ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 12 , December 2022

Comprehensive Study of Mineral Salts of the Lavlyakan Group of Lakes in Central Kyzylkums

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ABSTRACT: The material provides information about the Mullaly salt lake of Central Kyzylkum, describes the history of the study of the area and presents an overview map of its location. A comprehensive study of mineral salts was carried out, a geological section and a cosmostructural scheme, as well as the results of the analysis of the chemical composition of the water of Lake Mullaly, were presented. The necessity of carrying out additional geological exploration in this area is justified.

KEYWORDS: mineral salts, geological section, geological exploration, geological map, chemical composition, absolute altitude.

I. INTRODUCTION

The Republic of Uzbekistan occupies an area of more than 400 thousand km2, and more than 3/4 of its territory falls on desert areas. Deserts, as is known, are characterized by an extremely high moisture deficit, so for the most part it is lifeless "dead" spaces.

However, in deserts there is a lot of light and heat, which provides the most extended growing season for plants, so irrigated desert lands become the most productive. In addition, in the deserts, there are many sources of various mineral salts, which are widely used in the national economy.

As is known, mineral salts are rocks consisting of water-soluble minerals that precipitate during the evaporation of water in open reservoirs (halogen evaporites). Deposits of fossil mineral past and present salts are distinguished by a variety of chemical composition, geological structure and conditions of their formation. Therein, we carried out a complex application of methods for studying the mineral salts of the Lavlyakan group of lakes in the Central Kyzylkum (deposits of sodium sulfate and magnesium-astrakhanite).

Lavlyakan lakes are one of the exotic lakes. This phenomenon is not typical for the Kyzyl Kum and most arid regions. On the territory of the deserts of Central Asia, there are similar lakes in the Sarykamysh depression, as well as to the north of the city of Kyzyl-Arvat in Southwestern Turkmenistan (Chakurok, Gyaur, etc.) [1-2].

II. SIGNIFICANCE OF THE SYSTEM

The material provides information about the Mullaly salt lake of Central Kyzylkum, describes the history of the study of the area and presents an overview map of its location. The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

III. METHODOLOGY

Lakes of this type are most often found in the semi-desert and steppe regions of Western and Northern Kazakhstan. Similar lakes are also described in Central Asia and in some other areas. However, the real analogues of the Lavlyakan lakes are located in the Great Basin, the Mojave and Sonoran deserts, as well as other areas of the “basin and ridge region” in the southwestern United States and northern Mexico. This is due to the surprising similarity in the history of the geological development and formation of the Kyzylkum relief with the North American desert regions.

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IV. EXPERIMENTAL RESULTS

The group of salt lakes Lavlyakan is located north-northeast of the city of Kenimekh, about 100 km and in the southeast direction from the city of Tamdy at the same distance (Fig. 1).

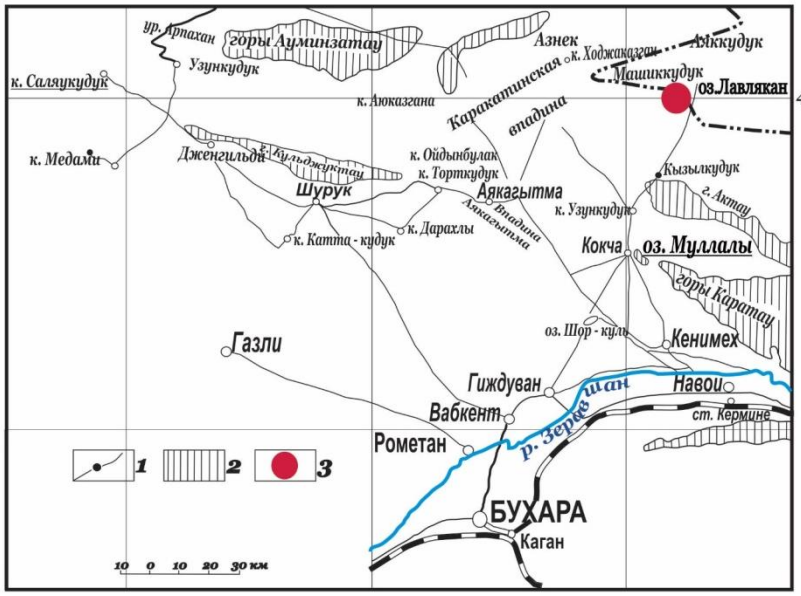

Fig.1. Overview map of Lavlyakan Lake (according to I.V. Rubanov).
1. Outcrops of the Paleozoic rocks; 2. Salt lakes (underlined); 3. Lavlyakan Lake

The largest lakes are the following three: in the southwest - Lavlyakan, the size of the lake is 0.5x4 km; to the north - Lakmagen, the size of the lake is 0.8x0.9 km; to the east - Lake Kazgan with a size of 1.3x1.5 km.

In addition to these three largest lakes, there are about a dozen smaller ones. For our study, of greatest interest were small lakes with a size of approximately 150x200 m, which were located directly east of Lavlyakan Lake. These lakes are designated as Lavlyakan II and Lavlyakan III.

Earlier, the lake was explored by V. Leonov (1896), A.G. Bergman (1935) and some other scientists. At that time, there was information only about Lavlyakan I Lake. So, according to A.G. Bergman, in 1932, a crust of salt up to 7-8 cm thick lay on the bottom of Lake Lavlyakan, which consisted mainly of sodium chloride [1-2].

The Paleozoic complex in the east of the Kyzylkum area of the Central Kyzylkum is a system of large linear folds of northwest strike, in the center - latitudinal, and in the west - southwest. These strikes are a direct continuation of the Hercynian structures of the Nurata Mountains. The main structures of the complex are complicated by additional folds of various orders and discontinuous faults of a complex type.

As a result of denudation, which lasted from the end of the Paleozoic to the Albian, which continued in some areas until the end of the Eocene, the Hercynian structures were almost completely eroded. Ultimately, a leveled surface was formed on the site of the Hercynian structures, covered with a thick weathering crust ranging in size from 20-30m to 50-80m [3].

Lavlyakan Lake is located inside a fairly large endorheic basin with a group of smaller lakes. This system of lakes arose as a result of the contact of the piedmont proluvial plain of the Sangruntau mountains with the sand massifs of the Karakata trough. From the northern and northwestern sides, the basin is sharply limited by a ledge, the height of which reaches 15-20 m. On the southern and eastern borders, one can notice a less distinct and gentle slope of the basin, which imperceptibly passes into the hilly surface of the sandy plain. The lowest elevation of the bottom of the lake basin is 193.4 m.

In this area, up to 20 lakes can be counted, which stretch in the latitudinal direction in two almost parallel echelon-shaped chains. Relative to the southern chain, the northern chain is slightly shifted to the east. The sizes and outlines of lake basins are extremely diverse.

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Lavlyakan Lake, being the largest lake, stretches up to 5.1 km in a narrow strip from the west-north-west to the east-south-east direction. The width of the lake is only 0.5 km, and only in the west the lake expands and reaches its widest size - up to 1 km. The coastline of the lake is somewhat uneven. This, to a certain extent, is typical for all lakes of the Lavlyakan group. The sandy island is located at the southern shore of the lake and stretches for 100 m - from the northeast to the southwest.

Kazgen Lake is the second largest lake in this group of lakes and is located to the east of Lavlyakan Lake. The size of Kazgen Lake in diameter reaches 2 km. In plan, Kazgan Lake has an isometric rounded shape and has an extremely complicated outline of the coastline. In this regard, the eastern coast of Kazgen Lake, where there are peninsulas and islands, can be separately emphasized.

Lakmagen Lake is the third large lake of the Lavlyakan group, in which the axis of the contour of the lake shore is extended by 800 m in width. This lake, in size, is significantly inferior to the two previous lakes and has an oval shape [3-4]. The rest of the lakes of the Lavlyakan group lie at different hypsometric levels and have a diameter of 500 m, and in most cases about 200 m. These lakes are mostly oval or even completely round in shape. Most likely, this is due to the unevenness of the impervious bed, since even adjacent lakes, sometimes, can have a height difference of up to 10 m or more. In the lakes of this group, in autumn, the water level rises to 1-1.5 m. In the highly mineralized water of the lake, the dense residue reaches 238.72 g/l.

This group of lakes is located within the vast field of development of Eocene water-resistant clays. The field of Eocene waterproof clays of the lake is covered with sandy-loamy material on the northern side and sandy material, i.e. dunes - on the south side. For example, the absolute height of the surface of Lavlyakan I Lake is 193 m, and the hilly hills adjacent to the lake have a height of 30 m to 50 m. Thus, during the study, the convergence of the edges and closed parts of the lake, the position of the faults and the change in their strike were revealed, as well as cracks, often of a hidden nature, were identified. Faults of the sublatitudinal direction, which are perpendicular to the strike of the fold system, can only be established by decoding satellite images (Fig. 2.) [5,6-7].

Fig.2. Parallel lineament structure of Lavlyakan lake (in 3D)

Small lakes of the Lavlyakan group, located east of Lavlyakan I Lake, almost everywhere contain a fairly thick deposit of astrakhanite. However, in terms of the thickness of the astrakhanite deposit, Lake Lavlyakan I is inferior to other lakes of the group. So, for example, a 1.82 m deep borehole drilled in the center of Lavlyakan III Lake did not reach the bottom of the astrakhanite deposit [4-5].

Our chemical and mineralogical analyzes of astrakhanite samples indicate that, in addition to this mineral, there are up to 20-30% impurities of halite and epsomite (Table. 1).

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International Journal of Advanced Research in Science, Engineering and Technology
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Table 1.
The mineral composition of the brine of the Lavlyakan group of lakes
(according to the results of microscopic studies, taking into account chemical analysis data)

№	Name of the rock	Halite	Thenardite	Mirabilite	Astrakhanite	Epsomite	Gypsum	Carbomate	Clay mineral
1	Astrakhanite with epsomite	5-10%	-	-	70-80%	20-30%	present	-	2-3%
2	Halite	70-80%	-	-	-	2-4%	present	-	present

During the study, we found that in the Lavlyakan group of lakes, the halite crust reaches 20 cm or more. Moreover, in the central part of the lakes, on the basis of halite, there is a layer of astrakhanite, up to 7 cm thick. As a result of the chemical analysis of halite, the presence of impurities of sodium and magnesium sulfate up to 15% was revealed. The brine taken from the borehole has a chloride-magnesium character of salinity. Of greatest interest to us was the discovery in this brine of an increased content of bromine - 612.4 and boron - 40.4 mg/l.

Regardless of the time of year, in the entire area of the Lavlyakan group of lakes, the chemical composition of water is very similar and mainly consists of sulfate-chloride magnesium-sodium water. In summer, during the hot season, the lakes dry up and a layer (or crust) appears on their bottom) salts of a light pinkish-gray color. Due to a long period, salt deposits were formed on some lakes, where salt deposits are 2 m or more thick.

For us, the origin of salt deposits and the rate of their growth was very interesting. So, according to I.V. Rubanov, the supplier of salt here is highly metamorphised river waters, which are filtered through gypsum-bearing soils.

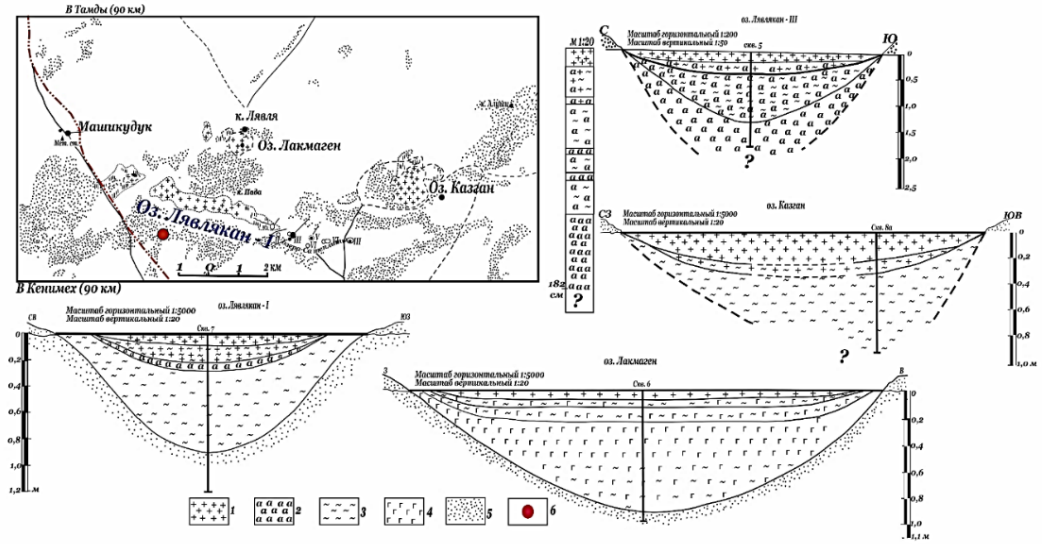

Fig.3. Scheme of location and structure of the Lavlyakan deposit of astrakhanite and halite:
1 - halite; 2 - astrakhanite; 3 - silts; 4 - gypsum; 5 - sand; 6 - observation points.

However, we believe it appropriate to note that the underground waters of the Lavlyakan group of lakes have not yet been studied in depth and detail, since our observations indicate rather complex hydrogeological conditions in this

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International Journal of Advanced Research in Science, Engineering and Technology
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area. So, in Fig. 3 we show the results of a study of the composition of the section of the salt deposit (from top to bottom) of Lyavlyakan I Lake:

– halite - loose gray, medium crystallization, there is an admixture of epsomite 0.1-0.5 cm;

– loose and coarse-grained astrakhanite, there is an admixture of halite with contaminated silty material. In the lower part there are large aggregates of astrakhanite up to 3 cm in size and more. 45.0 cm;

– dense, coarse-grained astrakhanite with an admixture of halite 7.0 cm;

– loose, finely and coarsely crystalline astrakhanite, there is a strong contamination with silt. In the lower part there is a layer of dense astrakhanite 4-5 cm. 45.0 cm;

– astrakhanite with an admixture of silt - loose at the top, and dense at the bottom. It has 2 layers of transparent astrakhanite, thickness from 2 cm to 4 cm, 29.0 cm;

– dense, medium crystalline and transparent astrakhanite;

– total explored thickness is 182.0cm.

In the autumn period of the year, due to periodic precipitation, a decrease in air temperature and a decrease in water evaporation from the capillary fringe, the groundwater level rises above the bottom of the lake depressions. As a result, swampy strips of hollows appear on the shores of lakes, and springs appear in ravines, which give rise to small streams.

The study of groundwater outlets from the shores of the Lavlyakan group of lakes made it possible to identify two flows of such waters. The host rocks for both streams are the sands of the Kyzylkum Formation (Lower Pleistocene), where the clays of the Upper Eocene, Oligocene and Miocene serve as a water-resistant bed. In these places, the entire existing layer of astrakhanite is saturated with oily brine, which practically does not protrude above the surface of the salt layer of lakes.

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Table 2.
The chemical composition of the brine of the Lavlyakan group of lakes

	The composition of the brine			Bottom salts		Salts from mining clamps		
	Lake II	Lake III	Lake IV	Lake III	Lake IV	Lake I	Lake III	Lake IV
Cations	Pr.II	Pr.III	Pr.IV	III-L-2	IV-L-2	I-L-3	III-L-3	IV-L-4
Na	3,534	5,315	5,811	31,71	-	25,20	30,54	33,28
K	0,050	0,034	0,025	0,02	0,02	0,02	0,02	0,01
Ca	-	-	-	0,10	0,10	0,10	0,10	0,05
Mg	4,518	3,868	3,502	1,70	1,70	3,77	2,25	1,88
NH_4	-	-	-	-	-	0,01	0,02	-
Total	**8,102**	**9,217**	**9,338**	**32,53**	**-**	**29,37**	**32,93**	**35,22**
Anions	Pr.II	Pr.III	Pr.IV	III-L-2	IV-L-2	I-L-3	III-L-3	IV-L-4
Cl	14,295	14,239	13,745	51,41	51,41	37,67	46,38	47,87
SO_4	5,589	8,617	7,117	3,56	3,70	16,74	9,27	12,43
CO_3	0,043	0,076	0,019	-	-	-	-	-
HCO_3	0,01	0,01	0,048	0,01	0,01	0,01	0,01	0,01
NO_3/NO_2	0,242	0,236	0,245	-	-	0,03/0,02	0,03/0,01	0,03/0
Total	**20,174**	**21,378**	**21,144**	**55,07**	**55,23**	**54,47**	**56,75**	**60,34**
Sum	**28,281**	**30,595**	**30,512**	**88,23**	**-**	**83,84**	**89,68**	**95,56**
The composition of salts								
NaCl	8,740	13,323	14,570	76,54	76,54	43,90	66,60	69,83
KCl				0,04	0,04	0,04	0,04	
$MgCl_2$	12,078	8,268	6,591	6,66	6,66	14,77	8,81	7,36
Na_2SO_4				4,91	5,12	24,42	13,36	18,22
$MgSO_4$	7,004	8,542	8,918					
CSO_4				0,34	0,34	0,34	0,34	0,17
$NaNO_3$	0,223	0,249	0,281					0,01
KNO_3	0,129	0,088	0,065					0,03
$Ca(HCO_3)_2$				0,01	0,01	0,01	0,01	0,01
$Mg(NO_3)_2$	0,012	0,012	0,058					
$MgCO_3$	0,060	0,106	0,024					
NH_4NO_3				0,04	0,04			
Sum	**28,246**	**30,588**	**30,026**					
Moisture content				9,41	9,20	14,51	9,10	2,70
J mg/l	25,4	20,28	10,14	0,0003%	0,0005%	0,0005	0,0005	0,0005
Br mg/l	1466,5	929,3	699,1	0,028%	0,023%	0,021	0,019	0,017
BrO_3 mg/l	239,8	170,4	76,5					
N.i.				1,79	1,87	1,68	1,48	1,40
Dry residue, g/l	358,30	388,490	385,392					
Sum				**99,74**	**100,17**	**100,14**	**99,76**	**99,75**

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As a result of chemical analysis, iodine - 1.2 mg/l, bromine - 65.4 mg/l and boron - 101.0 mg/l were detected in the composition of the brine taken from the borehole. In general, the composition of the brine is chloride-magnesium, which contains more than 60 g/l of magnesium. Salt deposits of other satellite lakes of the Lavlyakan group have approximately the same composition and structure. In the process of the conducted studies, we did not have the opportunity to conduct a detailed study of these lakes. However, taking into account the general geological situation of the area, it can be assumed that the modern scattered salt deposits of the lakes could previously form a single whole. In addition, we do not exclude the possibility that astrakhanite deposits under the sand have remained to this day.

It should be noted that the available data, which have found their scientific confirmation, testify to the uniqueness of the studied object, both in terms of the reserves of astrakhanite itself and brine enriched with magnesium, and in the presence of an increased content of bromine and boron in the brine.

We believe it appropriate to note one hydrogeological feature in the regime of the described salt lakes. All these lakes are surrounded by a ring of sand dunes, near the southern shores of which springs flow, feeding these lakes with water. In this area, salt crusts are almost absent, and the coastal soil, under which silt is located, is very soft [4-5].

Kazgan and Lakmagen Lakes have predominantly thin halite crust, where silt is also present under the halite crust. In the brine of Kazgan Lake, high levels of bromine were found, which is 325.7 mg/l and boron - 70.0 mg/l.

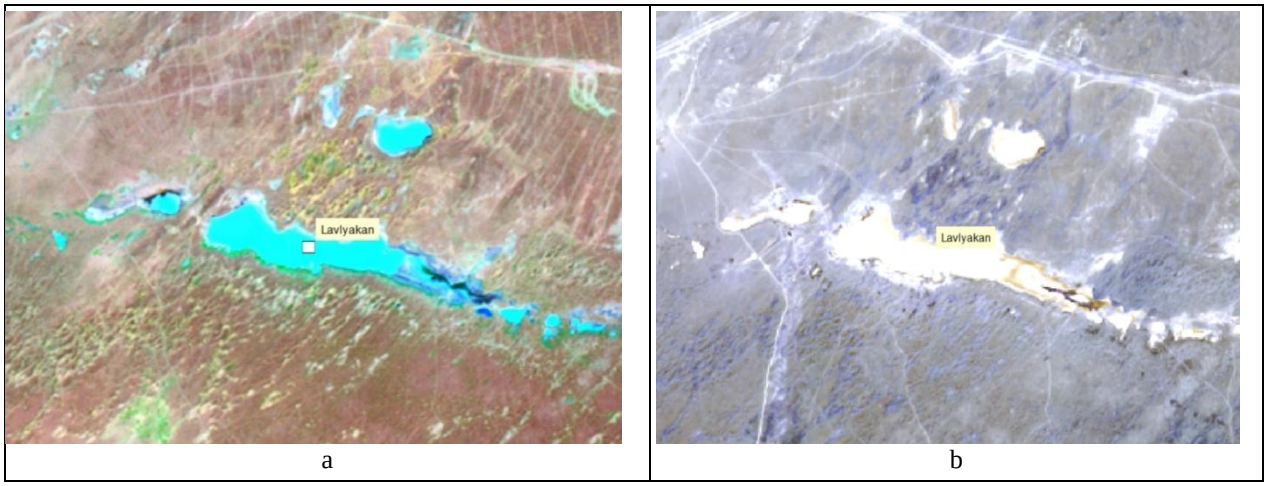
The study also found that in the southern part of Lakmagen Lake (and partly on Kazgan and Lavlyakan II Lakes), the local population is currently extracting table salt using artisanal methods [6-7-8].

To study the rock compositions of the Lavlyakan group of lakes, we used the methods of processing satellite images at a scale of 1:50,000: composite satellite image Landsat-5, satellite image Landsat-8, PCA and Hydrotermal Composition. All indices of identified rocks are based on their absorbing and reflecting properties, which are associated with their chemical composition (Nurkhodjaev A.K. et al., 2017).

Here are some examples of indices used in geological studies:

- clay rocks – TM5/TM7;
- mineral components – TM 5/7, 5/4, 3/1;
- hydrothermal components – TM 5/7, 3/1, 4/3.

In the process of a comprehensive study, all the main processing methods and indices were applied by us for each section of the Lavlyakan group of lakes (Fig. 4.) [6-7-8].



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International Journal of Advanced Research in Science, Engineering and Technology
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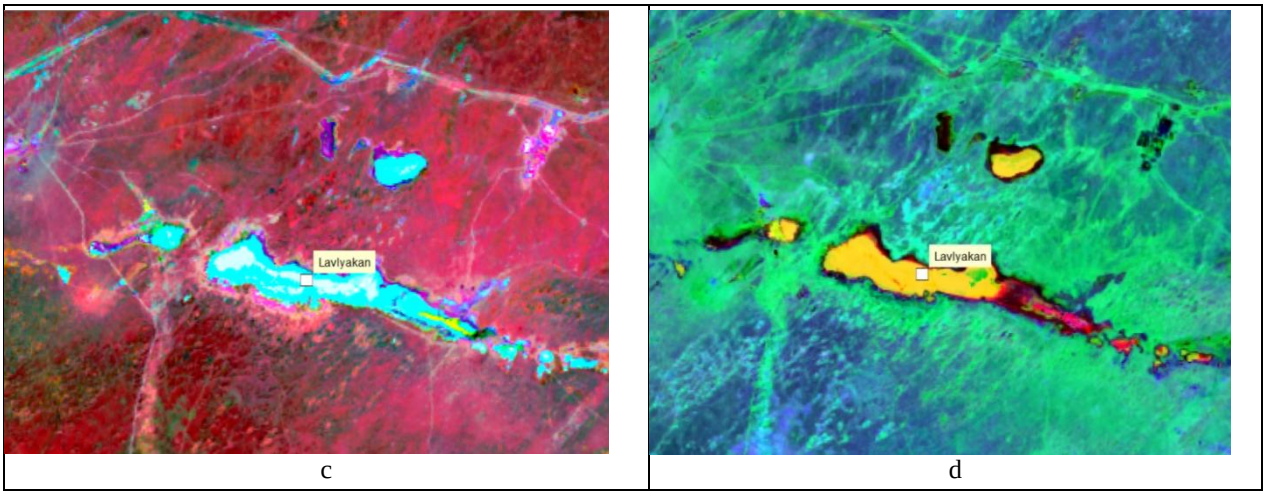

c d

Fig.4. The results of processing space images (scale 1:50,000) for the site of the Lavlyakan group of lakes: a - composite satellite image Landsat-5 (1994); b – Landsat-8 satellite image (June 20, 2013); c – PCA; d – Hydrotermal Composition.

In the course of the study, to map polygonal salinity zones due to changes in the physical properties of the objects under study, spectral processing of space images Landsat -5, 7 and 8 was applied.

In addition, the use of satellite image processing methods - Landsat-5 composite satellite images, Landsat-8 satellite images, PCA and Hydrotermal Composition in the process of studying the Lavlyakan group of lakes contributed to obtaining the most complete information regarding the composition of lacustrine rocks.

As a result of the studies, we have identified thick deposits of green clays of the Eocene age, which have a predominantly montmorillonite composition in the area of the Lavlyakan group, which is confirmed by microscopic and thermal studies, as well as by measuring the swelling value.

V. CONCLUSION AND FUTURE WORK

Thus, it can be argued that the integrated application of Landsat-8, PCA and Hydrotermal Composition research methods and the satellite image decoding method has the following advantages:

- contributes to the implementation of a targeted approach to the development of the methodology and practice of prospecting in the optimal places of salt accumulation, as well as the geological and economic assessment of the study area;
- establishing the role of tectonic structure in the formation of lake-soil salt accumulation;
- detection of faults within salt lakes that form as separate structures;
- mapping the places of potential accumulation of salt deposits and their boundaries, as well as determining the salinity level of the surface of the study area.

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