ISSN 0001-4370, Oceanology, 2015, Vol. 55, No. 2, pp. 253–262. © Pleiades Publishing, Inc., 2015.
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MARINE GEOLOGY

Geochemistry of Sediments in the Modern Aral Basin

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Received November 18, 2013; in final form, May 21, 2014

Abstract—The study presents the first geochemical data on the bottom sediments from the modern desiccating Aral Sea, which allowed a direct comparison between the compositions of the sediments collected during the pre- and postdesiccation periods. This study revealed the differences and similarities in the major and trace element composition of the sediments collected from the former bottom of the Large Aral Sea, the present-day sea bottom, the desiccated sea bottom, and the Amu Darya suspended sediments with respect to the average shale composition. The euxinic sediments from the western deep-water depression are characterized by high concentrations of U, Mo, and organic matter. The precipitation of evaporite salts occurs at the shallowest depths and in the western depression. The salt deposits exposed by the shrinking sea tend to be desalinated due to intense weathering. The mercury detected at high levels in the river suspended sediments of the former Amu Darya discharge was found to be absent in the modern marine sediments due to reductions in the river flow and the possible migration to the atmosphere. Many other trace elements, besides uranium, may also accumulate in seawater.

DOI: 10.1134/S0001437015020022

In recent years, the continuing shrinkage has split the Aral Sea into separate bodies of water (Fig. 1) due to the drastic fall in the water flow of the Syr Darya River feeding the Small (or North) Aral Sea and following the complete cessation of the discharge from the Amu Darya River formerly feeding the Large (or South) Aral Sea.

This basin known for its thriving fishing industry until the end of the 20th century has attracted the attention of many researchers who studied the changes in the water regime, biology, and sedimentation processes in the Aral Sea.

The first results concerning these problems were published in the late 1800s and early 1900s in the seminal monograph by Berg [7] and in the proceedings of the Turkestan Division of the Imperial Russian Geographical Society. Studies on the sedimentation and hydrologic processes in the Aral Sea were conducted in the Soviet era [8, 9, 21–24, 28–31] and were resumed in the last years on a new basis [14–20, 25–27, 32, 33, 36–38]. Our knowledge of the trace element compositions of the bottom sediments is essentially limited to only a few elements with the exception of uranium, for which geochemical data are available from previous studies [3, 23, 32, 33].

With the desiccation of the Aral Sea, much of the former sea bed has become a saline desert. This resulted in significant environmental impacts associated with changes in the chemical composition of the seawater and bottom sediments, which have undergone desiccation and erosion, which were the major causes of enormous dust storms originating on the exposed sea bed [11, 14].

The effects of desiccation on the sediment composition were analyzed by comparing two types of bottom sediments sampled before (a) and after (b) the desiccation of the Large Aral Sea. Part of this study was presented in abstract form at the international scientific conference in Moscow in 2013 [6].

MATERIALS AND METHODS

The material used in this study was sampled in different years by various expeditions. The bottom sediments of the predesiccation Large Aral Sea were collected by the first author during the 1965 geological expedition undertaken by the All-Union Research Institute of Mineral Resources aboard the motor boat *Oleg Koshevoy* provided by the Aral Division of the Kazakhstan Fishery Scientific Research Institute (KazNIIRKh). Bottom sediment samples were collected from a boat using a small (25 × 20 cm) dredge, which was lowered to the bottom on a nylon rope. One sample of suspended sediment collected from the Amu Darya River was provided by Yu.A. Sudakova (State Institute of Oceanography).

Samples of recent bottom sediments were taken from nearshore and shallow water depths of 2 and 7 m by P.O. Zavjalov and his colleagues during the expedition of the Institute of Oceanology in 2010. A deep-water sediment core (about 30 cm) was collected by J. Friedrich during the 2004 expedition from the west-

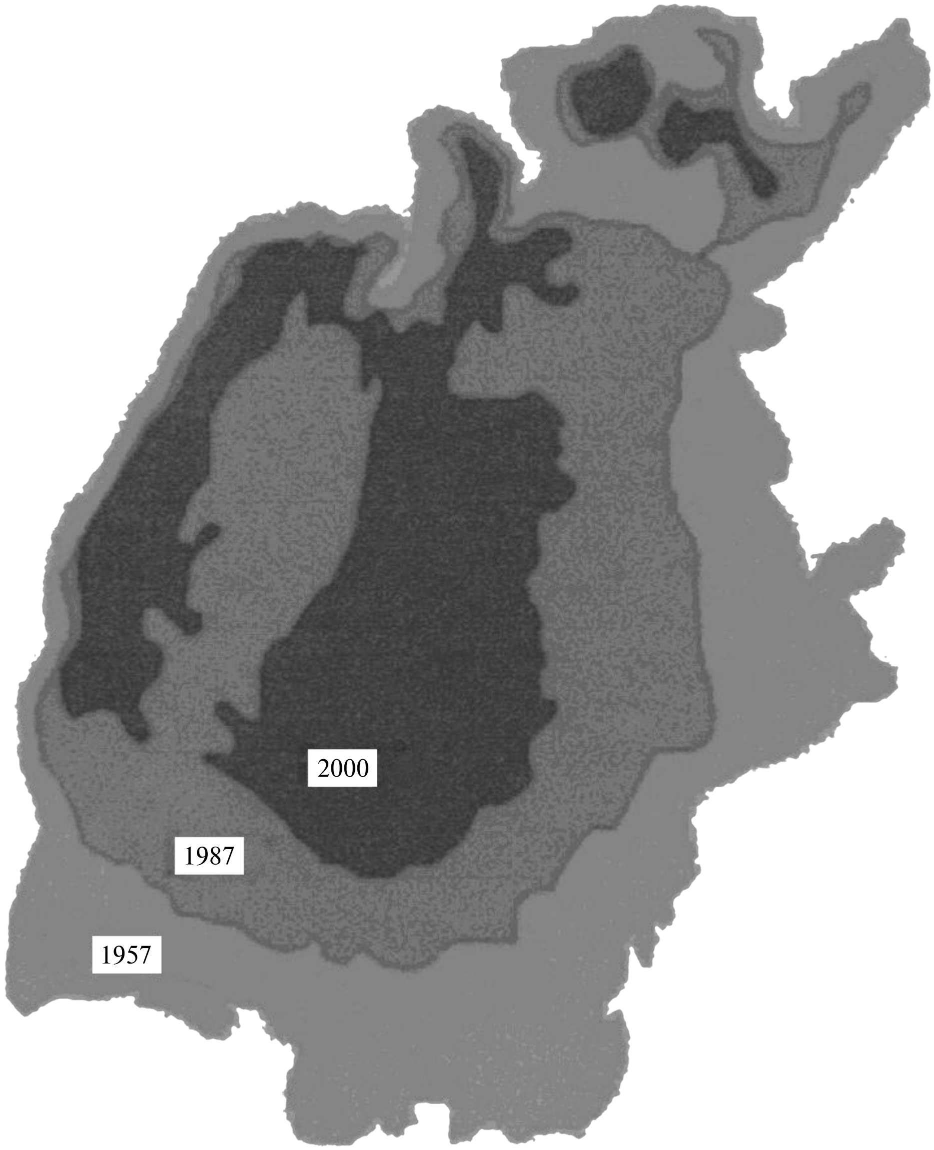

Fig. 1. Changing water area in the Aral Sea as a result of its desiccation by 2000.

ern deep-water depression of the Aral Sea using a flow-through corer [32, 33].

All the samples were analyzed for major and trace elements by ICP-MS at the Analytical and Certification Center of the Institute of Microelectronics Technology and High-Purity Materials using two geological reference materials—SGD-1A (GSO 521-84P) and SGD-2A (GSO 8470-2005)—under the guidance of V.K. Karandashev. The organic and inorganic carbon was determined chemically by N.P. Tolmacheva (Institute of Oceanology, Russian Academy of Sciences). The total silica was determined by E.O. Zolotykh (Institute of Oceanology, Russian Academy of Sciences) using a microchemical method proposed by A.B. Isaeva.

Since all the measurements were carried out on different aliquots and some of the important elements in the saline sediments such as halogens were not analyzed, the major element data for the bottom sediments appear to be inconclusive.

RESULTS AND DISCUSSION

The results of the major element analyses are given in Table 1. The left column shows the composition of the river suspended sediment and the bottom sediments during periods of a stable river runoff, and the right column shows the composition of the material deposited in the past years as a result of the progressive shallowing of the sea. Also shown are literature data on the average shales [12]. The REE and other trace element data in Tables 2 and 3 are presented in the same manner as in Table 1.

Table 1. Major element composition of the bottom sediments before and after the cessation of the river flow (%)

Element	Predesiccation Aral Sea				Desiccating Aral Sea			
	river suspended sediment	marine sediments	depression, bottom	crustal average	shore	water depth, 7 m	depression, top	water depth, 2 m
SiO_2	21.9	21.3	20.5	57.5	18.8	16.6	13.6	(0.3)
Al_2O_3	14.3	19.3	11.4	18	6.7	7.1	5.3	0.11
TiO_2	0.6	0.43	0.44	0.72	0.32	0.31	0.18	0.006
CaO	12.2	12.7	9.2	3.5	17.1	15.0	14.5	37.8
MgO	3.3	2.8	2.5	2.3	4.1	3.0	3.3	0.80
Na_2O	1.5	1.6	4.4	0.9	3.6	6.1	9.5	1.4
K_2O	2.5	2.05	2.1	2.75	1.85	1.6	1.4	0.78
Fe_2O_3	5.3	4.7	5.7	4.75	3.15	1.6	2.2	0.08
MnO	0.105	0.082	0.045	0.09	0.04	0.03	0.026	0.03
P_2O_5	0.125	0.17	0.09	0.17	0.11	0.077	0.13	0.030
S_{tot}	0.08	0.64	1.8	0.36	3.1	6.9	3.8	18.2
C_{org}	0.45	1.22	1.33	–	0.41	0.48	2.75	0.39
C_{inorg}	8.7	3.7	3.8	–	13.6	6.6	8.7	2.85

Major Elements

The comparison between the major element compositions of the Amu Darya River suspended sediment, the marine bottom sediments, and the average shales allowed the following conclusions to be reached (Table 1, Fig. 2):

(A) The major element concentrations in the bottom sediments prior to the modern desiccation of the Large Aral Sea were almost comparable to those found in river suspended sediment, except for an 8-fold increase in S (0.64 vs. 0.08%), a 3-fold increase in organic C (1.22 vs. 0.45%), and a 2.5-fold decrease in carbonate carbon (3.7 vs. 8.7%). This may indicate the influence of the biological productivity on the sediment composition.

The deep-water sediment samples (lower part of the sediment core, 22–24 cm) were significantly depleted in Al, Ca, Mn, and P but 2- to 3-fold enriched in S and Na. All three types of samples have lower concentrations of Si, Al, and Ti relative to the average shale and higher concentrations of Ca and Na, whereas the concentrations of the other major elements were broadly comparable in all the samples.

(B) The bulk chemistry of the sediments changed after the modern recession of the Aral Sea, as indicated by the decrease in the concentrations of Si, Al, Ti, Fe, K, P, and C (both organic and inorganic) and the increase in the concentrations of Ca, Mg, Na, and S.

At the same time, a relatively fresh mud sample collected in a near-shore setting appears to be very close in its chemical composition to sediment samples recovered from the 7 m water depth, except for its lower Na and S and higher Fe and inorganic C contents.

The chemical composition of the deep-water sediments changed considerably due to the marked recession of the sea, as indicated by the 1.5- to 2-fold decrease in the concentrations of Si, Al, Ti, K, Fe, and Mn and the 1.5- to 2.5-fold increase in the concentrations of Ca, Mg, Na, S, P, and organic and inorganic C.

Therefore, significant differences in the concentrations of all thirteen major elements were found in the sediments during the predesiccation and postdesiccation periods.

A sample of fine-grained saline sediments collected at about a 2 m water depth is composed mainly of gypsum and mirabilite and contains 37.8% CaO; 18.2% total S (calculated as SO_4); and 3% total Na, Mg, and K oxides, which approach 100%. Based on these data, the lithogenic components in these sediments account for about 1%.

Trace Elements

(A) The trace element compositions of the bottom sediments prior to the modern desiccation of the Large Aral Sea were also broadly comparable to those of the suspended sediment, which were found to be similar to the world average chemical composition of river suspended sediment and average shales (Table 2, Fig. 3). Of the trace elements, only mercury was present in significant concentrations (0.37 ppm) in the suspended sediment, which were five times higher than those of average shales (0.07 ppm) [12].

The comparison shows that the bottom sediments from the Large Aral Sea contain two times more U and As and three times more Sr relative to the world average composition of river suspended sediment.

The deep-water sediments have higher concentrations of Mo (up to 10 times) and lower concentrations of U, Pb, V, and Sr than the bottom sediments from the Large Aral Sea.

(B) Significant changes in the chemical composition of the sediments occur during the desiccation period.

Table 2. Trace element composition (ppm) of the sediments before and after the cessation of the river flow

Element	Sedimentary rock	Before reductions in the river inflow			After cessation of the river inflow			
		river suspended sediment	sediment samples collected in 1965	depression, bottom	shore	water depth, 7 m	depression, top	water depth, 2 m
Hg	0.068	0.37	0.13	0.02	0.03	0.017	0.018	0.006
Ag	0.2	0.12	0.07	0.045	0.20	0.057	<0.02	<.02
Bi	0.3	0.36	0.27	0.23	0.19	0.16	0.07	<.01
Cd	0.3	0.22	0.14	0.12	0.13	0.05	0.17	<.03
Ta	1.4	0.76	0.61	0.64	0.36	0.36	0.19	<.04
Sb	1.5	1.5	1.7	1.4	0.58	0.70	0.83	<.06
W	1.8	1.8	1.5	2.2	1.45	0.90	0.70	<.02
Mo	2	1.2	1.6	15.5	3.0	2.7	51.5	0.21
Be	3	2.0	1.5	1.3	1.0	1.1	0.45	0.12
U	3.2	2.5	4.7	5.6	3.4	3.1	10.1	2.6
Sn	3.5	2.6	1.5	1.6	1.05	0.92	0.52	<.14
Hf	4.5	2.2	1.7	2.6	1.3	1.7	0.78	<.04
Cs	5	5.9	5.8	6.6	3.0	3.3	2.3	.049
Th	10	10	8.1	8.5	5.0	4.8	2.2	0.10
Nb	11	5.7	7.2	9.0	4.4	5.6	2.5	0.16
As	13	17	38	24.8	9.7	8.9	5.8	1.2
Sc	13	14.4	12	9.4	6.2	7.5	4.0	<0.3
Ga	19	11.5	13.7	15.3	7.2	8.5	5.1	<.05
Co	20	16	19.5	15.7	8.7	7.6	6.3	1.1
Pb	20	19.6	15.1	19	11.8	10.1	7.1	0.24
Y	26	19	13	15.7	10.1	10.1	4.9	0.8
La	32	25	22.5	26	14.8	13.1	6.9	0.74
Cu	45	37	22.4	19.8	15	14.2	15	<0.9
Li	46	40	46.5	42.6	27.2	31.5	25.5	1.5
Ni	62	47.3	36.6	33.9	25	23.3	22.5	7.2
Zn	70	95	86	65.2	45.7	43.9	31.7	3.5
Cr	100	89	75	79	38	37.2	29.6	<0.9
V	130	100	106	146	57	55	51	<0.6
Rb	140	96	78.5	89.4	45	43	28	1.1
Zr	160	79	55	95	44	55	25	2.7
Sr	240	245	893	1163	1050	1782	4527	5300
Ba	510	400	480	376	307	230	174	79

The comparison between the bottom sediments from the former Large Aral Sea and the present-day sediments collected at the 7 m water depth shows that the present-day sediments are variably depleted in all trace elements, except for Mo, which was found in slightly higher concentrations (1.6 vs. 2.7 ppm), as well as for Hf and Zr, which remained constant. The strongest decrease was observed for Hg (8 times) and Cd and As (3–4 times), while all the other trace elements were 1.3–2 times lower.

The deep-water sediments showed remarkably higher concentrations of Mo (up to 51.5 ppm), U (up to 10 ppm), and Sr (up to 4527 ppm), whereas all the other trace elements were generally lower or remained constant.

The highest Sr concentration (5300 ppm) was found in a sediment sample collected at the 2 m water depth composed mostly of precipitated gypsum, which was likely explained by the precipitation of strontianite. The uranium concentrations in this sediment were slightly lower than in the bottom sediment collected at the 7 m water depth (3.1 and 2.6 ppm, respectively), which could indicate coprecipitation of dissolved uranium with gypsum, mirabilite, and strontianite.

The concentrations of some other trace elements (As, Hg, Mo, Ni, and Zn) in the saline sediments were considerably higher than their content in the minute

Table 3. REE composition of the bottom sediments and river suspended sediments (ppm)

Element	Before cessation of the river inflow				After cessation of the river inflow				
	Amu Darya suspended sediment	sediment samples collected in 1965		depression, bottom	shore	shore	water depth, 7 m	depression, top	shelf, 2 m
		st. 9	st. 73		0–2 cm	8–10 cm			
La	25.1	26.7	18.5	26.0	15.1	14.5	13.1	6.9	0.74
Ce	50.9	54.9	37.0	57.4	32.1	30.9	27.1	14.4	1.4
Pr	5.8	6.5	4.4	6.1	3.6	3.8	3.1	1.6	0.15
Nd	21.8	25.0	16.9	24.8	13.8	13.8	12.6	6.3	0.61
Sm	4.3	4.9	3.2	4.7	2.7	2.8	2.5	1.2	0.13
Eu	0.85	1.0	0.63	1.0	0.64	0.63	0.49	0.26	<0.004
Gd	4.0	4.2	2.9	4.1	2.6	2.6	2.4	1.1	0.15
Tb	0.63	0.65	0.43	0.60	0.39	0.40	0.34	0.17	0.018
Dy	2.7	3.3	2.3	3.48	2.1	2.0	2.0	0.98	0.069
Ho	0.57	0.68	0.47	0.67	0.42	0.39	0.38	0.20	0.023
År	1.8	1.9	1.3	1.9	1.2	1.2	1.1	0.56	0.064
Tm	0.22	0.28	0.19	0.29	0.18	0.17	0.16	0.084	0.088
Yb	1.5	1.9	1.3	1.9	1.2	1.2	1.1	0.56	0.052
Lu	0.23	0.29	0.20	0.27	0.17	0.17	0.15	0.078	0.088
$\sum$TR	114.44	128.95	88.92	133.21	75.20	74.56	67.12	34.39	3.60
Ce*	0.93	0.94	0.89	1.0	0.96	0.93	0.92	1.0	0.90
Eu*	0.89	0.97	0.91	1.0	1.05	1.08	0.88	1.0	–

Ce* and Eu* are the values of the anomalies.

amounts of lithogenic material dispersed in salts, which could also be indicative of coprecipitation of these elements from seawater. In this connection, the question may arise as to the concentrations of a number of trace elements in the Aral Sea water that have not been determined yet.

The trace element concentrations in the sediments from the desiccated Aral Sea are comparable to the levels found in terrigenous muds collected in a shelf zone at the 7 m water depth rather than those found in near-shore muds. The only difference is that shelf muds are 2–3 times more enriched in Ag, Cd, and Hg and up to 1.5 times depleted in immobile elements (Zr, Hf, Nb, and Sr) than near-shore muds.

It is reasonable to assume that the recession of the sea level resulted in subaerial exposure of the shallower, fine-grained saline sediments. However, this pelitic material proved to be very unstable and tends to quickly dry out and become airborne as salt dust during hot dry and windy summer conditions, whereas the wet muddy sediment covering the former seafloor is not subject to eolian erosion.

The distributions of some major and trace elements in six types of sedimentary material before and after cessation of the river discharge are shown in Figs. 4 and 3:

(1) suspended matter from the Amu Darya River similar in composition to bottom sediments from the Large Aral Sea collected in 1965;

(2) present-day muds from the Large Aral Sea collected at the 7 m water depth similar in composition to salt-free muddy sediment near the shore;

(3) these two types of sediments are similar in their composition and distribution of most trace elements;

(4) the highest concentrations of most trace elements, except for Ag, Hg, Bi, Mo, As, and Sr, were reported for the average shale compositions;

(5) the lowest concentrations of all the trace elements, except for Sr and U, were reported for the saline sediment.

In the saline sediments (the residual products of the Aral Sea desiccation), strontium is commonly found in aragonite and strontianite, whereas the form of uranium is not determined.

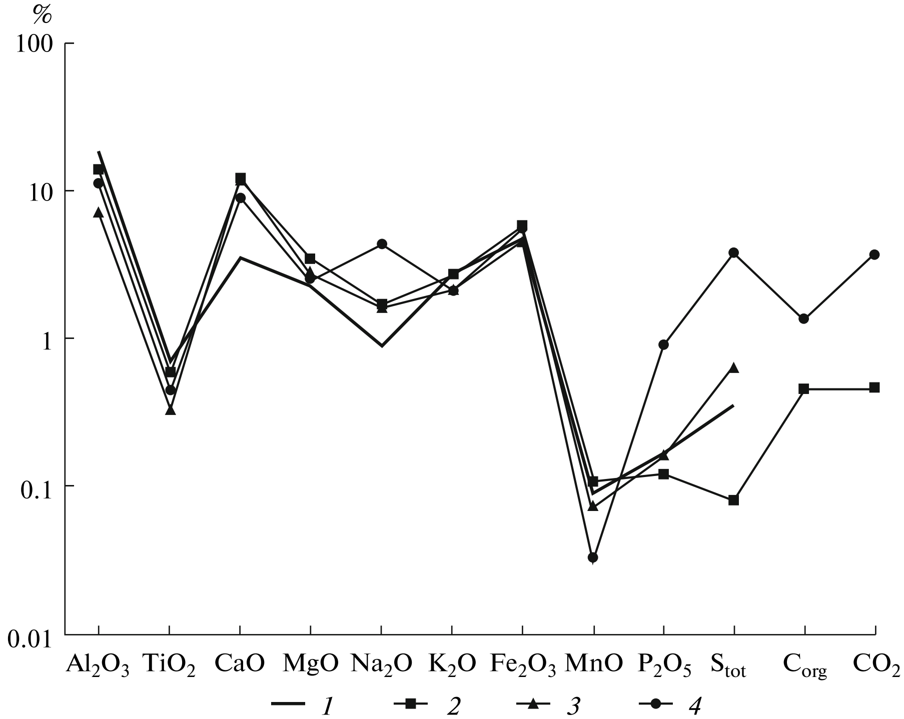

Fig. 2. Major element distribution in the bottom sediments during the predesiccation period. (*1*) Average shales [12]; (*2*) Amu Darya suspended sediment; (*3*) bottom sediments from the Large Aral Sea during the predesiccation period; (*4*) lower layer of the deep-water sediment core.

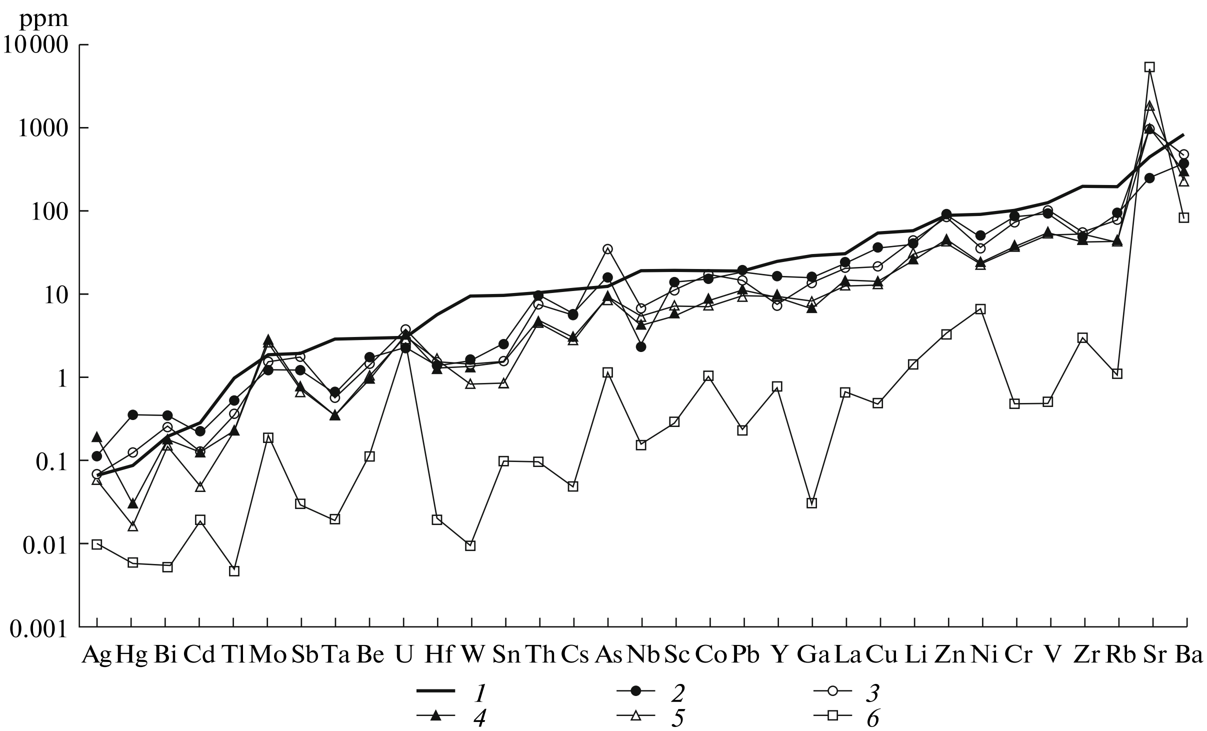

Fig. 3. Trace element distribution in the sediments. (*1*) Average shales [12]; (*2*) Amu Darya suspended sediment; (*3*) bottom sediments collected in 1965; (*4*) modern desiccating mud at the shore; (*5*) modern mud from a depth of 7 m; (*6*) salts from a depth of 2 m.

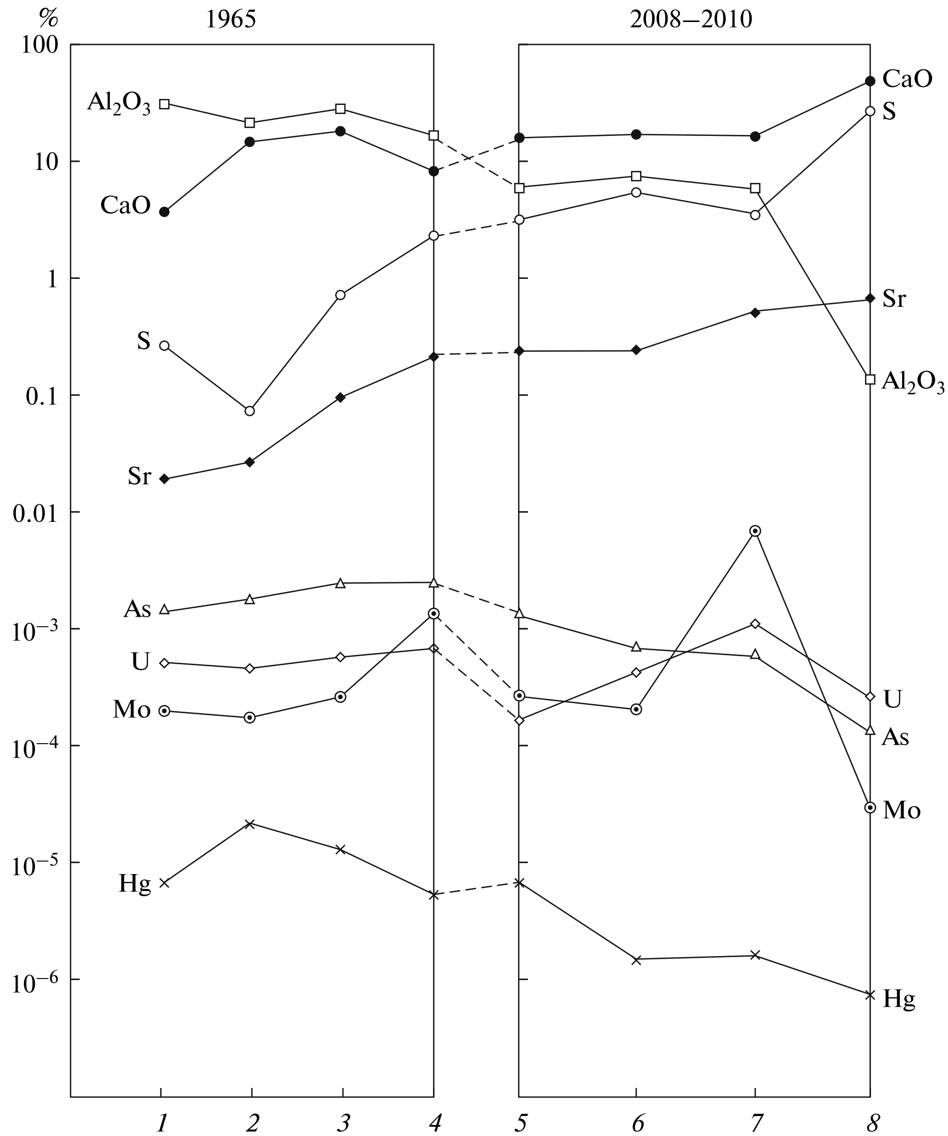

Fig. 4. Distributions of some elements in sediments during the pre- and postdesiccation period. (*1*) Average shales [12]; (*2*) Amu Darya suspended sediment; (*3*) bottom sediments of the Large Aral Sea collected in 1965; (*4*) lower layer of the deep-water sediment core; (*5*) modern desiccating mud at the shore; (*6*) top layer of the deep-water sediment core; (*7*) modern bottom sediment from the 7 m water depth; (*8*) salt from the 2 m water depth.

The least mobile elements, such as Ta, Be, Hf, W, Nb, Ga, and Zr, are present only in trace amounts in the finely dispersed lithogenic components of the saline sediments.

Rare-Earth Elements (REE)

All the samples analyzed display clear trends of the REE distribution patterns.

In the river suspended sediments and bottom sediments collected from the Aral Sea during the predesiccation period, including the lower layer of the deep-water sediment core (Table 3), the REE contents were the highest but slightly lower than those of the average shales.

In the sediments collected from the dried bottom of the Aral Sea and in the present-day marine sediments collected at the 7 m water depth, the REE contents were two times lower and even two times lower in the top layer of the deep-water sediment core. The lowest total REE contents (3.764 ppm) were found in the shallow-water saline sediments collected from the near-shore environment.

The REE contents in the bottom sediments collected during the predesiccation period were two times lower than those of the present-day sediments collected at the 7 m water depth.

The Ce and Eu anomalies calculated as the ratios between the shale-normalized values and the arith-

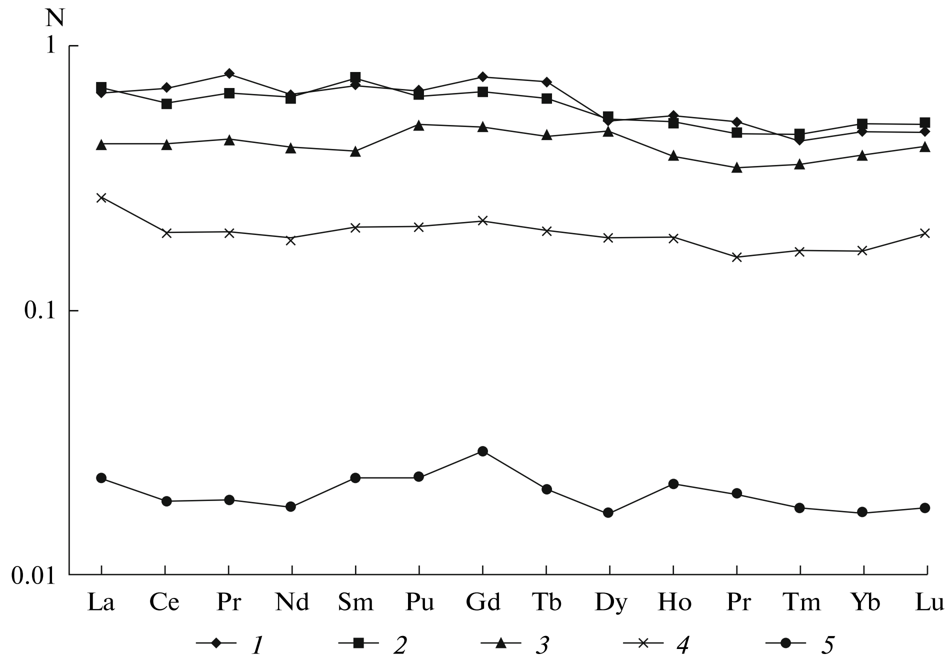

Fig. 5. REE distribution in the sediments. (*1*) Amu Darya suspended sediment; (*2*) bottom sediments of the Large Aral Sea collected in 1965; (*3*) modern desiccating mud at the shore; (*4*) top layer of the deep-water sediment core; (*5*) salt from the 2 m water depth.

metic mean of the respective neighboring REE [13, 34] display little or no variation. Both anomalies are slightly negative (0.93 and 0.89) in the Amu Darya suspended sediment and neutral (1.0) in the top and lower layers of the deep sediment core. The sediments collected from the dried bottom of the Aral Sea show a slightly negative Ce anomaly (0.93–0.96) and a slightly positive Eu anomaly (1.05–1.08), whereas all the other samples have negative Ce and Eu anomalies.

It is noteworthy that the highly uniform REE patterns in all the samples (Fig. 5) suggest their inheritance from the river suspended sediment.

The results generally demonstrate that the composition of the sediments during the predesiccation period was largely controlled by the river runoff and biological productivity, as indicated by the higher C_{org}, P, and S contents of the sediments compared to the river suspended material. At the same time, the higher Al concentrations in the sediments suggest an important role of the eolian factor.

The concentrations of most trace elements were lower in the bottoms sediments (before the onset of the Aral Sea desiccation) than in the river suspended sediments due to the influence of the eolian and biogenic factors. The only exception is the enrichment of Mo, U, As, and Sr in the bottom sediments, which can be explained by the additional inputs of these elements in dissolved form from the river during the predesiccation period.

After the cessation of the river discharge, the eolian contribution to the deep sea sediments increased. The concentrations of Al, Ti, K, Fe, Mn, P, C_{org}, and almost all the trace elements decreased, while the concentrations of Mo and Sr were 1.5–2 times higher probably due to the uptake of these elements from the seawater.

Similar trends are seen in the deep-water sediments, which have lower (1.5–4 times) concentrations of most trace elements and higher concentrations of Mo (19 times, 51.5 ppm), U (2 times, 10.1 ppm), and Sr (2.5 times, 4327 ppm) compared to the predesiccation values.

The process is terminated by the deposition of salt-bearing rocks, such as gypsum, strontianite, and mirabilite (sample collected from the 2 m water depth), which form through the evaporation of the relatively thin surface water layer in the near-shore region.

The behavior of U in the modern Aral Sea requires special attention.

The first data on the uranium concentration in the seawater (about 15 μg/L) were reported in 1963 [10]. Later studies showed that the U concentration in the seawater is several times higher (30–60 μg/L) [3, 23]. The uranium isotope composition was investigated to determine the absolute age of the Aral Sea [31].

The most recent data [32, 33] show that the Syr Darya waters have U concentrations of 16 μg/L and a salinity of 1.45 g/kg, which tend to increase to 35 μg/L and 18 g/kg in the waters of the Small Aral Sea (feeding the Large Aral Sea) and to 154 μg/L and 110 g/kg in the waters of the Large Aral Sea. The U (μg)/salinity (g) ratio varies in the order of 11–2–1.5 for this sequence; i.e., the salinity of the seawater increases more rapidly than the uranium concentrations mainly due to evaporation.

The high concentrations of uranium in the seawater can be explained by the lack of U precipitation within the present-day area of the Aral Sea, and the U concentrations in the bottom sediments are similar to the predesiccation values (estimated 50 years ago). However, two facts are noteworthy:

(A) Unlike most elements, except for Ca, S, and Sr, the uranium concentrations in the salts precipitated from the seawater in a shallow setting are comparable to those of the sediments.

(B) The uranium of the modern deep-water euxinic sediments is concentrated predominantly in organic-rich facies (up to $10 \times 10^{-4}\%$), which is two times higher than that of the bottom sediments deposited in the same deep-water depression during the predesiccation period. The C_{org} content of the modern sediment was found to be two times higher than the predesiccation values.

Therefore, the accumulation of dissolved uranium in the water of the Aral Sea is accompanied by local precipitation of U in the following: (a) organic-rich euxinic sediments (similar to the Norwegian fjords [35]) and (b) near-shore evaporite salts.

The presence of the uranium in the form of uranyl ion complexes and the high pH values of the Aral Sea water appear to be crucial factors in hindering the uranium precipitation from the seawater [32, 33]. Unfortunately, data on the concentrations of the other metals and the forms in which they occur in the water of the Aral Sea are not available, but it can be assumed that many other elements, besides uranium, may also accumulate in the seawater.

The comparison shows that different elements in two different geochemical environments exhibit complex behaviors, as indicated by the distribution of eight major and trace elements before and after the desiccation of the Aral Sea (Fig. 4.)

CONCLUSIONS

The results show that the Aral Sea desiccation due to the cessation of the river inflow caused major changes in the sedimentation regime and geochemistry of the bottom sediments, which were accompanied by an increase in salinity levels and a decrease in biological productivity.

The bottom sediments are characterized by an abrupt decrease in Al and organic carbon; only a minor decrease in Si, Ti, K, Fe, Mn, and P; and an increase in Ca, Na, and S. Similar trends, except for higher organic carbon contents, were identified for deep-water sediments. The desiccation of the sea was accompanied by the deposition of evaporitic beds consisting mostly of gypsum and mirabilite in the shallow-water, near-shore environments.

The comparison between the major and trace element compositions of the bottom sediments of the Aral Sea allows the following conclusions to be reached:

(1) The composition of the suspended sediment of the Amu Darya River, which formerly fed the Aral Sea, was similar to that of the bottom sediments prior to and after the desiccation of the sea.

(2) The deposition of evaporitic beds consisting mostly of gypsum and mirabilite occurs in the shallow-water (the first few meters of water depth) near-shore environments of the modern Aral Sea.

(3) The uranium content of evaporite salts is indicative of precipitation of uranium from shallow brine. However, there is no direct evidence for coprecipitation of other elements from the brine solutions.

(4) With continuing desiccation and increasing salinity levels, many other elements, besides uranium, may also accumulate in the seawater.

(5) Salt deposits exposed by the shrinking sea tend to quickly dry out and become airborne as salt dust, whereas the residual wet muddy sediment is close in composition to marine bottom sediments.

(6) The shallowing of the sea led to the establishment of euxinic conditions in a deep-water depression, which favored the deposition of organic-rich facies and the accumulation of Mo and U in the top layer of sediments.

(7) This fact may indicate that the deep-water depression in the Aral Sea may be interpreted as a new type of modern euxinic saline basin capable of generating carbon-rich metalliferous deposits, similar to the Norwegian fjords, Black Sea and Baltic Sea [1–5].

(8) Since the above results were obtained from a few samples, a detailed and comprehensive quantitative analysis of the contemporaneous sedimentation and salt accumulation on the bottom of the Aral Sea and the erosion of the exposed deposits of the former shorelines is required.

ACKNOWLEDGMENTS

This study was supported by the Presidium of the Russian Academy of Sciences (project no. 23).

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Translated by N. Kravets