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Geochemical, Sedimentological and Mineralogical Characterization of Surficial Sediments in Eynak Marsh (North of Iran)

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Abstract

A multidisciplinary study of the sedimentology, geochemistry and mineralogy has been conducted to understand the linkage between marsh and alluvial sediments and also their potential sources in Eynak marsh, North of Iran. The influence of the upstream potential sources on recent sediment geochemistry has been discussed based on geochemical, sedimentological and mineralogical results. A spatial grain size distribution study was carried out to investigate the hydrodynamic and deposition system of the marsh. So, the surficial sediment sampling was carried out to describe the sedimentological parameters and elemental geochemistry of sediments in Eynak marsh. Mineralogical complexes are mainly made up of felsic minerals such as quartz, calcite, feldspar, pyrite, mica, and clay minerals (in very low values) indicated by high amounts of Al, Ca, and Ni. As expected, the mineralogy of sediments is controlled mainly by the rock formations. Also sediment textures are controlled by the hydrodynamic condition in the marsh. So its distribution has been influenced by distance from the entrance sediments to Eynak marsh. The results showed that there are no enrichments related to fine grain sediment distributions. An association of Al with the trace elements such as Sc, Y, La, Ce, and Zr indicates that their distributions are mainly controlled by the felsic rocks in the upstream. On the other side, due to the waste water entrance to the marsh, Ni and Pb concentration could be under the effects of anthropogenic activities around the marsh. Results represented high values for Mn concentration (min 462, max 1784 and average 1037 ppm) and it showed a significant correlation with Ca, Sr, and Mg. A redox habitat and constantly calm hydrodynamic circumstance in the study area, likely cause high concentration of Ca, Sr, and Mg, and Mn. And they are representing negative correlations with some elements such as Al, Be, Fe, K, and Na.

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Keywords

Eynak Marsh, Sedimentology, Geochemistry, Element Distribution Pattern, Element Correlation

1. Introduction

Improvement of our understanding in the environmental and geomorphological changes' effects on marshes and isolated waters is a critical step to address issues related to continental marshes and their responses to these changes. Also, sedimentological studies are proper tools to interpret the evolution of sedimentary environment [1]. Additionally, to assess the ecological impact of contamination to the environment, it is vitally important to understand the full extent and the level of pollution into the background in the area.

Regarding its capabilities in providing goods, marshes environments are classified as the most precious ecosystems on earth [2] [3]. Considering the effects of climate changes and human interferences, today the future of these important landforms and ecosystems seems to be at risk and it may cause possibly irreparable transformations [4]-[10]. However, despite progress about geomorphology, sedimentology, accretionary processes and geochemistry, more work needs to be done to explain the sedimentology, stratigraphy and geochemistry of sediment in marshes on the subject of the evolution of the systems [1] [11] [12].

The particle size and morphology of sediments are the major implements to interpret the source of sediments, transportation modes and depositional environments [13] [14]. Variations in grain size distribution of isolated environments (specifically marshes habitats) may reflect air surface process such as developmental process of landforms through precipitational changes [15]. On the other side, mineral distributions are also standard tracers of regional geology, weathering characteristics in upstream and transport land mass [16]-[23]. Moreover, trace elemental compositions of sediments are controlled by lithologies, weathering, diagenesis, sedimentary sorting and human activities in catchments and it can be useful for identification of specific geochemical processes and provenance of clastic materials [24]. Also characterizing of the composition and the sedimentology of surface sediments is vital not only from geochemical point of view, but also from an environmental perspective. Thus variations in mineral compositions, trace elements and lithogenic components should be considered as valuable tools to find out the possible sediment sources and physico-chemical process affecting the geological records [23].

Nowadays, Eynak marsh is strictly isolated from any riverine and oceanic sediment input (**Figure 1**). Anthropogenic effects (as an instance intense construction operation, sewage input to marsh and etc.) likely contribute to changing the circumstances and its natural habitat. Despite the importance of this area, there is no worthy investigation devoted to the study of geochemical, mineralogical and sedimentological signature of Eynak marsh. This investigation could be more momentous if we spot contamination of sewage entrance from the urban areas and also underground linking to GoharRood River. It is noteworthy that, GoharRood by itself is a fully contaminated river transporting sewage from upstream.

Because of its position regarding urban area, being one of the biggest marshes in north of Iran and tourism industry, this marsh represents a crucially important ecosystem in the region. Detailed sedimentological and geochemical investigations on these marshes can help us to improve our knowledge about its generation. Then it led to precise relationship being deducted between marsh and river sediments. As the other aquatic environments in south of Caspian Sea, Eynak marsh is situated in the migration way of different birds (Africa-Eurasia and Asia-Pacific skyways) then lots of bird spices fly to this region every year. Also this marsh is populated by various plant species like *Myriphgllom verticillatum*, *Ceratophyllum submersum*, *Alisma plantago-aguatica*, amphibians like frog and creepers like snake, turtle, lizard adapted to the environment.

Due to reflecting the privilege geology of the source area by the deposited sediments [25], a comprehensive study has been conducted. This paper focuses on understanding of sedimentology, mineralogy and geochemistry variation pattern in the riverine sediment of Eynak marsh (North of Iran). So the main purposes of this paper are: 1) to provide information about the sediment size distribution, mineral composition and also the main potential source of marsh sediments; 2) to improve our understanding in trace element pattern distribution in the marsh; and 3) to assess metal contamination levels in surficial sediments and particles. To achieve these goals we have analyzed surficial sediments of the marsh thoroughly.

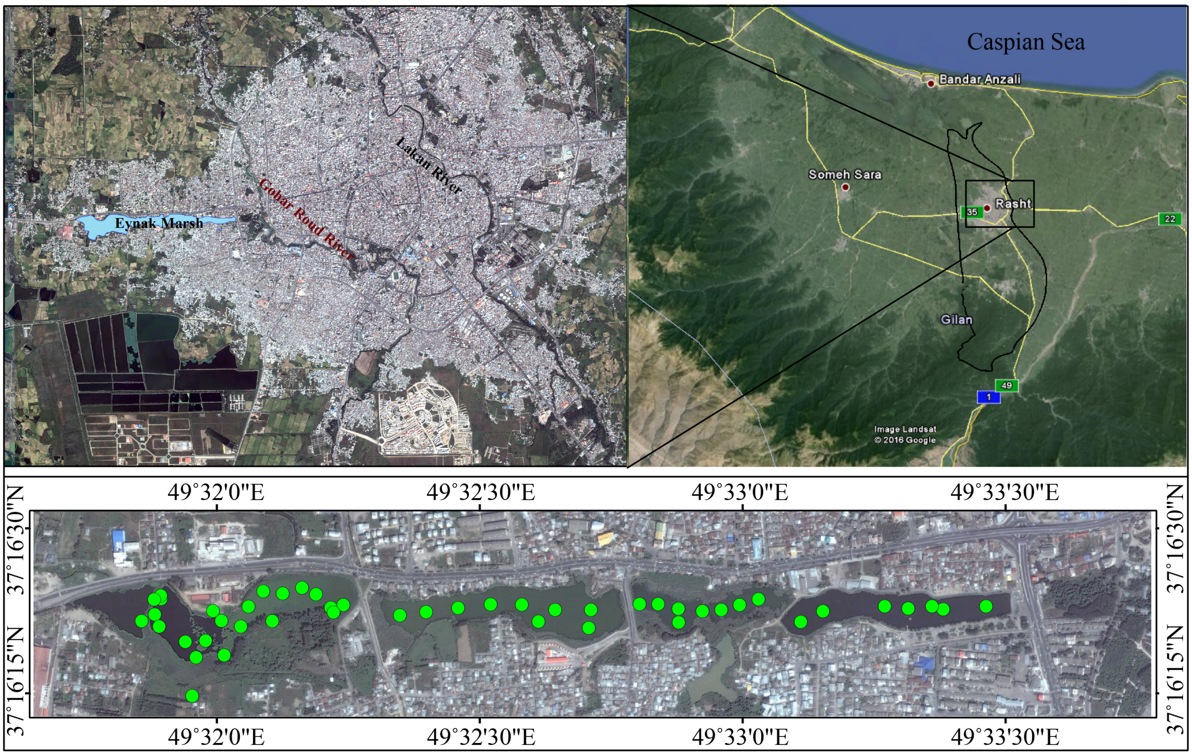

Figure 1. Geographical location and detailed sketch map of the study area in Eynak marsh.

2. Study Area

Marshes and bays across the Caspian Sea that are under the impact of 3 major processes of longitudinal transfer of coastal sediments, increasing the level of Caspian water, and syncline-anticline structure [26] are considered environment passages, from land to sea. Moreover, analysis of historical aerial photography depicts a relatively dynamic system in the area in which lateral migration of main channels caused some isolated small areas. So, Eynak marsh could be considered as such environments and it is located in Rasht countryside (Gilan province) and about 17 km away from Anzali costal lagoon, North of Iran. Also it is situated from 37˚16'25"E 49˚32'18"N to 37˚16'22"E 49˚33'31"N presumably is a separated pool from flowing rivers through time. It seems the main source of sediment in this marsh located in Kacha Mountain and sediments transported through Lakan and GoharRood Rivers. Nowadays Gohar rood and Lakan Rivers drain to Anzali coastal lagoon. Estimated area is about 214,650 m^2. Due to being situated in Rasht countryside and industrial activities around the marsh, irreversible changes is happening there which effects on its habitat and it may cause to destroy the marsh completely in the future. Unfortunately it has not been a comprehensive investigation in the area to discover the origination of this marsh yet. Better to know, the upstream sewage discharging to Lakan River and its probable underground linking to Eynak marsh, may cause more negative effects on the marsh habitat. Also, there are some transects cutting across Eynak marsh and separated it to smaller areas. It means there might be no more Eynak marsh in the area in future unfortunately.

Study area has a humid subtropical climate that is one of the wettest in Iran. It has certain Mediterranean features such as a drier summer, but is also relatively continental with cooler winters and higher seasonal temperature variation than in much of Iran, in spite of its marine position. The average humidity is 81.2%, contrasting heavily with cities in many other parts of Iran. Sunshine hours, averaging roughly 1520 per year, are lower than in most places in Iran and also compared to most places at this latitude.

The oldest rocks in the domain area consists of early Carboniferous made up of creamy-brown to dark-green slate to phyletic clastic sediment which in partly are calcareous and belongs to Mobarak Formation. After that, grey to green arkozic sandstone and shaly mudstone belongs to late Triassic can be seen (**Figure 2**). Cretaceous rocks such as massive sandy limestone, silty limestone-siltstone and dark grey basaltic-andesitic lava occurrence

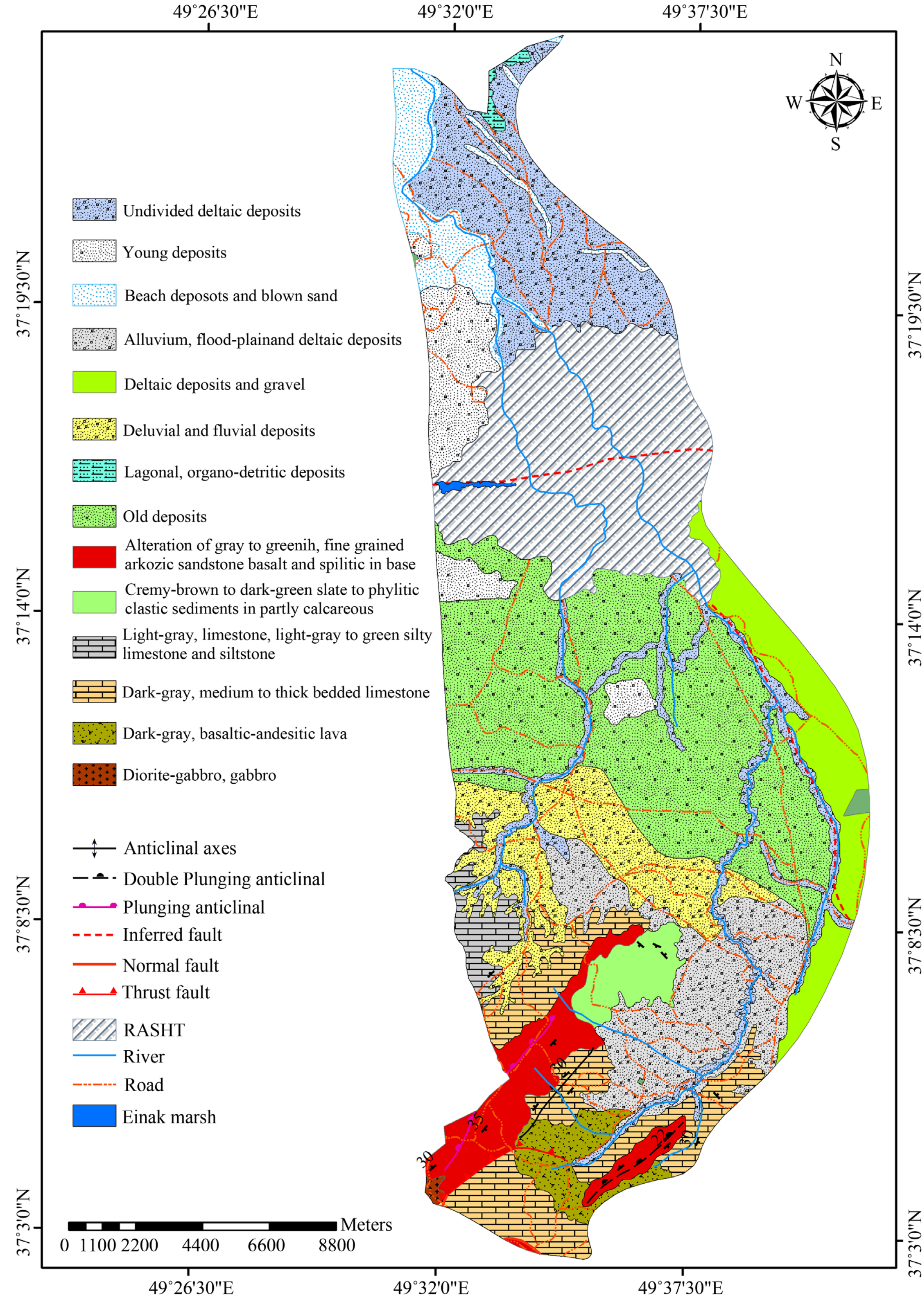

Figure 2. Geological map and the main hydrological features of the study area.

in the upstream area. Plain landscape is overlain by Quaternary deposits which [27] classified them in the area into: 1-Deltaic deposits and gravel, 2-Deluvial and fluvial deposits, 3-Old fluvial deposits, 4-Alluvium floodplain and deltaic deposits and finally 5-Blown sands (**Figure 2**).

3. Material and Method

Figure 1 shows the total 44 collected sediment sample locations along the marsh which sampling points took by GPS receiver. The primary distance between locations was about 40meters which it changed slightly based on convenient sampling. Sampling was carried out onboard small boat using a 4liter Van Veen grab sampler. Samples were taken onboard for sedimentology, mineralogy and geochemical analysis individually. Each sample was packed in polyethylene bags, tied, labeled and brought to GSI Lab for excess analyses. Detailed grain size, mineralogy and geochemical analysis has been carried out on all collected samples in order to recognize possible anomalies and basic pattern of sediment characteristics inside of the marsh.

Afterward, on the lab, samples were dried at 70˚ and dried bulk sediment was sieved to separate various fractions using wet sieving (based on standard test ASTM for determining average grain size). Grain size analysis of the 44 surficial sediment samples performed by Analysette 19 wet sieving instrument. Therefore, samples grouped into mud, sand and gravel fraction according to Udden and Wentworth. A detailed description of grain size <63 µm fractions executed by Laser Particle Seizer (model analysette 22).

Standard practice for total digestion of 44 sediment samples for chemical analysis of various metals (according to D-4698 preparing method) has been performed. So minor and major elements determined by inductively coupled plasma-optical emission spectrometry (ICP-OES-ES Varian 735) in Geological Survey of Iran chemistry lab. Moreover, X-Ray diffractions in 44 sediment samples in the area have been performed using an automatic powder EQUINOX 3000 X-ray diffractometer. Quantification and identification of the various minerals present in the crystalline fraction has been carried out following the standard procedure [28].

Fractional analyses were carried out using the software package SPSS20 for windows. In addition, on all samples in Eynak marsh, detailed grain size, geochemical and mineralogical analysis have been carried out to recognize a possible correlation between their distributions and depositional environments.

4. Result

4.1. Physical and Mineralogical Characteristic

Textural and size analyses are quantitative tools to determine the size frequency distribution [29]. Also, mineralogical and physical characteristics of the sediments in Eynak marsh can be influenced by rock assemblages in upstream such as basaltic-andesitic lava, dark grey limestone, slate and Arkozic sandstone which has been subjected into weathering, eroded and transported to downstream. In fact, due to terrestrial sources of sediments in Eynak marsh, it is characterized by similar mineralogical and physical features. Results showed that samples basically were angular to sub angular in shape (**Figure 3**), major component mineral were quartz, calcite, feldspar, and mica and minor mineral were pyroxene, evaporates along with some heavy minerals.

Grain Size Distribution

According to grading studies, 13 sedimentary types existed in surface sediments including: Gravelly Mud, Muddy Gravel, Gravelly Sand, Muddy Sandy Gravel, Gravelly Muddy Sand, Muddy Sand with a Little Gravel, Sandy Mud with a Little Gravel, Mud with a Little Gravel, Silty Sand, Muddy Sand, Sandy silt, Silt, Sandy Mud (**Figure 4**). Considering its pattern, east side of the marsh represented a variety of sedimentary types. Moreover, grain size distribution maps reveal that, silt and clay fractions are the most important sediment constitutes concentrated mostly in the middle and the east. Also, gravel size grains increased eastward approaching GoharRood River.

4.2. Statistical Parameters

Various statistical parameters of Eynak marsh sediments computed. **Mean grain size:** The variation in mean size reflects the variety of energy conditions to deposit and shows the average kinetic energy of the depositing agent [30]. Different values obtained for textural statistical parameters varying from minimum 1.5 to maximum 6.6, *i.e*. thus it falls between coarse sand and medium silt. **Sorting:** Sorting indicate the differences in kinetic

Figure 3. Sediment grains in Eynak marsh.

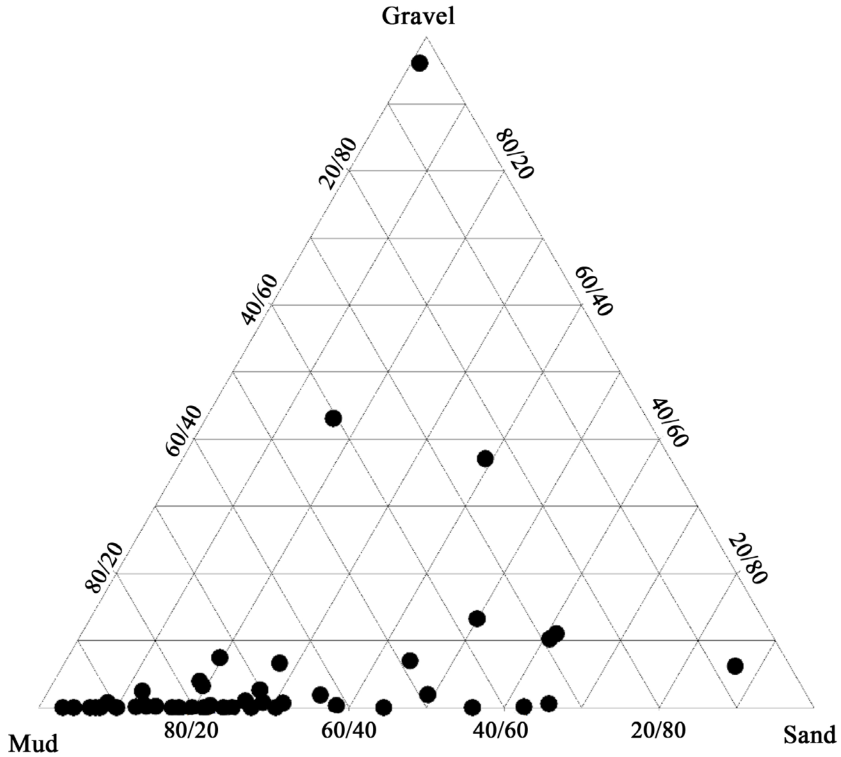

Figure 4. Ternary plot showing the content of gravel, sand and mud fractions in the surficial sediments of Eynak marsh.

energy associated with these mode of depositions. In the study area sediments ranges in 3 sorts: poorly sorted, very poorly sorted, and moderately sorted. The closer to GoharRood, the sorting number increases and sediments poorly sorted. **Skewness:** It measures the asymmetry of frequency distribution and marks the position of mean according to median [29]. In the present study skewness values ranges −0.43 to 0.68 with an average −0.02 represents five sorts: strongly fine skewed, fine skewed, near symmetrical, coarse skewed, strongly coarse skewed. Eastern samples showed near symmetrical to coarse skewed which it accounts as the abundance of coarse particles of energetic environment. Also, strongly fine skewed can be seen in the middle of Eynak marsh. **Kurtosis:** Many curves designated to minute Kurtosis and it varies from platy kurtic to mesokurtic. Also the values are among 0.5 to 2 with an average of 0.99. The platy kurtic to mesokurtic nature of sediments refers to fewer addition of finer or coarser materials to the depositional environment [30]. In general and regarding average values, sediments are fine grained (**Figure 4**), moderately to poorly sorted associated with very low current flow in eastern side of the marsh.

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4.4. Scatter Plot

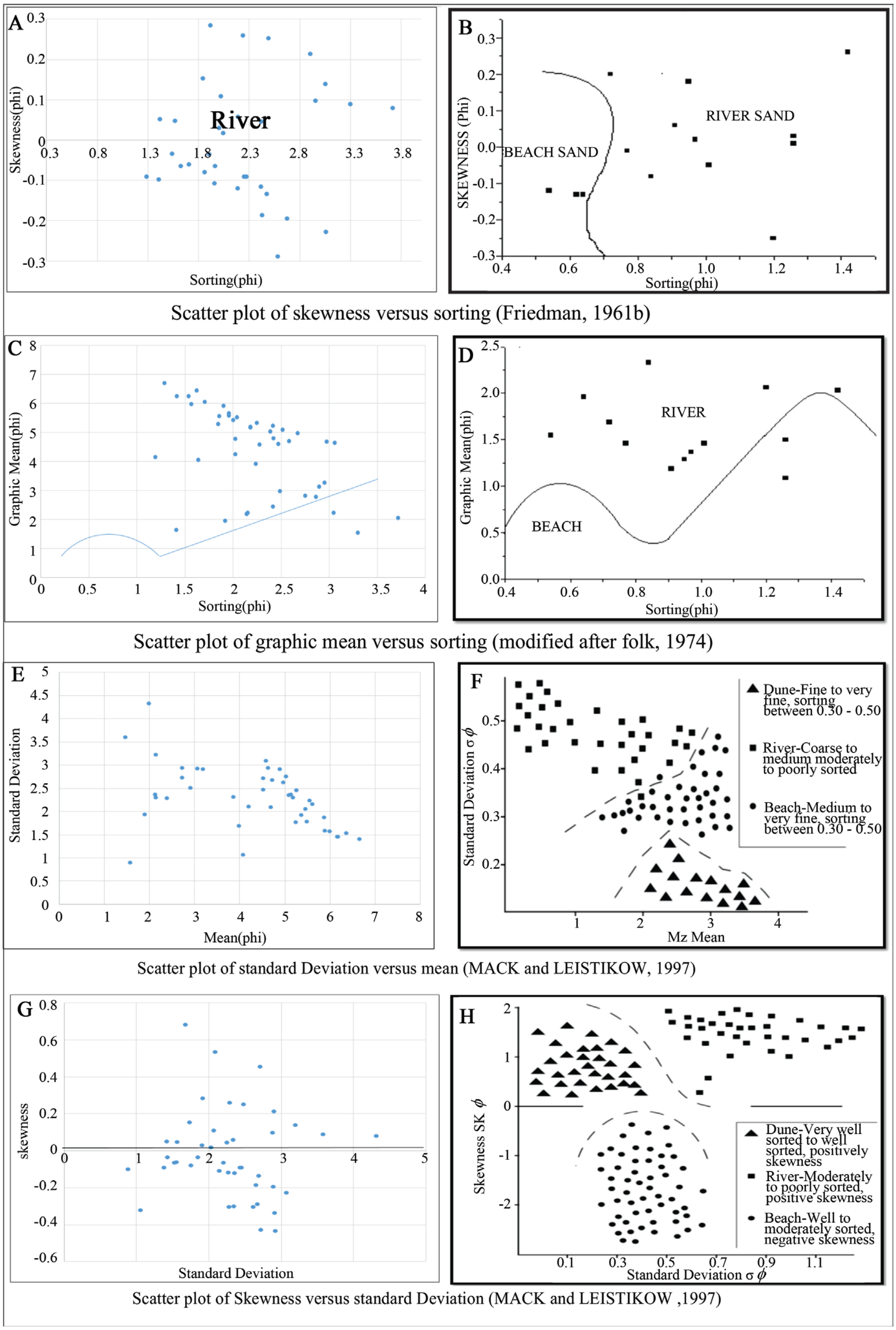
Scatter plot with mean, standard deviation and skewness can be used successfully for the distinction of the sedimentary environments, always using a large number of samples for each sedimentary body sampled [31]. Moreover, scatter plots are useful to identify geological signature of the grain size parameters [32]. Scatter plots *viz.* skewness versus standard deviation, mean versus standard deviation, and standard Deviation versus mean is brought in **Figure 5**. The scatter diagram proved that the distribution of grains belongs to fluvial and riverine sediments.

4.5. Sediment Composition

The significant correlation of elements with each other may indicate same source, chemical behavior, sediment-water interface and etc. [33]. Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. Unlike Pearson's correlation, there is no requirement of normality and hence it is a nonparametric statistic. Regarding unmorally in our data diversity, Spearman's correlation analysis has been conducted on the calculated data to determine the relationship between various elements and sedimentary parameters as well as to find out the main sources of elements and grains.

4.5.1. Mineral Diversity

Eynak marsh sediments were mainly composed of muddy fractions (**Figure 4**). Mineralogically, quartz, calcite, feldspar, dolomite, and mica were the main constitutive minerals present in surficial sediments (**Table 3**). Considering opposite geochemical behavior in Quartz and Calcite, high values of quartz from the middle to east and



Scatter plot of skewness versus sorting (Friedman, 1961b)

Scatter plot of graphic mean versus sorting (modified after folk, 1974)

Scatter plot of standard Deviation versus mean (MACK and LEISTIKOW, 1997)

Scatter plot of Skewness versus standard Deviation (MACK and LEISTIKOW ,1997)

Figure 5. Various scatter plot of surficial sediments in the study area to show the origin of grains.

west of Eynak marsh correlated to calcite and dolomite depletion. As well as, higher amounts of calcite along with pyrite and gypsum can be seen in the middle of the marsh. Also, silicates such as feldspars, mica, pyroxene and clay minerals are distributed regularly throughout the surficial sediments. Mineralogy data diversity was proofed by geochemical analysis of sediments throughout the study area.

4.5.2. Element Diversity

Usually, fine grain sediments are common hosts and controlling factor in distribution of elements, especially metals, in aquatic sediments [34]. The correlation matrix, element composition and Dendrogram using Ward method are shown in **Table 1** and **Table 2** and **Figure 6** respectively. Trace elements incorporated in heavy minerals like Y, Zr, Th, Cr, have lower content in the finer grained sediments (**Figure 7**) indicating depletion of

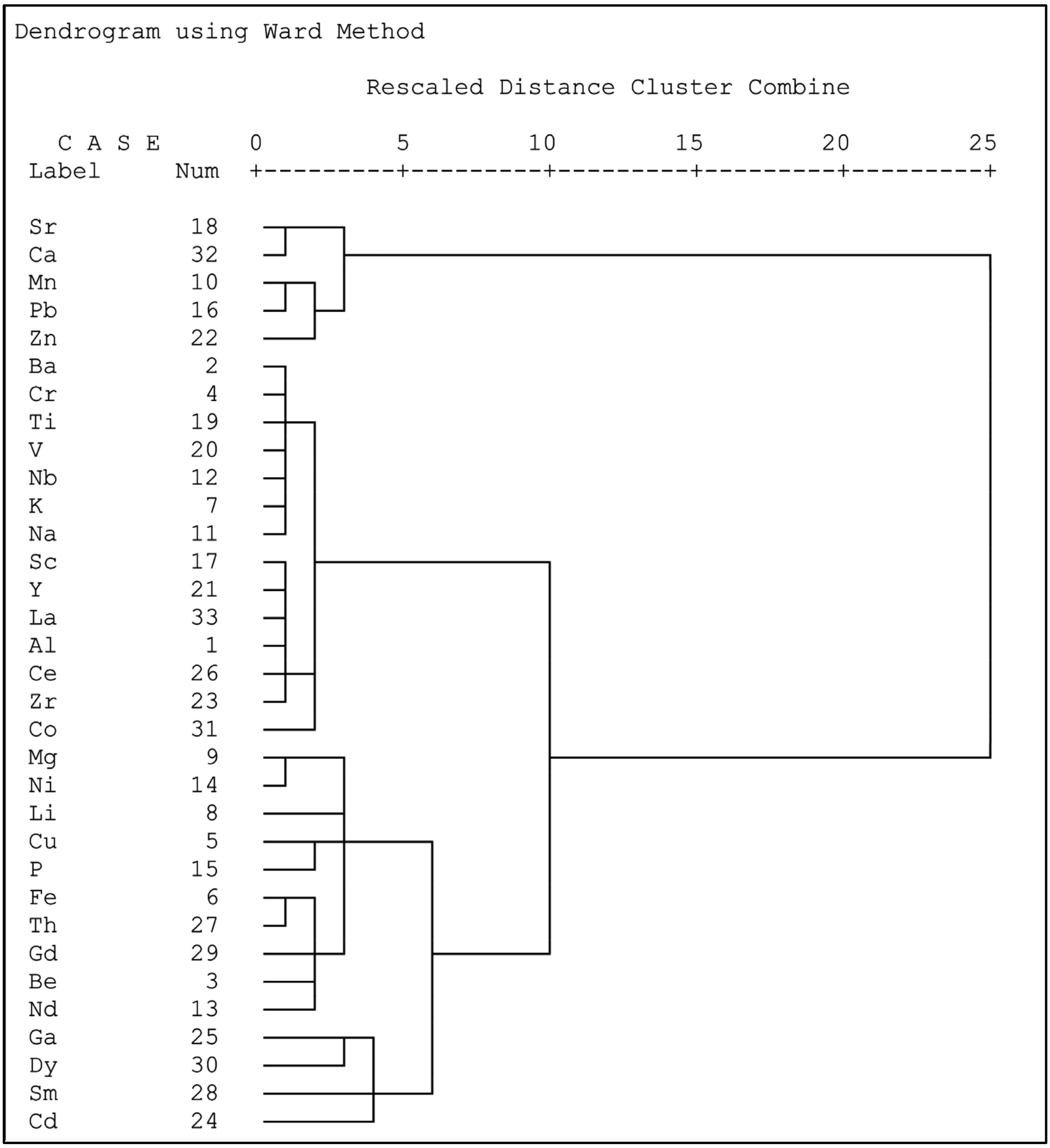


Figure 6. Dendrogram using Ward Method illustrating the relationship of elements in the study area.

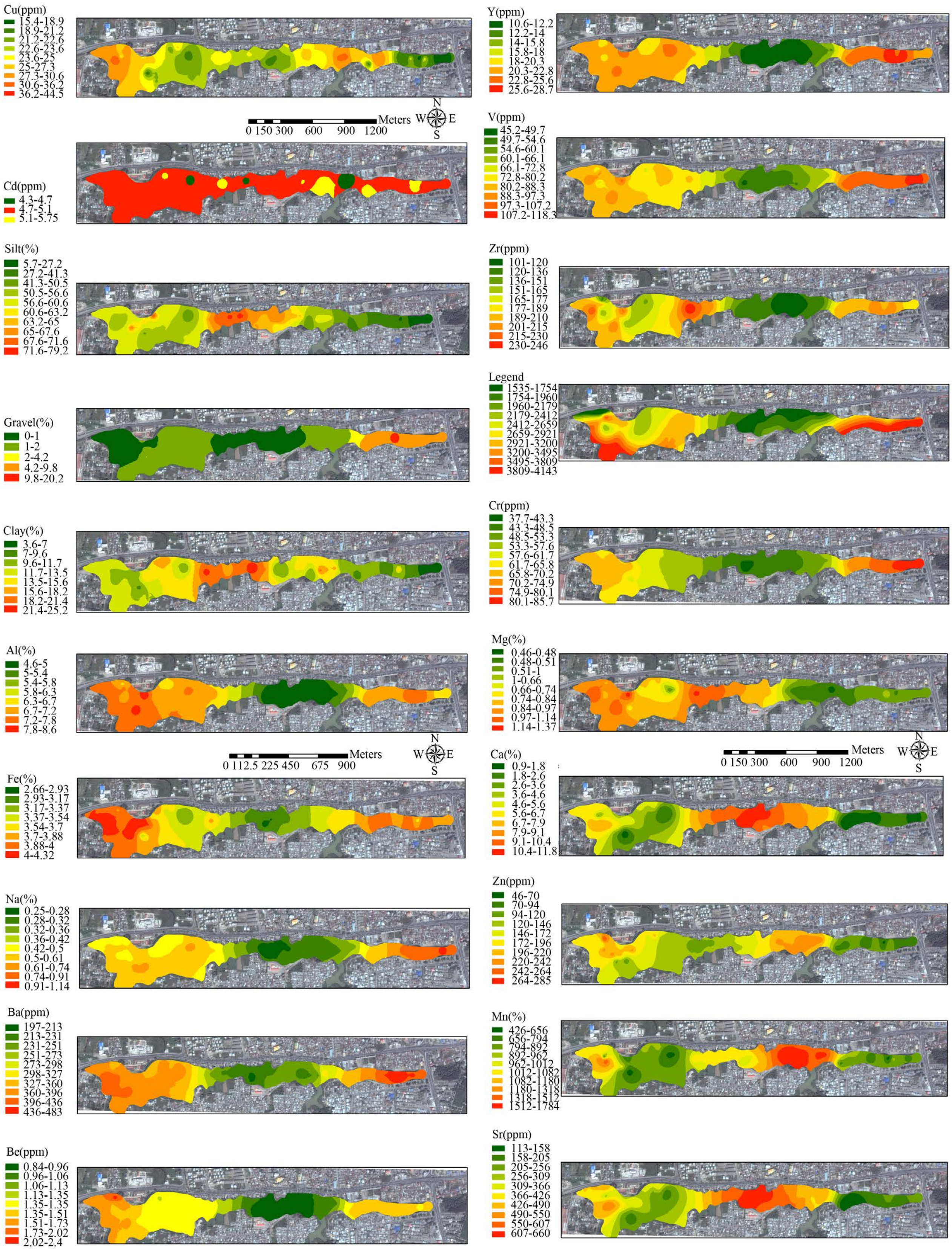


Figure 7. Contour plots showing the distribution of sediment composition along the study area.

Table 1. Spearman correlation coefficient matrix for elements in the marsh sediments.

	Al	Ba	Be	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Nb	Nd	Ni	P	Pb	Sc	Sr	Ti	V	Y	Zn	Zr	Cd	Ga	Ce	Th	Sm	Gd	Dy	Co	Ca
Al	1																															
Ba	0.77	1																														
Be	0.87	0.66	1																													
Cr	0.78	0.82	0.79	1																												
Cu	0.21	0.06	0.28	0.23	1																											
Fe	0.66	0.52	0.69	0.78	0.55	1																										
K	0.84	0.80	0.79	0.76	−0.09	0.46	1																									
Li	0.22	−0.02	0.15	0.09	0.33	0.30	0.10	1																								
Mg	0.36	0.03	0.46	0.20	0.31	0.33	0.35	0.36	1																							
Mn	−0.61	−0.56	−0.45	−0.43	0.43	0.01	−0.68	0.15	−0.04	1																						
Na	0.83	0.88	0.72	0.79	−0.14	0.46	0.89	−0.04	0.05	−0.73	1																					
Nb	0.84	0.72	0.82	0.82	0.14	0.65	0.87	0.15	0.31	−0.54	0.84	1																				
Nd	0.55	0.35	0.53	0.43	0.27	0.49	0.40	0.22	0.39	−0.22	0.37	0.46	1																			
Ni	0.71	0.34	0.74	0.55	0.60	0.74	0.43	0.38	0.70	−0.08	0.32	0.52	0.53	1																		
P	0.49	0.35	0.51	0.47	0.59	0.65	0.12	0.18	0.26	0.02	0.19	0.31	0.33	0.68	1																	
Pb	−0.59	−0.39	−0.52	−0.41	0.32	−0.10	−0.61	0.01	−0.07	0.75	−0.64	−0.54	−0.26	−0.17	0.03	1																
Sc	0.97	0.76	0.84	0.82	0.17	0.66	0.80	0.17	0.23	−0.62	0.83	0.83	0.50	0.65	0.46	−0.62	1															
Sr	−0.76	−0.72	−0.63	−0.70	0.13	−0.39	−0.70	0.09	0.17	0.74	−0.87	−0.72	−0.31	−0.25	−0.26	0.62	−0.84	1														
Ti	0.88	0.83	0.83	0.89	0.05	0.65	0.90	0.10	0.16	−0.61	0.93	0.93	0.47	0.48	0.31	−0.59	0.91	−0.85	1													
V	0.88	0.78	0.83	0.87	0.07	0.63	0.86	0.09	0.14	−0.64	0.89	0.89	0.51	0.50	0.35	−0.62	0.92	−0.87	0.97	1												
Y	0.96	0.78	0.82	0.75	0.07	0.53	0.84	0.09	0.18	−0.69	0.88	0.82	0.49	0.56	0.37	−0.66	0.97	−0.86	0.91	0.90	1											
Zn	−0.35	−0.27	−0.25	−0.22	0.52	0.16	−0.59	0.15	0.00	0.67	−0.52	−0.42	−0.07	0.12	0.39	0.65	−0.39	0.53	−0.49	−0.48	−0.49	1										
Zr	0.84	0.59	0.83	0.71	0.09	0.56	0.88	0.25	0.52	−0.51	0.72	0.82	0.47	0.62	0.22	−0.56	0.83	−0.60	0.84	0.81	0.83	−0.55	1									
Cd	0.08	−0.04	0.02	−0.08	−0.10	−0.10	0.02	0.05	−0.12	−0.12	0.03	0.02	−0.01	−0.08	0.10	−0.29	0.05	−0.06	0.02	0.10	0.06	−0.09	−0.02	1								
Ga	0.46	0.40	0.40	0.35	−0.02	0.22	0.47	0.03	0.08	−0.31	0.42	0.42	0.16	0.23	0.08	−0.32	0.43	−0.36	0.44	0.43	0.49	−0.44	0.49	0.18	1							
Ce	0.83	0.67	0.77	0.61	−0.04	0.35	0.80	0.16	0.20	−0.64	0.82	0.76	0.43	0.41	0.21	−0.68	0.80	−0.75	0.81	0.78	0.87	−0.52	0.75	0.14	0.42	1						
Th	0.67	0.43	0.61	0.65	0.35	0.82	0.46	0.41	0.32	−0.13	0.44	0.60	0.57	0.70	0.59	−0.28	0.65	−0.37	0.58	0.60	0.55	0.05	0.55	0.09	0.22	0.42	1					
Sm	−0.08	−0.07	−0.04	0.04	0.03	0.18	−0.14	−0.22	−0.27	0.22	−0.04	0.03	−0.01	−0.09	0.05	0.05	−0.01	−0.03	−0.01	0.00	−0.02	0.00	−0.09	−0.18	0.14	−0.08	0.14	1				
Gd	0.64	0.63	0.57	0.65	0.41	0.65	0.53	0.02	0.12	−0.20	0.53	0.59	0.33	0.49	0.41	−0.14	0.66	−0.49	0.64	0.61	0.61	−0.07	0.51	−0.13	0.30	0.45	0.37	0.17	1			
Dy	0.32	0.33	0.33	0.40	0.05	0.25	0.26	−0.18	0.08	−0.24	0.26	0.21	0.01	0.24	0.27	−0.14	0.33	−0.28	0.27	0.28	0.35	−0.06	0.28	−0.05	0.22	0.21	0.19	−0.01	0.39	1		
Co	0.76	0.55	0.72	0.71	0.15	0.63	0.67	0.19	0.20	−0.40	0.69	0.78	0.39	0.56	0.32	−0.49	0.77	−0.68	0.79	0.79	0.73	−0.33	0.72	0.06	0.35	0.64	0.60	0.03	0.52	0.18	1	
Ca	−0.73	−0.76	−0.60	−0.69	0.17	−0.36	−0.69	0.18	0.23	0.75	−0.88	−0.68	−0.29	−0.19	−0.26	0.61	−0.79	0.98	−0.82	−0.84	−0.83	0.49	−0.53	−0.05	−0.34	−0.72	−0.35	−0.02	−0.48	−0.29	−0.60	1
La	0.94	0.82	0.82	0.80	0.08	0.59	0.85	0.10	0.14	−0.68	0.91	0.85	0.47	0.52	0.38	−0.66	0.96	−0.88	0.94	0.92	0.97	−0.48	0.81	0.08	0.47	0.83	0.55	−0.06	0.65	0.33	0.76	−0.85

Table 2. (a) (b) Element composition in the sediment samples of Eynak marsh.

(a)

Sample	LI ppm	Sc ppm	Cd ppm	Pb ppm	Cr ppm	Co ppm	Ni ppm	Cu ppm	Ga ppm	Y ppm	Nb ppm	Pb ppm	Th ppm	U ppm	Be (ppm)	Ge (ppm)
ES-01	<20.0	17.5	5.00	30.1	82.4	15.5	26.9	24.2	17.4	31.6	12.5	30.1	12.5	<20.0	1.63	<5.00
ES-02	34.9	17.3	5.00	33.5	85.7	17.0	27.3	27.8	18.3	32.2	15.3	33.5	14.2	<20.0	1.69	<5.00
ES-03	<20.0	11.3	5.01	30.9	84.4	13.9	11.0	10.0	11.2	18.8	13.3	30.9	10.4	<20.0	1.21	<5.00
ES-04	<20.0	13.8	5.08	23.2	78.7	16.1	19.0	12.8	16.1	23.1	16.3	23.2	<10.0	<20.0	1.38	<5.00
ES-05	<20.0	12.3	5.90	<20.0	77.1	12.4	15.7	13.7	22.3	23.0	10.9	<20.0	10.0	<20.0	1.29	<5.00
ES-06	<20.0	16.3	5.10	<20.0	80.8	18.6	26.1	44.6	16.6	26.0	12.6	<20.0	12.5	<20.0	1.57	<5.00
ES-07	<20.0	15.7	5.80	<20.0	61.9	16.8	24.1	15.0	21.1	26.2	12.3	<20.0	10.8	<20.0	1.46	<5.00
ES-08	<20.0	9.19	4.00	39.8	51.0	13.6	21.1	21.7	<10.0	12.9	5.89	39.8	11.1	<20.0	0.98	<5.00
ES-09	21.2	8.86	3.30	58.5	49.2	11.1	23.2	37.4	15.8	12.7	7.54	58.5	<10.0	<20.0	0.99	<5.00
ES-10	<20.0	8.73	5.40	37.2	48.6	12.9	18.8	36.4	<10.0	12.7	6.91	37.2	<10.0	<20.0	0.99	<5.00
ES-11	21.5	8.18	6.10	45.8	49.5	13.4	21.2	25.3	14.0	11.5	7.03	45.8	<10.0	<20.0	0.98	<5.00
ES-12	27.1	7.43	5.70	36.7	42.3	13.1	18.5	21.6	15.4	9.60	5.16	36.7	10.4	<20.0	0.89	<5.00
ES-13	<20.0	7.85	6.60	49.8	48.4	11.4	18.8	22.9	11.9	10.6	6.79	49.8	<10.0	<20.0	0.89	<5.00
ES-14	<20.0	8.00	3.60	32.7	45.8	10.9	17.3	22.9	<10.0	10.2	<5.00	32.7	<10.0	<20.0	0.87	<5.00
ES-15	<20.0	8.13	5.70	41.2	47.6	13.2	20.0	29.6	12.2	11.7	7.73	41.2	<10.0	<20.0	0.90	<5.00
ES-16	<20.0	7.56	4.20	38.3	42.2	11.2	19.3	21.8	15.4	11.3	8.30	38.3	<10.0	<20.0	0.91	<5.00
ES-17	<20.0	8.03	4.50	34.7	48.8	12.6	19.8	21.5	12.4	11.8	7.87	34.7	10.9	<20.0	0.94	<5.00
ES-18	<20.0	7.49	5.00	33.2	41.8	11.0	19.9	19.9	17.2	10.8	<5.00	33.2	<10.0	<20.0	0.95	<5.00
ES-19	<20.0	8.33	5.10	36.6	42.7	11.2	23.3	24.8	12.9	11.9	5.22	36.6	<10.0	<20.0	1.01	<5.00
ES-20	21.6	6.56	5.90	32.8	37.7	10.4	16.4	17.8	11.7	8.97	<5.00	32.8	<10.0	<20.0	0.85	<5.00
ES-21	20.9	9.11	4.00	34.6	46.5	8.22	21.5	24.1	11.3	13.4	8.89	34.6	<10.0	<20.0	1.11	<5.00
ES-22	<20.0	10.5	5.30	31.3	50.0	15.2	26.0	23.5	14.0	17.3	8.72	31.3	<10.0	<20.0	1.20	<5.00
ES-23	32.0	10.8	5.70	36.4	52.3	13.6	22.9	24.6	15.3	17.5	10.0	36.4	<10.0	<20.0	1.30	<5.00
ES-24	40.3	12.8	5.00	29.3	60.8	15.5	28.6	24.7	18.9	21.0	11.7	29.3	12.0	<20.0	1.41	<5.00
ES-25	<20.0	12.5	3.90	33.6	56.8	13.5	22.4	22.6	12.0	25.3	10.3	33.6	<10.0	<20.0	1.36	<5.00
ES-26	<20.0	13.6	5.00	20.9	48.0	13.3	18.5	15.9	15.8	26.6	9.18	20.9	<10.0	<20.0	1.25	<5.00
ES-27	<20.0	13.0	5.40	25.5	58.6	13.2	21.9	22.3	13.3	23.7	8.97	25.5	<10.0	<20.0	1.21	<5.00
ES-28	<20.0	11.1	4.00	38.8	58.5	13.8	24.8	27.8	13.1	18.1	11.4	38.8	10.4	<20.0	1.32	<5.00
ES-29	<20.0	10.8	5.90	35.2	59.5	15.0	20.9	19.7	11.5	17.0	8.22	35.2	<10.0	<20.0	1.15	<5.00
ES-30	<20.0	11.4	5.00	40.9	59.7	12.0	28.5	25.3	11.0	17.6	9.43	40.9	10.7	<20.0	1.27	<5.00
ES-31	27.5	12.5	5.00	25.2	56.1	12.5	25.6	24.2	<10.0	20.5	7.29	25.2	10.7	<20.0	1.16	<5.00
ES-32	<20.0	11.9	5.00	39.4	65.9	11.7	25.2	26.0	21.5	19.7	9.72	39.4	11.9	<20.0	1.20	<5.00
ES-33	23.4	16.3	5.00	31.3	76.3	16.7	41.8	27.8	14.3	24.1	12.9	31.3	13.7	<20.0	1.72	<5.00
ES-34	20.1	12.8	5.00	35.5	67.3	16.1	30.3	26.1	11.6	20.8	10.9	35.5	12.3	<20.0	1.35	<5.00
ES-35	38.3	12.2	5.00	30.6	62.8	14.3	27.7	25.8	11.9	19.3	11.2	30.6	13.0	<20.0	1.35	<5.00
ES-36	42.8	15.3	5.00	35.6	77.1	15.4	35.4	40.5	20.1	24.7	11.2	35.6	13.2	<20.0	1.65	<5.00
ES-37	<20.0	13.1	5.00	29.5	69.5	15.0	26.2	22.1	16.2	22.6	10.0	29.5	10.5	<20.0	1.39	<5.00
ES-38	25.6	13.9	5.00	27.7	77.4	14.2	34.9	36.7	11.9	21.8	13.5	27.7	12.9	<20.0	1.51	<5.00
ES-39	<20.0	15.4	5.00	<20.0	69.5	15.8	35.4	26.6	16.6	26.8	13.6	<20.0	12.0	<20.0	1.90	<5.00
ES-40	<20.0	11.3	5.00	26.0	56.8	14.3	21.5	16.5	20.0	21.1	10.9	26.0	<10.0	<20.0	1.22	<5.00
ES-41	<20.0	10.3	5.00	29.1	62.2	13.8	26.0	26.7	12.8	17.0	9.53	29.1	10.3	<20.0	2.90	<5.00
ES-42	<20.0	10.7	5.00	47.1	74.9	12.0	24.6	31.5	15.5	16.9	6.90	47.1	<10.0	<20.0	1.25	<5.00
ES-43	<20.0	11.3	5.00	34.0	57.2	12.2	25.7	20.7	12.7	18.9	9.03	34.0	10.1	<20.0	1.80	<5.00
ES-44	21.9	15.6	5.00	23.6	62.4	15.4	29.0	22.7	15.8	27.9	10.0	23.6	11.3	<20.0	1.46	<5.00

(a)

Sample	La ppm	Ce ppm	Nd ppm	Sm ppm	Gd ppm	Dy ppm	Er ppm	Yb ppm	Al (%)	K (%)	Mg (%)	Na (%)	Mn ppm	Zn ppm	Ti ppm	V ppm	Fe (%)	Sr ppm	Zr ppm	P ppm	Ba ppm	Ca (%)
ES-01	31.0	50.0	29.1	5.82	4.87	3.29	<5.00	<5.00	7.85	1.56	0.57	0.67	958	119	3694	105	4.21	185	213	843	443	1.88
ES-02	29.8	65.4	31.1	8.00	5.75	8.55	<5.00	<5.00	8.48	1.42	0.58	0.71	949	123	3859	109	4.31	190	212	874	473	2.05
ES-03	25.0	32.4	31.0	<5.00	3.87	2.73	<5.00	<5.00	6.12	1.78	0.55	1.14	729	52.8	4143	118	3.79	209	185	483	448	1.54
ES-04	25.4	57.3	28.6	8.23	4.92	<2.00	<5.00	<5.00	6.97	1.49	0.55	0.89	614	65.6	3790	106	3.73	176	200	551	401	1.63
ES-05	24.3	51.6	23.9	<5.00	3.58	9.79	<5.00	<5.00	7.09	1.72	0.48	1.07	524	46.6	3224	93.1	3.31	229	193	529	483	1.80
ES-06	29.1	47.4	29.0	11.9	4.73	4.50	<5.00	<5.00	7.80	1.16	0.52	0.48	830	72.7	3447	107	4.37	114	201	1057	342	1.08
ES-07	30.4	46.2	23.9	<5.00	3.89	4.40	<5.00	<5.00	7.63	1.37	0.49	0.59	712	66.2	3492	106	3.83	131	202	839	362	0.99
ES-08	14.7	27.8	28.9	5.95	3.57	<2.00	<5.00	<5.00	5.25	0.79	0.47	0.30	1624	247	2029	61.0	3.65	461	125	619	237	7.07
ES-09	16.1	22.3	27.6	<5.00	4.16	<2.00	<5.00	<5.00	5.17	0.74	0.50	0.32	1628	244	2060	58.6	3.53	493	123	632	359	8.26
ES-10	15.6	33.3	26.0	<5.00	3.93	2.93	<5.00	<5.00	4.83	0.75	0.49	0.29	1382	237	2087	62.5	3.59	412	120	627	218	6.56
ES-11	15.0	21.2	25.4	<5.00	4.20	8.66	<5.00	<5.00	4.79	0.74	0.51	0.27	1708	261	1935	55.2	3.70	488	114	691	226	8.44
ES-12	11.8	26.1	23.0	10.2	2.94	2.02	<5.00	<5.00	4.50	0.68	0.47	0.27	1589	210	1776	60.0	3.32	490	101	691	198	8.15
ES-13	13.9	15.9	23.7	5.84	3.16	<2.00	<5.00	<5.00	4.58	0.63	0.50	0.30	1770	256	1862	52.8	3.43	543	110	660	235	9.03
ES-14	13.9	13.6	25.7	12.6	4.10	<2.00	<5.00	<5.00	4.58	0.62	0.49	0.28	1680	219	1737	49.5	3.38	548	102	634	232	8.73
ES-15	13.4	18.1	24.6	5.36	3.30	<2.00	<5.00	<5.00	4.61	0.74	0.52	0.29	1784	238	1865	51.8	3.34	558	110	668	238	9.30
ES-16	12.4	28.3	26.5	9.53	3.33	2.68	<5.00	<5.00	4.66	0.80	0.79	0.25	1096	171	1744	52.0	2.90	653	128	655	227	11.3
ES-17	15.1	29.3	26.3	<5.00	3.11	2.96	<5.00	<5.00	5.09	0.87	0.71	0.35	1059	183	1934	49.0	3.40	587	132	651	252	9.27
ES-18	12.9	26.5	27.4	<5.00	2.55	<2.00	<5.00	<5.00	4.62	0.86	0.82	0.25	982	151	1688	49.6	2.85	661	129	632	215	11.1
ES-19	14.4	19.6	30.0	<5.00	3.66	3.65	<5.00	<5.00	5.05	0.88	0.90	0.23	1055	148	1826	59.8	3.01	598	146	602	212	10.1
ES-20	12.5	20.2	24.8	<5.00	2.51	<2.00	<5.00	<5.00	4.27	0.79	0.71	0.21	919	143	1535	45.2	2.66	655	115	586	198	11.9
ES-21	14.8	30.7	25.7	<5.00	3.17	<2.00	<5.00	<5.00	5.56	1.05	0.94	0.27	1007	120	1957	58.0	3.10	589	169	591	214	9.84
ES-22	15.9	26.8	26.2	<5.00	4.06	9.35	<5.00	<5.00	6.02	1.11	1.10	0.33	1028	112	2266	68.8	3.29	521	210	573	218	9.45
ES-23	20.0	37.7	26.6	<5.00	3.68	<2.00	<5.00	<5.00	6.43	1.28	1.14	0.39	1041	106	2549	72.0	3.58	449	219	603	234	8.30
ES-24	24.0	53.2	29.9	<5.00	3.57	<2.00	<5.00	<5.00	7.29	1.41	1.26	0.54	1095	106	3001	85.4	4.00	365	247	680	276	7.12
ES-25	27.2	61.4	27.1	<5.00	4.54	6.77	<5.00	<5.00	7.32	1.38	0.56	0.74	596	149	2974	81.5	3.23	225	177	931	417	1.99
ES-26	27.9	57.1	30.5	<5.00	4.06	2.95	<5.00	<5.00	7.64	1.42	0.49	0.74	561	89.1	2829	84.3	2.91	200	184	631	408	1.30
ES-27	23.8	51.3	27.4	<5.00	3.74	7.45	<5.00	<5.00	7.06	1.01	0.58	0.45	741	139	2456	81.9	3.09	205	171	784	347	2.31
ES-28	20.0	36.9	30.9	<5.00	3.87	<2.00	<5.00	<5.00	6.75	1.12	0.77	0.45	984	220	2550	81.4	3.79	343	168	1026	366	5.06
ES-29	19.2	28.0	22.8	<5.00	3.66	7.74	<5.00	<5.00	6.24	1.07	0.64	0.47	827	152	2383	67.6	3.32	265	148	746	373	3.82
ES-30	17.7	32.9	28.2	<5.00	4.47	4.66	<5.00	<5.00	6.44	1.05	0.85	0.40	1011	217	2400	80.4	3.97	354	161	942	325	5.42
ES-31	20.4	42.3	30.2	<5.00	3.20	<2.00	<5.00	<5.00	6.54	0.94	0.59	0.40	741	164	2338	77.8	3.36	262	151	896	322	3.39
ES-32	20.3	21.0	30.6	10.4	4.37	9.73	<5.00	<5.00	6.95	1.04	0.77	0.43	1001	240	2414	74.4	4.23	368	165	975	359	5.40
ES-33	26.7	46.6	29.5	<5.00	4.91	9.58	<5.00	<5.00	8.89	1.56	1.37	0.53	728	223	2960	105	4.86	348	220	828	406	5.50
ES-34	21.4	37.0	28.6	<5.00	3.91	<2.00	<5.00	<5.00	7.49	1.27	0.93	0.47	1006	225	2906	82.4	4.21	368	189	955	361	5.71
ES-35	21.7	52.4	32.8	<5.00	4.09	8.16	<5.00	<5.00	7.23	1.20	1.01	0.43	1084	242	2698	78.1	4.09	473	178	881	360	7.19
ES-36	26.3	50.3	33.0	<5.00	5.53	<2.00	<5.00	<5.00	8.64	1.56	1.20	0.51	1302	184	3333	101	4.90	394	224	1034	454	6.34
ES-37	25.3	46.3	32.3	<5.00	4.86	3.97	<5.00	<5.00	7.64	1.34	0.80	0.66	796	136	3005	94.1	4.05	296	177	844	389	3.31
ES-38	25.6	37.0	26.1	<5.00	4.73	2.75	<5.00	<5.00	7.81	1.39	0.98	0.55	986	285	3234	95.6	4.46	369	184	1055	398	5.60
ES-39	28.0	62.9	30.9	16.3	5.61	4.17	<5.00	<5.00	8.81	1.78	1.19	0.76	805	94.5	3508	105	4.43	288	219	747	437	3.77
ES-40	24.4	57.0	23.0	<5.00	3.85	<2.00	<5.00	<5.00	7.23	1.46	0.63	0.75	463	80.0	2695	79.8	3.04	210	159	505	383	1.43
ES-41	17.7	37.5	31.6	<5.00	3.09	2.03	<5.00	<5.00	6.17	1.03	0.81	0.39	1041	284	2381	79.5	3.64	412	147	902	321	6.36
ES-42	18.4	28.7	22.7	<5.00	4.49	9.78	<5.00	<5.00	6.03	1.10	0.74	0.39	1529	239	2296	63.5	3.89	493	159	985	446	7.33
ES-43	18.8	43.9	26.5	7.23	3.84	9.32	<5.00	<5.00	6.40	1.21	1.00	0.41	1051	178	2454	72.6	3.78	404	190	821	307	6.33
ES-44	27.2	46.7	32.6	<5.00	3.41	4.05	<5.00	<5.00	8.07	1.34	0.90	0.60	634	137	3001	92.4	4.06	248	202	802	367	3.06

heavy minerals in fine grain size fraction. Aluminum (Al) is the major element of sediments mostly influenced by human activities and upstream feldspathic rocks (ranging 4.2% - 8.8%) (**Figure 7**). After that Ca (0.9% - 11.8%), Fe (2.6% - 4.9%), K (0.6 - 1.7), Mg (0.4 - 1.3), and Na (0.2 - 1.1) are the most common elements in the area. On the other hand, an important enrichment of Ca along with Fe, K, Mg, etc. indicating a proper situation for deposition of these elements.

There are significant correlations among variety of elements through the marsh sediments. As an instance Al versus Ba, Be, Cr, Fe, K, Na, Ni, and Ti displayed significant correlations. On the opposite, Al versus Ca, Mg and Mn showed negative correlations. On the other side, there are no significant correlation in some elements versus others such as Li, Cu, P, Zn, and etc. Besides, fine grained sediments, which are the fundamental sediment components, showed significant correlations with Ca, Mn, Sr and Mg indicating identical sources and the predominant associations of these elements with clay minerals [33]. High values for Mn concentration was observed (ranged in 462 - 1784 ppm average 1037 ppm) and it showed a significant correlation with Ca, Sr and Mg. If Mn could remobilize to the water column, it would be found in low values in the sediments [35]. So, a redox condition and constantly calm hydrodynamic circumstance in Eynak marsh, likely causes high concentration of these elements. Besides, it represents negative correlations versus some elements such as Al, Be, Fe, K, Na, and etc. **Figure 7** summarizes the spatial distributions of some elements in surface sediments. According to these maps, some elements such as Al, Na, Be, Fe, Ba, Y, Zr, V, Sc, Cr, and Ti displayed similar patterns. It means that, an obvious increase of element values in the middle and also its depletion into the west and east side of the marsh has been observed. Unlikely, Mg, Ca, Zn, Sr and Mn presented a distribution in which values were low at the western side then increased locally, decreased again and finally showed higher concentration eastward. Moreover, Cu and Cd were highly irregular and it may depend on human activities or garbage dump to the marsh.

Pb concentration varies between 20 ppm and 58.5 ppm averaged at 34.4 ppm in the surface sediments. Its concentration showed a significant correlation with Ca and Sr. Zn values ranged from 46.6 ppm to 285 ppm with the average 168 ppm and it did not represent any correlation with the other elements. The low concentration of Zn in the eastern side is preferably attributed to the remobilization of trace elements in the water column during the change in bioturbation before reaching the sediments [36]. Contrary to Sr, Ca and Mg distribution pattern, some elements like Sc, Y, V, Ba, Be, etc. showed a different trend. Therefore, it could indicate the same sources among each group of these elements and mechanism controlling the pattern.

The positive association among Fe and Mn proposing a common detrital origin and a relevant transporting phase for the grains [37]. Regarding Mn and Fe to be the vitally important scavengers for trace metals [38] [39], trace elements like La, Gd, Th and Y showed a positive correlation with Fe. Ni distribution along the marsh decreases westward and it may be attributed to the high density of this elements and its tendency to immobilization.

In order to improve our understanding of the main sediment sources in Eynak marsh, we compared its composition to Kiakelaye marsh (located in southeast of Eynak, 70 Km away from Eynak marsh) using discrimination diagram suggested by [40]. Discrimination diagram (**Figure 8**) are more useful to evaluate dependence to geochemical end-members in the region and compare them with each other [40]. Sediments from Eynak marsh have Sc-Th-Cr compositions similar to what we have in Kiakelaye, representing Cr enrichment in sediments. Moreover, increasing Cr values in distribution maps suggest the upstream as a main source for the sediments and Chromium. Also Cr concentration strongly reveals that Cr-bearing minerals such as pyroxene have been deposited in the marsh and it has been proofed by mineralogy results (**Table 3**). Furthermore, due to the depletion of Sc in the sediments, it could not be said that the ultramafic xenolith is the probable source rock for the sediments. Moreover, Sc-Th-La indicates an enrichment of La in Eynak marsh in comparison with Kiakelaye. So this increase in La may come from a batholith-type composition in the domain area.

5. Discussion

Considering granulometric data, its predominant grains composed by coarse sand and medium silt (**Figure 3**, **Figure 4** and **Figure 7**) and it represented a low energy hydrodynamic circumstance in the marsh. A few gravels in sediments considered mostly as a gastropod shell remnants (**Figure 3**). Textural and statistical parameters proved the predominant fluvial origin of sediments (**Figure 5**). It means the probable origin of sediments is mostly related to fluvial input that have precipitated in the past. Regarding the cut off occurrence between

Table 3. The summary of mineralogical data in 44 surficial sediments in the study area.

Sample	Major	Minor	Trace
Es-01	Quartz + Feldspars (Microcline + Anorthoclase + Anorthite)	Calcite	Chamosite + Mica (Lepidolite)
Es-02	Quartz + Feldspars (Anorthite + Sanidine)	Pyroxene (Wollastonite) + Mica (lepidolite)	Chlorite (Clinochlore)
Es-03	Quartz + Feldspars (Anorthite + Sanidine).	-	-
Es-04	Quartz + Feldspars (Anorthite + Sanidine)	Calcite + Mica (Muscovite + Lepodolite)	Pyroxene (Enstatite)
Es-05	Quartz + Feldspars (Albite + Orthoclase)	Pyroxene (Diopside)	Mica (Muscovite)
Es-06	Quartz + Feldspars (Anorthite)	Mica (Muscovite)	Clay Minerals (Nacrite)
Es-07	Quartz + Feldspars (Albite)	Mica (Muscovite)	-
Es-08	Calcite + Quartz	Pyrite + Halite + Gypsum	Feldspars (Anorthoclase) + Mica (Muscovite)
Es-09	Calcite + Quartz	Pyrite + Gypsum	Feldspars (Albite + Sanidine) + Mica (Muscovite)
Es-10	Calcite + Quartz	Olivine (Fayalite) + Gypsum + Talc + Mica (Muscovite)	Feldspars (Sanidine + Albite) + Pyrite
Es-11	Calcite	Quartz + Feldspars (Anorthite + Sanidine)	Bornite + Mica (Muscovite)
Es-12	Calcite	Quartz + Gypsum + Pyrite + Feldspars (Sanidine + Albite)	Mica (Muscovite) + Chlorite (Clinochlore)
Es-13	Calcite + Quartz	Pyrite + Feldspars (Anorthite + Sanidine)	Mica (Muscovite) + Hematite.
Es-14	Calcite + Quartz	Pyrite + Gypsum	Feldspars (Anorthite + Sanidine) + Mica (Muscovite)
Es-15	Calcite + Quartz	Feldspars (Anorthite) + Pyroxene (Enstatite) + Gypsum + Pyrite	+ Mica (Muscovite)
Es-16	Calcite + Quartz	Pyrite + Feldspars (Albite + Sanidine)	Mica (Muscovite) + Chlorite (Chloritoid)
Es-17	Calcite + Quartz	Pyrite +Feldspars (Albite + Sanidine) + Gypsum	Mica (Muscovite)
Es-18	Calcite + Quartz	Feldspars (Albite) + Mica (Muscovite) + Pyrite.	-
Es-19	Calcite + Quartz	Pyrite + Feldspars (Albite + Sanidine)	Mica (Muscovite)
Es-20	Calcite	Quartz + Pyrite	-
Es-21	Calcite + Quartz	Pyrite + Feldspars (Anorthite + Sanidine)	Mica (Muscovite)
Es-22	Calcite + Quartz	Mica (Muscovite) + Feldspars (Anorthite + Orthoclase)	Gypsum + Pyrite + Pyroxene (Enstatite)
Es-23	Calcite + Quartz	Feldspars (Anorthite) + Pyrite	Pyroxene (Enstatite) + Mica (Muscovite)
Es-24	Quartz + Calcite	Feldspars (Anorthite) + Mica (Muscovite)	Pyroxene (Enstatite) Chlorite (Clinochlore)
Es-25	Quartz + Feldspars (Anorthite + Orthoclase)	Mica (Muscovite)	Chlorite (Chamosite) + Pyrite
Es-26	Quartz + Feldspars (Albite + Microcline)	Pyroxene (Enstatite)	Mica (Lepidolite + Muscovite)
Es-27	Quartz +Calcite	Feldspars (Albite + Sanidine)	Pyroxene (Enstatite) + Pyrite + Mica (Muscovite)
Es-29	Quartz +Calcite + Feldspars (Albite)	Pyroxene (Enstatite) + Pyrite	Mica (Muscovite)
Es-30	Calcite + Quartz + Pyrite + Feldspars (Anorthite + Sanidine)	Gypsum + Mica (Muscovite)	Chlorite (Clinochlore)
Es-31	Quartz + Calcite	Feldspars (Anorthite + Sanidine)	Mica (Muscovite) + Pyrite
Es-32	Quartz + Calcite	Pyrite + Feldspars (Albite + Sanidine)	Mica (Muscovite)

Continued

Es-33	Quartz + Calcite	Pyrite + Gypsum	Mica (Muscovite) + Feldspars (Anorthite + Sanidine)
Es-34	Quartz + Calcite	Pyrite + Halite + Pyroxene (Enstatite)	Feldspars (Albite + Sanidine) + Chlorite (Clinochlore) + Mica (Muscovite)
Es-35	Quartz + Calcite + Feldspars (Anorthite + Sanidine)	Pyrite + Gypsum + Mica (Muscovite)	Chlorite (Chamosite) + Clay Minerals (Kaolinite) + Pyroxene (Enstatite)
Es-36	Quartz + Calcite + Feldspars (Albite)	Gypsum + Pyrite	Chlorite (Clinochlore) + Mica (Muscovite)
Es-37	Quartz + Calcite + Feldspars (Albite + Orthoclase)	Pyroxene (Enstatite) + Pyrite	Chlorite (Clinochlore) + Mica (Muscovite)
Es-38	Quartz + Calcite	Mica (Muscovite) + Feldspars (Albite + Sanidine)	Mica (Muscovite)
Es-39	Quartz + Calcite	Feldspars (Anorthite + Sanidine)	Pyrite + Mica (Muscovite)
Es-40	Quartz + Feldspars (Anorthite + Sanidine) + Calcite	Pyrite + Mica (Muscovite)	
Es-41	Calcite + Quartz + Feldspars (Anorthite + Sanidine)	Gypsum + Pyrite	Mica (Muscovite)
Es-42	Calcite + Quartz + Feldspars (Anorthite + Sanidine)	Gypsum	Pyrite + Mica (Muscovite)
Es-43	Quartz + Calcite + Feldspars (Anorthite)	Mica (Muscovite)	Pyrite.
Es-44	Quartz + Calcite + Feldspars (Albite + Sanidine)	Mica (Muscovite)	Pyrite.

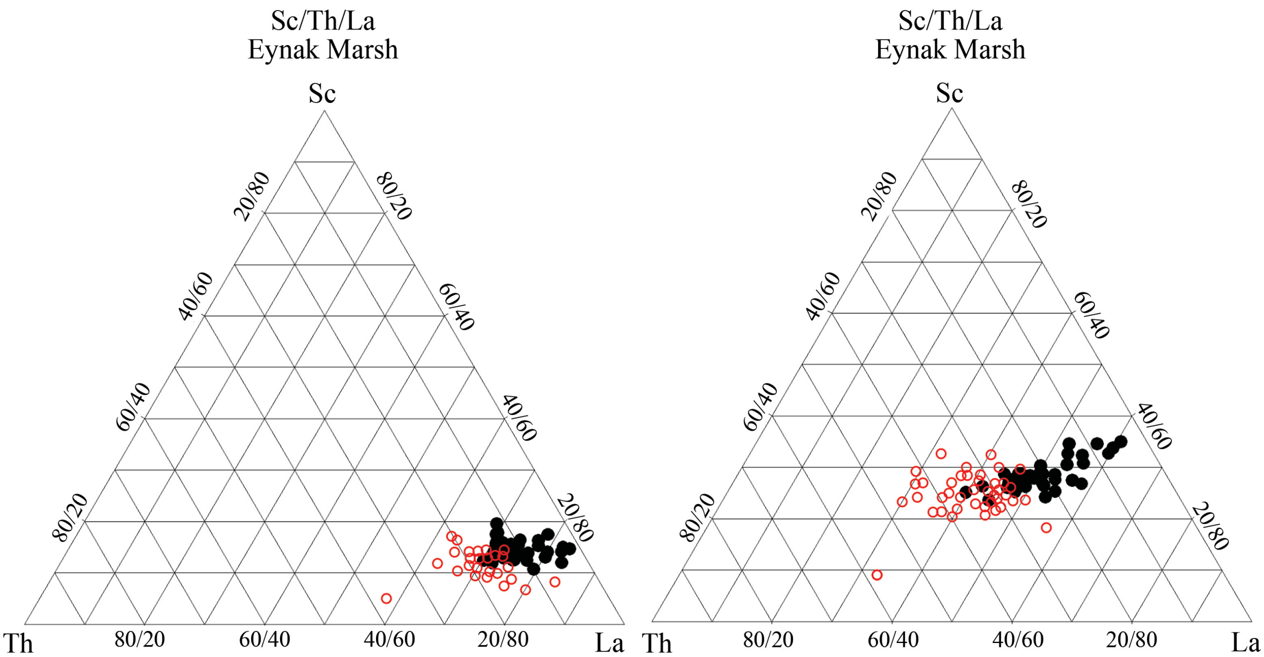


Figure 8. Discrimination diagram of Sc-Th-La and Sc-Th-Cr for surficial sediments of Eynak marsh (black dots related to Eynak marsh and red circles related to Kiakelaye).

GoharRood River and Eynak marsh, it is not nourished by the river anymore and it can be seen a very calm hydrodynamic condition in the marsh. In addition, another possible source of material could be organism shells (as instance Gastropoda) precipitated after the death. The continental shelf sediments are characterized by the high abundance of calcite derived from biogenic mechanism [23]. Moreover, due to the distance between marsh and Caspian Sea beach (more than 30 Km), and the low values of biogenic calcite; there are no possibility and documented proof supporting the idea of the coastal sediment source in Eynak marsh.

Due to the main mineral involved in surficial sediments like quartz, calcite, feldspar, pyrite mica and clay minerals, chemical elements are mostly related to terrigenous input. These minerals derived from continental sources and weathered rocks such as granite that are covering the land mass in the upstream. Since muscovite reflects the influence of metamorphic and igneous rocks as a source of clastic sediments [17], the existence of this mineral in the most corners of the marsh can be explained by the riverine supply from granitic rocks in the watershed. As a result, the increased abundance of biotite, muscovite and Chloritoid could be derived from igneous and metamorphic rocks weathering. Moreover, the high content of pyrite is supported by the high values of Fe detected there and this could be related to relict sediments enriched in pyrite in Gastropod infillings [41]. Some elements like Mg, Ca and Sr showed significant correlations with calcite distribution and it is mainly indicated by the substitution of these elements in calcite. Likely, Mg distribution shows a similar pattern, and mineralogy reported a dolomite increase to the east of Eynak marsh. Mn distribution pattern shows the maximum values in the inner part and the west side of the marsh. The existence of gypsum and pyrite in sediments could be mentioned as a proof for reduction condition in the inner side of the marsh. Considering its generation and chemical formula, the abundance of feldspars in west and east side should be related to the distribution of elements such as Al, Be, V, Na, Fe, etc.

Universally, one of the most important source of chrome to the marine environments is the household sewage and it contains about 32.2 percent of total chrome in marines [42]. Also cupper is an element which can enter the environment through waste water [43] [44]. Likely, sewage entrance in the west and east part of the marsh may cause the increasing trend of these elements to both west and east sides. Niobium can be siderophile, chalcophile, or lithophile [45], also it aggregates in Granites, Nepheline Syenite, Alkali granites, etc. [46]. So, the highest value of Nb in the east of the marsh as well as the majority of Quartz and Feldspars in there should be under the influence of granitic and alkali granite source rock of the domain area.

Nickel value changing pattern represented an increase trend westward. The major source of nickel exposure has a direct affiliation to organic matter [47]. Though, the entrance of organic and agricultural wastewater to the west side of the marsh could be a reason for high values of Ni in the area. As well as, Pb enrichment in the study area could be under the effects of anthropogenic activities around the marsh which has been conducted recently. Moreover, considering Spearman correlation coefficient of Mn versus Pb and Zn (showing a significant correlation), likely they should have similar sources.

6. Conclusions

Sedimentological, geochemical and mineralogical investigation was conducted in Eynak marsh to reconstruct the pathways of modern input from continental domain and also to find out the sediment generation. Surficial sediments integrate mineralogical, sedimentological and geochemical characteristics of the draining area by upstream and anthropogenic effects.

Textural investigations indicate that the sediments belong to the coarse sand to medium silt fractions suggesting that the sediments were deposited under calm or low energy condition. Moreover, sediments being poorly sorted to moderately sorted reveal texturally immature of a fluvial environment. The sedimentary fraction influences some elements fractionation in the surficial sediments. Distribution pattern of fine sediments is closer to Ca, Sr, and Mg pattern and it is supported by the correlation between fine grain sediments and these elements. Due to the depletion of fine grain sediment in clay minerals (which have a strong adsorption capacity), lower content of trace elements is reported from analyzed sediments. In another word, no correlation exists between the abundance of mud and concentration of some contaminations (like Fe, V, Ni, and Cr), making us believe that grain size cannot be used as a normalizer to assess contaminant sources in this area.

Mineral assemblages in sediments are truly controlled by source rocks of the domain area. The immature sediments of Eynak marsh with high feldspar relative to quartz could be classified as having an uplifted basement source. Normally, gypsum and pyrite indicate reduced environment. So the existence of these mineral along with calcite concentration represents a proper circumstance for such minerals. The chemical composition of the analyzed sediments is controlled by source composition, textural and mineralogy characteristics. The high amount of feldspar and quartz is supported by high value of Al, Fe, Na, K, etc. and decrease in Ca, Mg and Sr values representing the entrance of these minerals from east and west side of the marsh. The inner part of the marsh is characterized by presence of calcite, Pyrite and Gypsum and high concentration of Ca, Mg, Sr, etc. showing a reduction situation in the environment in which some minerals such as gypsum and pyrite representing higher amounts. In another word, higher pyrite content could be related to authigenic sources.

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