806	–20	gypsum	~0.2 kg
138	Inder	51.9796389	48.488806	–30	water	500 ml
139	Inder	51.9801667	48.489	–32	salt	~0.2 kg
140	Inder	51.8674167	48.531944	5	core ……..	~0.25–0.3 kg

All *72* water, *17* soil and *10* salt samples were analysed for lithium by the atomic absorption method in the chemical Laboratory (1) of the "Scientific Analytical Center" LLP (NAC) (1) and by the ICP-MS method in the Laboratory of Ion Plasma Technology of the RK Institute of Nuclear Physics (INP) (2) at the RK Ministry of Energy (Table 2).

To clarify the gold content of the Shalkar and Inder salt domes, the grab samples of these objects were also analysed in the chemical laboratory of the "Scientific Analytical Centre" LLP (NAC) by atomic-absorption method well-known and widely used for determination of gold (Table 3).

In addition, the authors obtained results of *10* water samples (Table 4) analysed by the ICP-MS method in the laboratory of "SGS Vostok Limited" (Chita, Russia), the branch of the "SGS" internationally certified laboratory. The purpose of additional analytical tests by the "SGS" laboratory is an external control of results obtained from NAC and INP laboratories. Comparison of the "SGS" laboratory results with those of the NAC and INP shows that its lithium values are different from both of the laboratories. Moreover, this comparison of lithium determination in the NAC laboratory sharply differ from the other two laboratories by its very low lithium content. Therefore, it is more reliable to estimate lithium content in water samples from the lower Chu River using the INP laboratory determinations, which, similarly to the reference samples, have more significant lithium content.

The data analysis of Table 2 shows that results of lithium determination in samples from solonetz and sors of the lower reaches of the rivers Chu and Talas and salt domes Shalkar and Inder in different laboratories (NAC, INP) significantly dif-

Table 2

Comparison of Li contents in water samples from solonetz of downstream drainless rivers Talas and Chu and salt domes of Shalkar and Inder as per the data of the NAC LLP and RK ME INP laboratories [13]

No.	No. sample	Sampling location	Result Li (AAS), mg/dm^3	Li content (ICP-MS), mg/l	No.	No. sample	Sampling location	Result Li (AAS), mg/dm^3	Li content (ICP-MS), mg/l
1	1	Talas	0.0144	0.117	37	52	Chu	0.1631	0.762
2	2	Talas	0.0202	0.0873	38	53	Chu	0.0148	0.977
3	5	Talas	0.1271	0.613	39	54	Chu	0.3605	3.22
4	8	Talas	0.0661	0.202	40	55	Chu	0.0242	3.01
5	10	Talas	0.0320	0.0373	41	56	Chu	0.0384	0.579
6	11	Talas	0.0946	0.234	42	58	Chu	0.1559	0.953
7	12	Talas	0.0156	0.0182	43	59	Chu	0.0447	1.2
8	13	Talas	0.0180	0.438	44	60	Chu	0.0287	1.13
9	14	Talas	0.0528	0.682	45	66	Chu	0.0029	0.52
10	15	Talas	0.1771	0.691	46	69	Chu	0.2520	0.592
11	16	Talas	0.0618	0.696	47	71	Chu	0.1136	0.282
12	18	Talas	0.0095	0.044	48	72	Chu	0.0858	0.28
13	19	Talas	0.0087	0.0531	49	73	Chu	0.0858	0.31
14	22	Chu	0.0069	0.0231	50	74	Chu	0.0257	0.15
15	23	Chu	0.0541	0.138	51	75	Chu	0.2327	0.642
16	24	Chu	0.0227	0.149	52	76	Chu	0.0096	0.0135
17	28	Chu	0.2058	0.504	53	77	Chu	0.0076	0.0423
18	29	Chu	0.1121	0.325	54	78	Chu	0.1138	0.381
19	30	Chu	0.0241	0.0153	55	79	Chu	0.0501	0.368
20	31	Chu	0.1001	0.43	56	80	Chu	0.4270	1.203
21	32	Chu	0.0812	0.161	57	81	Chu	0.0408	0.499
22	34	Chu	0.0257	0.222	58	82	Chu	0.0239	0.554
23	35	Chu	0.0671	0.686	59	83	Chu	0.0923	3.45
24	36	Chu	0.0348	0.199	60	84	Chu	0.3245	0.761
25	37	Chu	0.0708	0.366	61	85	Chu	0.0937	0.879
26	38	Chu	0.0066	0.0293	62	86	Chu	0.2699	0.596
27	39	Chu	0.0659	0.444	63	88	Chu	0.0521	0.123
28	40	Chu	0.0447	2.27	64	110	Shalkar	0.0195	0.146
29	40/A	Chu	0.0010	0.004	65	111	Shalkar	0.0114	0.138
30	41	Chu	0.4115	5.17	66	119	Inder	0.2705	0.726
31	43	Chu	0.2918	–	67	120	Inder	0.1513	0.271
32	44	Chu	0.2195	4.51	68	128	Inder	0.3328	1.486
33	45	Chu	0.7004	6.03	69	132	Inder	0.3724	0.782
34	49	Chu	0.0748	1.154	70	133	Inder	0.1733	4.212
35	50	Chu	0.0433	1.134	71	136	Inder	0.2129	0.557
36	51	Chu	0.0439	0.926	72	138	Inder	0.6249	2.736

fered. According to the data of both laboratories, Li content in water samples is higher than in standard samples (soils and salts).

Thus, in NAC determinations, excluding those for Inder, Li contents in water samples in relation to its clarkee in seawater (0.17 mg/l) [14] exceed it only in single cases by 1.2–2.4–4.12 times, while, according to the INP laboratory determinations, its content above the clarkee is found in about 76 % of analysed samples.

The lithium concentrations in salts and soils have been found to be much lower than the lithium clarkee in the Earth's crust of 21 mg/kg [14]. Rarely are samples above the clarkee (1.5–2) found. All these samples are taken from lower reaches of the Chu River, and most of these significant samples are located in south-eastern and southern parts of the area (Fig. 4). Therefore, these data cannot be regarded as final for the area as sampling of the site was unfortunately uneven due to weather conditions. As a result, the entire central part of the investigated area remained uncharacterized, hence it is too early to draw any conclusions about the lithium-bearing potential of the whole region.

The Li concentrations, according to determinations in the INP laboratory, which significantly differ from those of the NAC laboratory by high values, determine also a different assessment of the prospects of the objects. Moreover, if we look at technology of South Korean scientists, extracting Li from

Table 3

Gold and platinum contents in Shalkar and Inder salt dome samples [13]

No.	No. sample	Sampling location	Au content, g/t	Pt content, g/t	No.	No. sample	Sampling location	Au content, g/t	Pt content, g/t
1	100	Shalkar	0.02	<0.01	24	99	Shalkar	2.57	<0.01
2	96	Shalkar	<0.01	<0.01	25	–	Shalkar	<0.01	<0.01
3	95	Shalkar	<0.01	<0.01	26	116	Inder	<0.01	<0.01
4	92	Shalkar	<0.01	<0.01	27	125	Inder	<0.01	<0.01
5	106	Shalkar	<0.01	<0.01	28	130	Inder	<0.01	<0.01
6	92	Shalkar	<0.01	<0.01	29	140	Inder	<0.01	<0.01
7	101	Shalkar	<0.01	<0.01	30	114	Inder	<0.01	<0.01
8	109	Shalkar	<0.01	<0.01	31	127	Inder	<0.01	<0.01
9	97	Shalkar	<0.01	<0.01	32	113	Inder	<0.01	<0.01
10	91	Shalkar	<0.01	<0.01	33	135	Inder	<0.01	<0.01
11	89	Shalkar	3.93	<0.01	34	122/A	Inder	<0.01	<0.01
12	93	Shalkar	1.36	<0.01	35	115	Inder	<0.01	<0.01
13	98	Shalkar	2.36	<0.01	36	123	Inder	<0.01	<0.01
14	99	Shalkar	1.59	<0.01	37	122	Inder	<0.01	<0.01
15	103	Shalkar	3.75	<0.01	38	117	Inder	<0.01	<0.01
16	105	Shalkar	1.67	<0.01	39	121	Inder	<0.01	<0.01
17	104	Shalkar	<0.01	<0.01	40	124	Inder	<0.01	<0.01
18	98	Shalkar	<0.01	<0.01	41	137	Inder	2.37	<0.01
19	102	Shalkar	<0.01	<0.01	42	129	Inder	1.6	<0.01
20	90	Shalkar	<0.01	<0.01	43	131	Inder	1.57	<0.01
21	94	Shalkar	<0.01	<0.01	44	118	Inder	1.46	<0.01
22	108	Shalkar	6.02	<0.01	45	134	Inder	3.39	<0.01
23	107	Shalkar	4.65	<0.01	46	126	Inder	2.45	<0.01
					47	112	Inder	3.91	<0.01

Table 4

Results of analytical studies on some water samples of salts from the lower reaches of the Chu River and salt lake Inder by ICP-Ms method in the laboratory of JSC "SGS Vostok Limited" (Chita, Russia)

Element		SO4 2-	Li	Clppm	Li	Li	Li
Scheme		CLA13V_7	ICP80T7	ISE08B_7		INP	NAC
Unit measurements		%	PPB	%	mg/l	mg/l	mg/l
Sample number	Sample number						
CH16-00404.001	40	1.20	970	47.3	0.97	2.27	0.0447
CH16-00404.002	41	1.69	1260	47.3	1.26	5.17	0.4115
CH16-00404.003	43	1.18	1240	40.1	1.24	–	0.2918
CH16-00404.004	44	1.20	1900	44.2	1.9	4.51	0.2195
CH16-00404.005	45	1.28	2870	45.0	2.87	6.03	0.7004
CH16-00404.006	55	5.17	1330	39.0	1.33	3.01	0.0242
CH16-00404.007	83	1.15	1860	40.5	1.86	3.45	0.0923
CH16-00404.008	120	0.10	<10	4.87	0.00	0.271	0.1513
CH16-00404.009	133	0.15	<10	6.96	0.00	4.212	0.1733
CH16-00404.010	138	0.07	1050	56.6	1.05	2.736	0.6249
Average					1.3	3.5	0.27

seawater [15], then the results obtained can be considered as a serious claim for the prospect of this object.

The low Li contents in water samples in comparison with known industrial deposits can be explained by the fact that the authors took water samples from the surface brine, watered due to seasonal rainfall, while industrial Li extraction on almost all deposits is carried out from mineralized deep waters (10 to 170 m). Consequently, for a final assessment of the prospects of the surveyed objects, of course, additional work is required, the justification for the statement of which may well serve the given data.

The results on estimation of gold content in Shalkar and Inder salt domes are much more optimistic (Table 3). Out of 25 samples of Shalkar salt dome area, 9 samples contain Au with grades from 1.36 to 6.02 g/t. The percentage of significant samples is 36 %. The average Au grade in the Shalkar salt dome including all other "empty" samples is 1.2 g/t. According to this data, taking into account modern technologies of Au extraction at its low content, the Shalkar salt dome may well be classified as a high-volume deposit of low-grade ores. Preliminary estimates of prognostic Shalkar gold resources are 6.534 tons for 10 m depth, and 13.068 tons for 20 m depth.

The results of quantitative analysis by atomic absorption method in the same laboratory of samples from the Inder salt dome also indicate the presence of significant Au contents ranging from 1.6 to 3.9 g/t in seven samples. The average gold content for the entire sample volume would be 0.78 g/t, which can be considered commercially significant under current conditions.

A preliminary estimate of Au inferred resources of the Inder salt dome indicates that it is a large deposit with reserves of 1067.22 tons for a depth of 10 m, 2134.44 tons for a depth of 20 m, at an average Au grade of 0.7 g/t.

The gold-bearing nature of the Inder salt dome rocks is confirmed by the first determinations made by Yu. S. Parilov (2004) and B. S. Zeilik (2012). The Lake Inder and the Inder salt dome deserve special attention, because in those few water samples taken from the lake and watered bottoms of salt mines (7 samples totally), according to both laboratories (NAC and INP), elevated Li concentrations were detected, compared to the sea water Li content (0.17 mg/l). In the first case (NAC) contents are higher than in sea water (1.5 to 3.6 times), and in the second case (INP), 3.31 to 24.7 times (Table 2).

The data on Li contents in the Inder salt dome seem to be obtained for the first time, as even in a detailed description of chemical composition of Inder lake brine (in g/kg): surface brine: K – 5.192, Na – 85.84, Mg – 8.709, Ca – 0.589, Cl – 160.1, Br – 0.460, SO_4 – 4.364, sum of ions – 265.2, H_3BO_3 – 0.10, brine temperature – 31°C. The bottom brine from depth of 30 m: K – 7.551, Na – 81.24, Mg – 4.503, Ca – 0.677, Cl – 142.9, Br – 0.373, SO_4 – 4.655, sum of ions – 241.9, H_3BO_3 – 0.09, brine temperature – 2–1.4 °C; there are no data on lithium [16].

The obtained data on Au and Li contents in samples from Inder (Tables 2 and 3) allow speaking boldly about its multicomponent character which raises its industrial significance. The organization of a simultaneous mining of such sought-after components is very promising.

Conclusions. The above results of the study on hydromineral raw materials for possible extraction of lithium and noble metals, inspite of their preliminary character and insignificant volumes, unequivocally testify to necessity of carrying out large-scale prospecting works for final estimation of the described objects and discovering similar lithium- and gold-bearing sors and salt domes. At that, the main prospects for development of prospecting lithium-bearing pores should be associated with the Shu-Sarysu province (South Kazakhstan) having the highest level of lithium content (Li, 5–165 mg/dm^3) in comparison with other provinces of industrial waters of Kazakhstan, as it is stated in the article by M. K. Absametov, D. A. Kassymbekov, E. J. Murtazin, 2014 [17]: North-Caspian province (Li, 13–82 mg/dm^3), Aktobe Ural province (Li, 0.1–2.7 mg/dm^3), South-Emba province (Li, 1–16 mg/dm^3), East-Caspian province (Li, 10–17 mg/dm^3), Mangistau-Ustyurt (Li, 5–11.3 mg/dm^3), Buzachi-Ustyurt (Li, no data), Moinkum (Li, 5–11.3 mg/dm^3), Terenbulak (Li, no data). By the way, this is the only work in Kazakhstan providing the data on Li in mineralized waters.

No less promising for identification of lithium-bearing and gold-bearing deposits of the considered types are the salt domes of the Inder type, where, according to the authors' research results, the presence of complex mineralization, including lithium and gold, is evident. Studies of the Inder type salt domes should be targeted on their waste pits, which are low-cost mining works, and as a result of which unconventional large deposits of rare, rare-earth and noble metals can be discovered.

The shift in the world production of these types of raw materials from endogenous sources (pegmatites) to brine and salt domes is largely due to the significantly low cost of obtaining them from open accumulations of mineral salts.

If the proposed direction of prospecting for lithium raw materials non-traditional for Kazakhstan proves to be effective, the Caspian and the Aral Regions will turn into the largest rare-metal-gold-bearing provinces. The described direction in many respects echoes and is accordingly substantiated by ideas of M. K. Absametov and others, established in their article "Prospects of use of hydro-mineral raw materials in exploration and production of oil" [18], where they state that the industrial development of hydro-mineral resources in promising areas of Western and South-Western Kazakhstan is expedient to implement in complex with the development of hydrocarbon raw materials. As a rule, formation brines accompany oil and gas deposits, and their processing noticeably increases the efficiency of investments into development of oil and gas-bearing areas. Special process flows are required for working out such brines in an integrated, non-waste manner (recovering all or most of the useful components).

In recent years, a number of works have been carried out to adapt the most advanced technologies used in the processing of hydromineral raw materials to the reservoir waters of oil fields. Further research should be aimed at evaluating specific areas and sites for implementation of pilot commercial technologies for extraction of useful components and compounds from the formation brines of hydrocarbon deposits. The greatest practical interest is in organising the extraction of components such as iodine, lithium, bromine and strontium.

Keeping in mind that the Caspian Basin is a giant oil and gas bearing basin, investments from the profits of existing oil companies could make sound economic prerequisite to solve the tasks on identifying a new major ore province of noble, rare and rare-earth metals, especially Li.

In summary, the authors, while not questioning the relevance of the work carried out, believe that their preliminary results provide a convincing justification for its continuation.

Acknowledgement. *This article was written on the basis of research results under grant funding from the Ministry of Science and Higher Education of the Republic of Kazakhstan, Grant No. AP13067798.*

References.

1. Benson, T., Coble, M., Rytuba, J., & Mahood, G. (2017). Lithium enrichment in intracontinental rhyolite magmas leads to Li deposits in caldera basins. *Nature Communications, 8*(1). https://doi.org/10.1038/s41467-017-00234-y.

2. Aitkulov, B. (2022). *Lithium may become the second oil for Kazakhstan*. Retrieved from https://kapital.kz/experts/91508/bau-yrzhan-aytkulov-litiy-mozhet-stat-vtoroy-neft-yu-dlya-kazakhstana.html.

3. Ikaev, S. (2022). *The triple Li price rise is now affecting the cost of batteries*. Retrieved from https://hightech.plus/2021/11/01/skachok-cen-na-litii-na-300-nachal-skazivatsya-na-stoimosti-batarei.

4. Kesler, S., Gruber, P., Medina, P., Keoleian, G., Everson, M., & Wallington, T. (2012). Global lithium resources: Relative importance of pegmatite, brine and other deposits. *Ore Geology Reviews, 48,* 55-69. https://doi.org/10.1016/j.oregeorev.2012.05.006.

5. Karenov, P. S. (2007). Problems of shaping the market of rare and rare-earth metals in Kazakhstan. *Bulletin of the Karaganda State University, 3,* 37-42.

6. Kan, S., Murtazin, E., & Edilhanov, A. (2017). About distribution rare microcomponents in passing stratal waters at the oil and gas fields of peninsula mangyshlak. *News Of The National Academy Of Sciences*

Of The Republic Of Kazakhstan, Series Of Geology And Technical Sciences, 3(423), 84-94.
7. Cabello, J. (2021). Lithium brine production, reserves, resources and exploration in Chile: An updated review. *Ore Geology Reviews, 128,* 103883. https://doi.org/10.1016/j.oregeorev.2020.103883.
8. Parilov, Yu. S. (2004). Assessment of salt sediments in the Pre-Caspian Basin for gold-platinum mineralization. *News Of The National Academy Of Sciences Of The Republic Of Kazakhstan, Series Of Geology And Technical Sciences, 1,* 15-30.
9. Miletskiy, B. E. (2011). Forecast based on man-made prototype: Pre-Caspian sedimentary basin of noble metals of halogen formation. *Ores and Metals, 3-4,* 120-121.
10. Korytov, F., & Prokof'ev, V. (2002). Metallogeny of salt domes. In *Modern Problems of Metallogeny*, (pp. 32-34). Tashkent.
11. Kudryashov, A. (2001). *Verkhnekamskoe deposit of rock salt.* Perm': Mining Institute of the Ural Branch of the Russian Academy of Sciences. ISBN: 5-89095-041-X.
12. Zeylik, B. S., & Shevelev, G. A. (2012). Caspian Oil and Gas Basin as a New Major Ore Province of Noble Metals. *Oil & Gas, 2*(68), 63-80.
13. Zeylik, B., Seitmuratova, E., Baratov, R., Dautbekov, D., & Seytzhanov, C. (2016). *Identification of lithium-bearingness of solonets and pores of the lower reaches of the Talas and Chu rivers and gold-platinum-bearingness of the Shalkar and Inder salt domes*. Information report, (p. 27). Almaty: "Kazphosphate" LLP.
14. Kudryavtsev, P. (2016). Lithium in nature, application, methods of extraction (review). *Journal "Scientific Israel-Technological Advantages", 18*(3), 63-83.
15. KO. IT for business (2013). *A method for economical extraction of lithium from seawater was developed*. Retrieved from http://ko.com.ua/razrabotan_sposob_jekonomichnoj_dobychi_litiya_iz_morskoj_vody_103162.
16. *Committee on Geology and Subsoil Use – Inder Lake* (2022). Retrieved from http://info.geology.gov.kz/ru/informatsiya/spravochnik-mestorozhdenij-kazakhstana/tverdye-poleznye-iskopaemye/item/озеро-индер.
17. Absametov, M. K., Kasymbekov, D. A., & Murtazin, E. Zh. (2014). Prospects of development of hydrogeothermal and hydrogeomineral resources of Kazakhstan. *Bulletin of the Tomsk Polytechnic University, 1*(325), 110-116.
18. Absametov, M. K., Zavaley, V. A., & Murtazin, E. Zh. (2010). Prospects for the use of hydromineral raw materials in oil exploration and production. *Geology and bowels of the earth, 1*(34), 92-9.

Літієносність і золотоносність соляних куполів і солончаків Західного й Південного Казахстану

Е. Ю. Сейтмуратова[1], *Р. Т. Баратов*[1], *Я. К. Аршамов*[*1], *Д. О. Даутбеков*[1], *Ш. А. Сейтжанов*[2]
1 – Satbayev University, м. Алмати, Республіка Казахстан
2 – ТОО «Yildirim Holding Kazakhstan», м. Астана, Республіка Казахстан
[*] Автор-кореспондент e-mail: y.arshamov@satbayev.university

Мета. Виявити літієносність мінералізованих солончаків низовий безстічних річок Чу й Сарису та золотоносність соляних куполів Індер і Шалкар, дати прогнозну оцінку їх промислових перспектив.

Методика. Основою методології дослідження є класичний комплекс пошуково-знімальних робіт: збір матеріалів попередників, польові роботи, що включають картування об'єктів, гідро- й літохімічне опробування, аналітичні дослідження та аналіз лабораторних даних.

Результати. Був проведений весь комплекс намічених робіт по досліджуваним об'єктам. У результаті чого у 76 % проаналізованих водних пробах установлено вміст літію вище кларка в морській воді (0,17 мл/л) в 1,2–2,4–4,12 рази. Вміст літію в солях і грунтах відзначається набагато менше кларка літію в земній корі, у поодиноких випадках значення літію у пробах вище кларка в 1,5–2 рази. Із 25 проб у районі соляного куполу Шалкар у 9 пробах установлений вміст Au від 1,36 до 6,02 г/т. Відсоток значимих проб складає 36 %. Середній вміст Au в соляному куполі Шалкар з урахуванням усіх інших «пустих» проб складає 1,2 г/т. За цими даними, ураховуючи сучасні технології вилучення Au при його малих вмістах, соляний купол Шалкар цілком можна класифікувати як великооб'ємне родовище бідних руд. Результати кількісного аналізу методом атомної абсорбції проб із соляного купола Індер також свідчить про наявність у семи пробах значимих вмістів Au – від 1,6 до 3,9 г/т. Середній вміст золота на весь об'єм відібраних проб складає 0,78 г/т, що в сучасних умовах може розцінюватися промислово значимим. Наведені результати дослідження гідромінеральної сировини для можливого вилучення літію й благородних металів, не дивлячись на їх попередній характер і незначні об'єми, однозначно свідчить про необхідність постановки пошукових великомасштабних робіт для остаточної оцінки описаних і виявлення нових подібних їм об'єктів.

Наукова новизна. Новизна дослідження є в тому, що подібні роботи проводяться вперше**.** Кількісна оцінка вмісту літію та золота в солончаках і соляних куполах Казахстану показала перевищення їх кларка та перспективність цих об'єктів для проведення подальших досліджень.

Практична значимість. Полягає у виявленні літієносності гідромінеральної сировини й золотоносності соляних куполів Казахстану як можливих рентабельних нових джерел літію та золота.

Ключові слова: *Казахстан, гідромінеральна сировина, соляні куполи, мінералізовані води, літієносність, золотоносність*

The manuscript was submitted 04.05.22.