VOL. 12, NO. 7, APRIL 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

THE INTEGRATED EXPLORATION OF RAIFA LAKE SEDIMENTS AND DENDROCHRONOLOGICAL ANALYSIS OF RAIFA FORESTRY PINES

Kosareva L. R., Nurgalieva N. G., Frolova L. A., Gafiatullina L. I., Krylov P. S., Terekhin A. A., Tishin D. V., Batalin G. A., Gareev B. I., Kuzina D. M., Antonenko V. V. and Akhmerov R. D.
Kazan Federal University, Kremlyovskaya St., Kazan Republic of Tatarstan, Russian Federation
E-Mail: lina.kosareva@mail.ru

ABSTRACT

The article presents some results of comprehensive research on the properties of Raifa lake bottom sediments and dendrochronological study of Raifa forestry pines (Russia). A preliminary seismic acoustic investigations have been carried out, which allowed to select the sampling site (E 48 ° 43'40.6" N 55 ° 54'21.7"). The length of core sample was 32 cm. Laboratory studies of the core, including the study of the elemental composition, magneto-mineralogical and carcinologic analysis revealed the features of sedimentation mass formation.

Keywords: lacustrine sediments, paleolimnology, paleoclimate, seismic acoustic studies, elemental composition, magnetic properties, carcinologic analysis, dendrochronological analysis.

1. INTRODUCTION

Paleoclimate is currently an interesting area of scientific research related to understanding the processes and causes of climate change in the past, which in turn makes it possible to accurately predict such changes in the future.

Raifa Lake is located on the territory of the Volga-Kama State Natural Biosphere Reserve of the Tatarstan Republic (Russia) at the confluence of the Sumka and Ser-Bulak rivers (Figure-1a). The territory of reserve is situated on the left slope of the Volga valley on its high quaternary terraces above the flood-plain. The pond has a karst origin and crescent elongated form. The lake covers an area of 330 thousands m^2; the length reaches 1400m with a maximum width of 300m. The lake is mainly fed by the spring waters, the rivers flowing into the lake, and the ground waters.

Despite the fact that all modern lakes are a valuable sources of information about environmental changes in the last thousand years, the lakes of the Volga region remain poorly understood. Among the most significant studies of the lake we can mention monitoring observations of hydrochemical regime and composition of plankton communities, conducted in reserve since 1983. [1-4]. It should be noted that bottom sediments of the lake are entirely unexplored.

For the best solving of the climatic conditions reconstruction requires analysis of large amounts of related data it becomes apparent that applying an integrated approach in comparison with any of the other specific research methods is most relevant, especially in terms of getting reliable results. Currently the instrumentation laboratory facilities reached a level when it is possible to carry out an integrated analysis of obtained data. An integrated approach will enable to conduct a comparative evaluation of the magnetic properties, a number of chemical and paleobiological indicators in layer by layer core samples of Raifa Lake and dendrochronological indicators.

2. METHODS

The expedition, carried out by KFU staff members in summer of 2015 was held for the purpose of preliminary seismic acoustic investigations, coring of bottom sediments and sampling for dendrochronological research on the territory of Raifa forestry.

Seismic profiling was collected with Boomer complex designed and manufactured on the base of Kazan Federal University. The Boomer data were collected along 3 km of survey lines (Figure-1a). Average survey speed was about 1.5 km/h. Navigation coordinates were obtained by a hand-held Garmin™ GPS unit, and were recorded with recorded each Boomer shot (shot time interval was 2 s). The survey was conducted from inflatable boat with the use of ecological electric motor. The depths discussed in this paper assume a speed of sound in water 1500 m/s.

Core samples were taken with a UWITEC Gravity Corer (Australia) at the 12 m water depth, core length is 32 cm, and coordinates are E 48° 43′40.6″ N 55 ° 54′21.7″. Bottom sediments are represented by homogeneous dark gray clays (Figure-1b). Sampling was carried out layer by layer with the interval of 1 cm in labeled plastic containers.

Core studies were conducted using an integrated approach. Samples were subjected to magnetic-mineralogical, paleobiological research, as well as to the study of the elemental composition.

2.1 Studies of elemental composition

The studies of elemental composition were conducted on a wavelength dispersive X-ray fluorescence (WDXRF) spectrometer S8 Tiger (Bruker, Germany), which allows determining the elemental composition of solid, powdery and liquid samples ranging from B to U in a vacuum or helium atmosphere. The device is equipped with a rhodium X-ray tube with a power of 4 kW.

The sample was placed in non-magnetic agate grinding jar of planetary ball mill, grinding was carried out for 10 minutes to achieve the required grain size of less than 10 microns.

ARPN Journal of Engineering and Applied Sciences

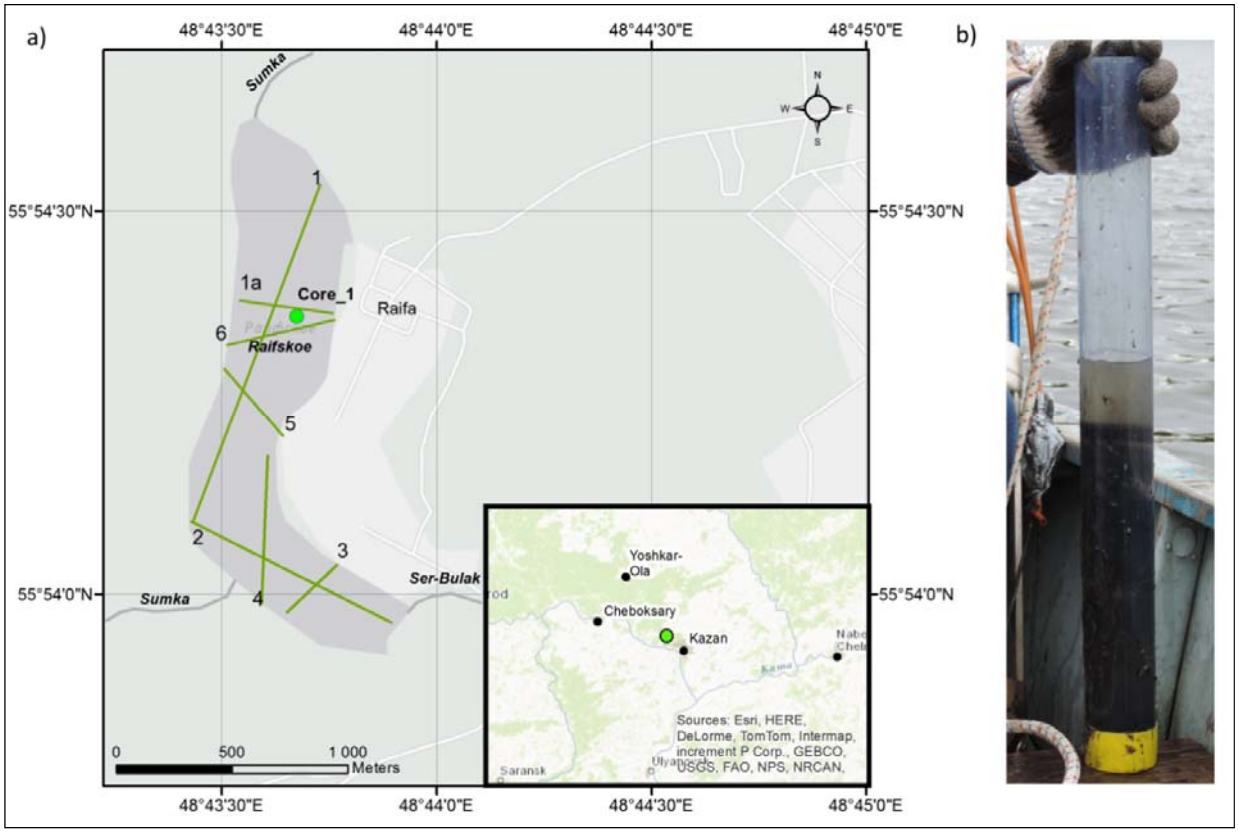

Figure-1. a) The location map of Raifa Lake, Volga region, Russia. Map showing location of seismic reflection (Boomer) profiles obtained in 2016 year and location of sampling site with the use of gravity corer. b) Photo of the column.

A 0.5 g subsample was placed in a ceramic crucible and had been heated at 1100˚C for two hours to determine the loss on ignition (LOI).

Another test subsample with a mass of 4g was weighted on an analytical balance with an accuracy of 100 mg, mixed with an organic wax and pressed onto a substrate of boric acid with a force of 300 kN.

This pressed powder pellet was placed in a spectrometer, which hosted the analysis by Geo-quant standardized methodology.

The obtained spectrum was processed by the method of fundamental parameters, the automatic recognition errors and spurious peaks were removed, the diffraction phenomenon and matrix effects were considered, the undefined elements were taken into account using LOI value.

2.2 Magnetic-mineralogical studies

Initially, the magnetic susceptibility (χ) was measured on all samples of the core column using the MFK-1A (AGICO, Czech Republic). The sediment was previously dried, all samples weight were measured.

Thermomagnetic analysis is a main type of diagnosis of ferromagnetic fraction's composition in rocks. For conducting the thermomagnetic studies samples were taken from different depths of the column.

The induced magnetization dependence on temperature was measured using Curie express balance in the magnetic field of 0.4 T at a heating rate of 100°C/minute. Before measuring the dried sample was ground and weighed.

The spectrums of normal magnetization in the fields of up to 0.5 T were obtained by means of coercitivity spectrometer «J_meter» [5], which allows separate registering of induced and remanent magnetization of samples at a room temperature. The following parameters were obtained using the normal magnetization curves: normal remanent saturation magnetization (Jrs), saturation magnetization, excluding the effect of the paramagnetic component (Js), the magnetization of the paramagnetic component in the field of 0.5 T (Jp), the coercitivity force after removing the effect of the paramagnetic component (Bc), the remanent coercitivity force (Bcr), the position of maximum coercivity spectra of NRM (Bda), the position of maximum coercitivity spectra of NRM demagnetization from saturated state (Bdb), superparamagnetic susceptibility in the field of up to 8 mT (Ksp).

In order to determine the nature of changes of magnetic susceptibility we have identified the contribution of the different components - ferromagnetic (χf), paramagnetic and diamagnetic (χp), as well as

superparamagnetic (χsp). Each component has a different nature of origin related to sedimentation processes changes. Methods of determining the contribution of paramagnetic component to the total signal by inductive normal magnetization curve, determining ferromagnetic component by inductive normal magnetization curve minus paramagnetic component, determining the superparamagnetic component by Jr curve and its total value were applied to all samples of core column [6].

These samples were also used to carry out a component analysis to determine the components of ferromagnetic fraction through analyzing normal magnetization spectra by continuous wavelet transform method with the Gaussian-based wavelet (MHAT) [7].

2.3 Paleobiological studies

Carcinology analysis required pretreating samples for microscopy: thermochemical treatment with 10% potassium hydroxide solution at 70-80 °C and staining with safranin dye. The samples were sieved through a 50-μm mesh. Microscopy of cladoceran remains was conducted using a microscope, Carl Zeiss Axiolab A1. The most abundant body part was chosen for each species to present the number of individuals. The species diversity for Cladocera was estimated with the Shannon species diversity index. At least 50 individuals per sample were countedfrom each sample. The taxonomic affiliation was established using domestic and foreign specialized qualifiers [8-12]. TILIA version 2.0.b.4 was used to generate a cladoceran percentage diagram [13]. (Grimm 1993). The program CONISS was used to perform a stratigraphically constrained incremental sum-of squares cluster analysis and identify the major groups in lake composition throughout the transect [14].

2.4 Dendrochronological studies

Dendrochronological method is widely used for reconstruction of climate, landslide processes, glacier dynamics, water level fluctuations in lakes and other natural processes [15].

The work was carried out according to the methodology adopted in the dendrochronological studies, [16]. The sampling area was placed in 63rd square of Raifa forestry, where pine trees had reached the age of 140 years. Sampling was conducted with Haglof increment borer at a height of 1m from root collar of 15 trees. The tree-ring widths were measured on a semi-automatic LINTAB device with TSAP-Win software [17]. The tree-ring chronology was built and analyzed in a freely distributed dplR package [18]. The growth trend has been excluded from the individual radial growth chronologies, on the assumption that it reflects the tree age features.

Trend estimates were obtained using a spline curves. Also, individual time series have been standardized for construction of master chronology.

The data on mean monthly air temperature and precipitation sum from All-Russian Research Institute of Hydrometeorological Information - World Data Center (ARRIHI-WDC) 27595 Kazan weather station (55.80 N 49.30 E) and meteo observatory Kazan university weather station in vil. Sadoviy (55.9 N, 48.73 E) was used to identify the reaction of pine growth on the climate. The statistical relationship of radial tree growth with weather factors was analyzed by Spearman rank correlation using PAST software [19]. The Spectr software was used to identify the cyclical dynamics in radial growth of trees.

3. RESULTS

3.1 Seismic studies

Lake basin is divided in two depression in North part (maximum depth of the lake is 20.5m) and South-East part (depth is 9.5 m). West slope of the lake basin is gradually deepening, however east slope is steeper (Figure-3). Seismic reflection data indicated less than 0.4 m of sediment.

3.2 Laboratory studies of the sediment cores.

3.2.1 Studies of the elemental composition

The elemental composition was measured in 31 samples. Table-1 presents the elementary statistics of the element contents (in oxide form). The elements are arranged in order of decreasing average values of the element contents, showing the dominant role of silicon, aluminum and iron (a total of more than 70%) in the sediments composition.

Verification of normality of the elements distribution showed that the samples are statistically significant only for Al, Na, Mg, Ba, V, Ni, Sr, Rb, As, Ga, Nb elements. In terms of water migration of these elements [20] no express regularities in the distribution of active (Mg), mobile (Ni, Ba), low mobile (Al, Na, V, Rb) and inert (Ga) migrants were found.Therefore, it's hardly worth expecting the value of the element ratios in geochemical pairs (active, mobile - to low mobile and inert), characterizing the intensity of the weathering processes (maximum values of these coefficients may indicate a minimum intensity of weathering, ie cooling and vice versa [20] to be informative, as is confirmed below, in Figure-4.

Based on the statistical analysis, aluminum is worth to be taken as a binding (grouping) element as it is the second element by content and statistically significant. Valuation results on aluminum as the least mobile element in the system of "lake water - sediment", conducted according to the expression [21]:

EF= (Cxi/CxAl) sample/(Cxi/CxAl)shale,

where (Cxi)sample - the content of a chemical element in the study object; CxAlsample - aluminum content in the study object; Cxishale - the content of the chemical element in the clay shale (shale), CxAlshale = 8% - the content of aluminum in the shale [22], are presented in Figure-4. Conducted valuation shows that inert geochemical environment played the dominant role in the formation of the chemical composition of sediments [23].

A significant relationship between aluminum and silicon has not been established. A significant positive

relationship is observed (values in parentheses indicate the correlation coefficients) in aluminum with magnesium (0.95), rubidium (0.89), titanium (0.83), vanadium (0.77), potassium (0.73), nickel (0.62), galiem (0.57), zinc (0.47), iron (0.45). A significant negative relationship is observed in aluminum with chlorine (-0.51), calcium (-0.37), phosphorus (-0.41), zirconium (-0.48). For the pairs of aluminum with the remaining elements a significant relationship was not found. The application of principal component analysis revealed two factors (Table-2). The first factor is responsible for the input of aluminum,

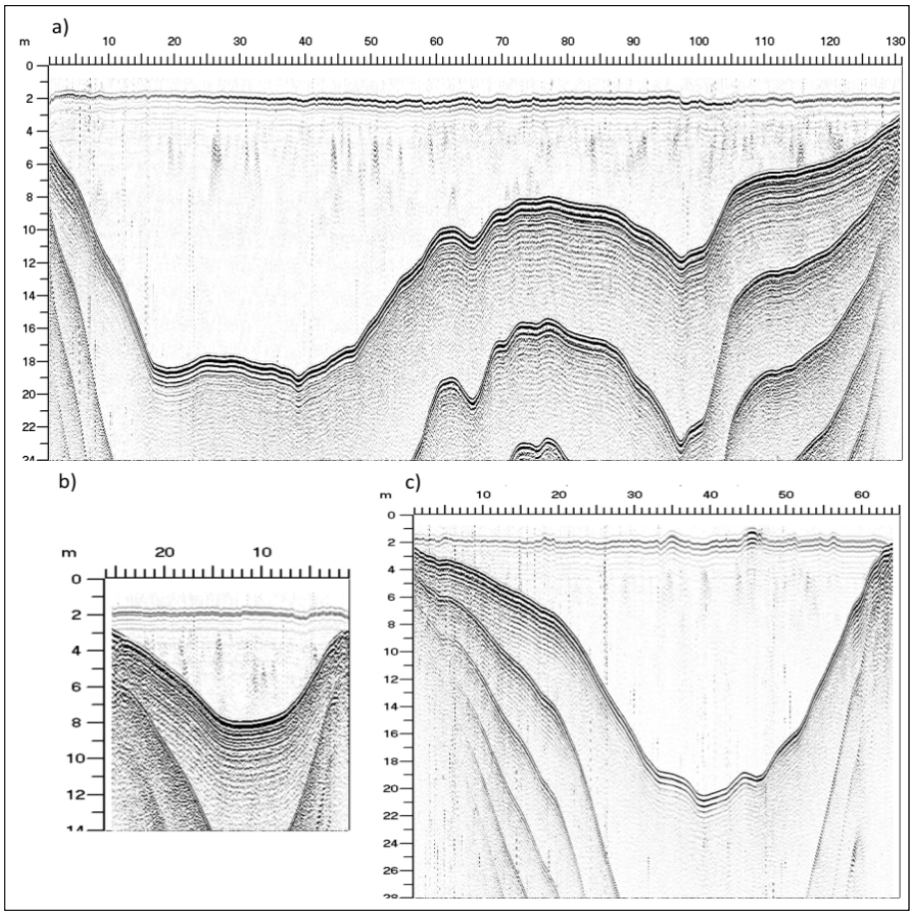

Figure-2. a) Seismic profile 1. b) Seismic profile 3.c) Seismic profile 6.

ARPN Journal of Engineering and Applied Sciences

Table-1. Elementary statistics for the element contents (in oxide form).

	Descriptive Statistics (Raifa)				
Variable	**Valid N**	**Mean**	**Min.**	**Max.**	**Std. Dev.**
SiO_2	31	54,312	43,842	59,543	3,180
Al_2O_3	31	12,906	11,226	14,488	0,805
Fe_2O_3	31	8,523	5,985	9,975	1,128
K_2O	31	2,457	2,248	2,646	0,112
CaO	31	2,222	1,293	5,174	1,088
MgO	31	1,769	1,512	2,049	0,136
P_2O_5	31	0,950	0,655	1,474	0,199
TiO_2	31	0,841	0,759	0,925	0,038
Na_2O	31	0,503	0,313	0,7243	0,096
SO_3	31	0,492	0,091	1,129	0,286
MnO	31	0,240	0,114	0,577	0,097
BaO	31	0,070	0,059	0,081	0,005
V_2O_5	24	0,030	0,024	0,039	0,003
ZrO_2	31	0,026	0,017	0,045	0,006
Cr_2O_3	31	0,019	0,017	0,023	0,001
Cl	17	0,018	0,011	0,022	0,003
ZnO	31	0,018	0,013	0,021	0,002
NiO	31	0,0129	0,009	0,016	0,001
SrO	31	0,012	0,009	0,014	0,001
Rb_2O	31	0,012	0,009	0,014	0,001
CuO	31	0,008	0,006	0,010	0,0008
PbO	5	0,003	0,002	0,003	0,0003
Y_2O_3	23	0,003	0,002	0,003	0,0003
As_2O_3	31	0,002	0,0007	0,005	0,0015
Ga_2O_3	31	0,002	0,0014	0,0031	0,0004
Br	10	0,001	0,0013	0,0023	0,0003
Nb_2O_5	27	0,001	0,0008	0,0021	0,0002
CoO	7	0,0004	0,00001	0,0014	0,0005

magnesium, vanadium, nickel, gallium and rubidium (clay component). The second factor is responsible for the output of barium (indirect increase of salinity).

Based on the above-mentioned analysis it seems possible to consider aluminum (input of clay component), strontium (indicator of a cold snap - as its content increases), Sr/Ba ratio (increasing indicates salinization, it is known that with increasing water salinity association of barium and strontium decays) to be informative in reconstructive respect [24]. Magnesium is positively correlated with aluminum, which indicates its better relationship with clay rather than a carbonate component. The Al / Ca ratio can be used as an indicator of sediment carbonatization (ratio decrease indicates sediment carbonatization, and possibly the cold snap/ global cooling [20]. The V / Cr ratio is also applicable, indicating the reducing conditions for ratio values more than one, and oxidizing conditions for ratio values less than one [25]. The appearance of bromine may indicate an increase of sedimentation bioefficiency (global warming) [26].

The behavior of these parameters is shown in Figure-5. All the indicators except for the bromine do not allow differentiating the sediment, you can talk about the bottom and top part of the sediment, the boundary between which passes at a depth of 12.5 cm, only by the "noise" level in data. Only the appearance of bromine in the upper part of the sediment suggests that that this part was accumulated in conditions of warming, increasing salinity

and bioefficiency growth [26]. The values of the V/Cr are greater than one in all samples, which suggest reducing conditions of sedimentation on the respective depositary levels.

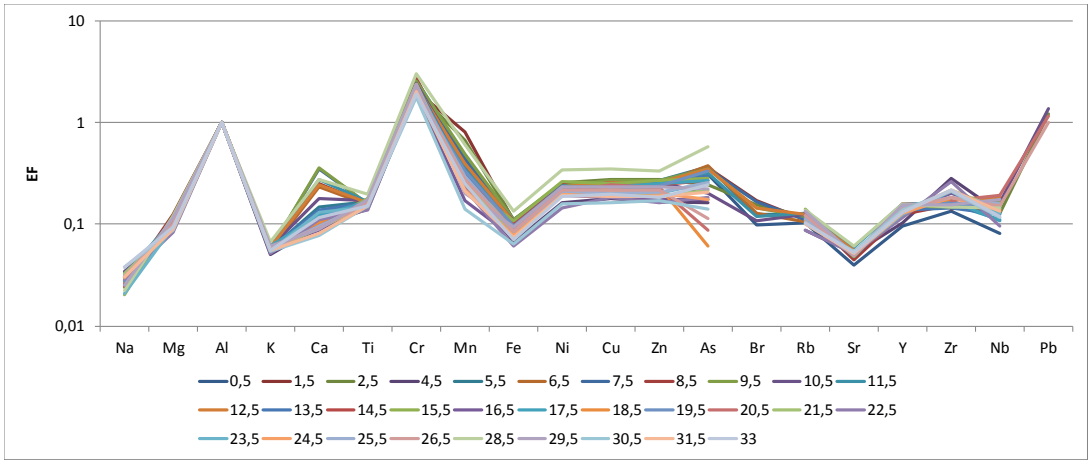

Figure-3. Spider-diagram EF for the sediment column of Raifa lake.

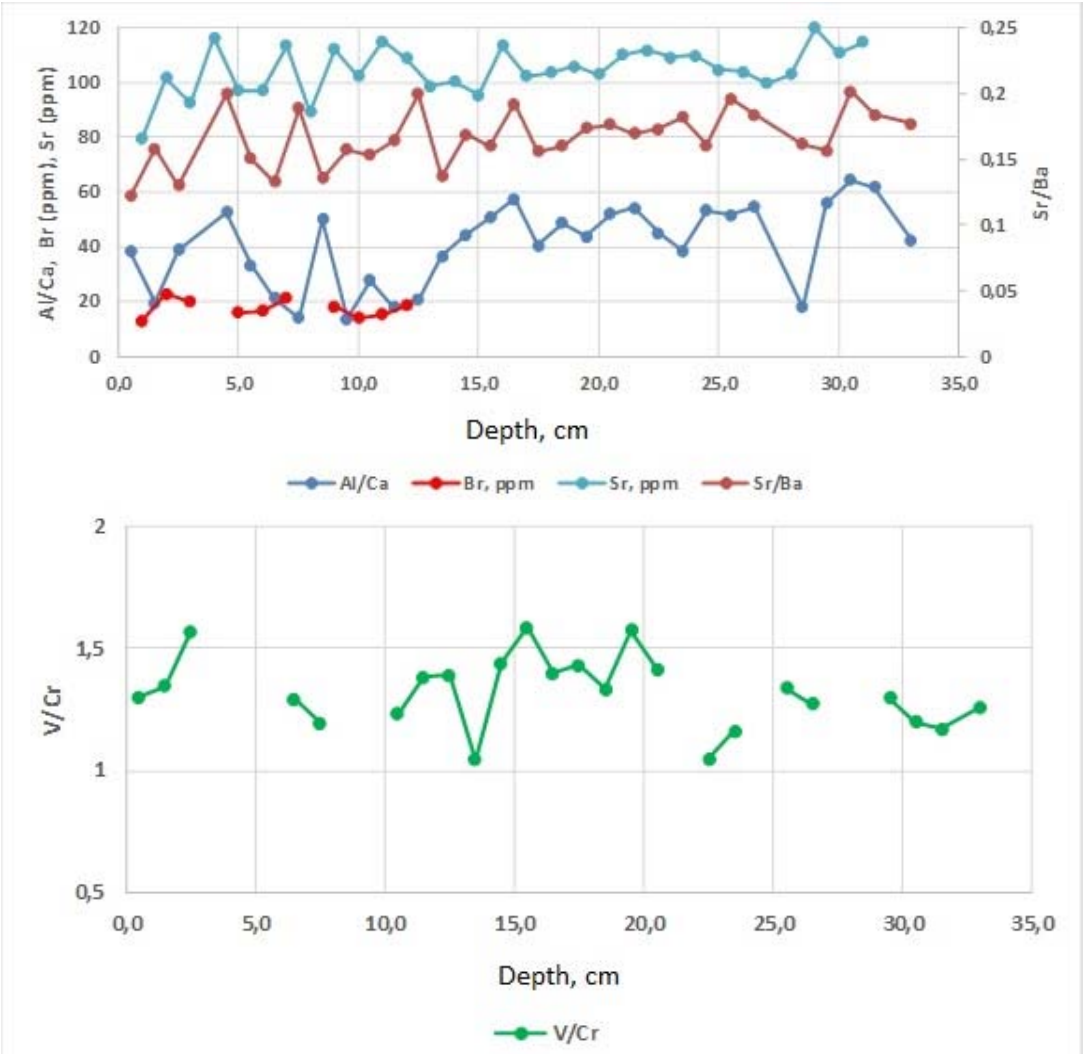

Figure-4. The behavior of geochemical indicators in the sediment column.

Table-2. The results of the principal component analysis.

Variable	Factor Loadings (Varimax normalized) (Raifa) Extraction: Principal components (Marked loadings are >,700000)	
	Factor 1	Factor 2
MgO	0,890774	-0,145599
Al2O3	0,934014	-0,006827
Na2O	-0,611983	0,450758
V2O5	0,863362	-0,104043
NiO	0,831906	-0,425860
SrO	-0,427431	0,619145
Rb2O	0,900454	0,192305
BaO	-0,145292	-0,743266
Ga2O3	0,829831	0,028710
Nb2O5	0,574130	0,588323
As2O3	0,124773	-0,657166
Expl.Var	5,526285	2,168192
Prp.Totl	0,502390	0,197108

3.2.2. Magnetic-mineralogical studies

The diagrams of differential-thermomagnetic analysis do not have significant differences between them, which indicates the uniformity of the magnetic mineralogical composition of the samples, which in turn suggests the uniform conditions of sedimentation. Figure-6 shows an example of DTMA diagrams of the lake sediment.

The diagrams show several thermo-magnetic effects associated with the outflow of different types of water from rocks. Growth of magnetization intensity after the first heating at around 500 °C and following decrease at Curie temperature of 570 °C indicates the presence of pyrite in the rock, which dissociates to form magnetite or burning of organic leads to reducing conditions in which magnetite is formed.

Figure-7 shows the variation of the magnetic susceptibility values measured on MFK-1A (χ), magnetic susceptibility determined using coercimeter as the sum of the components (χful), paramagnetic and diamagnetic (χp), ferromagnetic (χf), as well as superparamagnetic (χsp) components with depth.

The values of magnetic susceptibility estimated using kappameter and coercimeter are close, reflecting the reliability of estimates using coercimeter (Figure-7). The χp values are associated with the input of allothigenic minerals to sedimentary basin and proportional to the volume of the water inflow. Reducing of χp values is associated to the presence of salts in the sediment, and therefore with an increase of evaporation. The presence of the magnetic susceptibility minimums is due to the lowering of the lake level. This permits to distinguish the stages, caused by the low water level and the stages related to an increased water level in the lake.

χf and χsp allow us to identify the stages of increased lake bio-productivity, when there were created a good conditions for the development of the magnetotactic bacteria population [6]. It should be noted that these zones are areas with a high water level, but these values

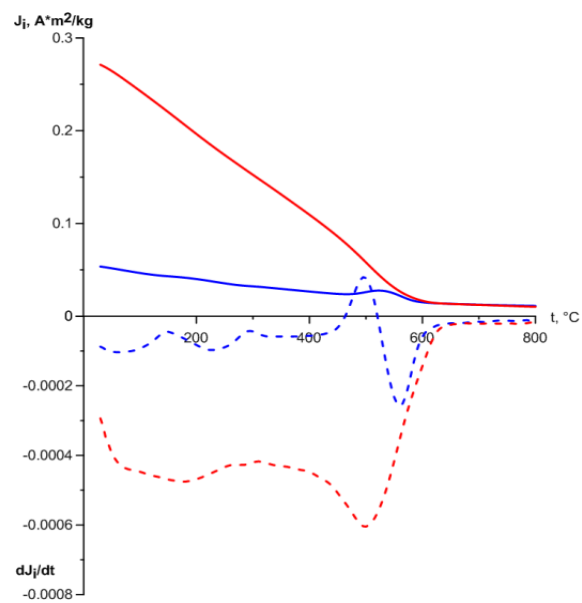

Figure-5. Diagrams of differential thermo-magnetic analysis of samples 14-15 of Raifa lake sediments.

are not maximum. Decreasing the bioefficiency of magnetotactic bacteria or worst safety of magnetofossils (dissolution of magnetite nanoparticles under reducing conditions) is due to the lowering of the lake level.

Figure-8 shows the variation of hysteresis parameters and their correlation.

Analysis of Day diagram (Figure-9) reveals homogeneity of the ferromagnetic fraction. The magnetic material is represented by single-domain and pseudo-domain material with a noticeable influence of superparamagnetism, and to a lesser extent by multidomain grains. This suggests that the main carriers of sediment magnetization are biogenic minerals, most likely the magnetite.

The component analysis by normal magnetization spectrums was carried out to identify the components of the ferromagnetic fraction. This was accomplished using the wavelet decomposition into components with Gaussian curve shapes [7]. Data analysis reveals at least 5 significant groups by PMCS values (position of the maximum of the coercivity spectrum) (Figure-10). The identified components we named according to R. Egli [27, 28], where such components were distinguished from the decomposition of coercivity spectrum using the generalized Gaussian distribution.

The first most significant component to allocate is «BS» - (biogenic soft) provided mainly with a single-domain grains of magnetic minerals having biogenic origin (magnetotactic bacteria remnants). Modal PMCS values of this component are in the range of ~ 34-46 mT in the spectra of magnetization (Figure-10). Distinguished component is present in all sediment samples, in most cases providing the greatest contribution to the magnetization.

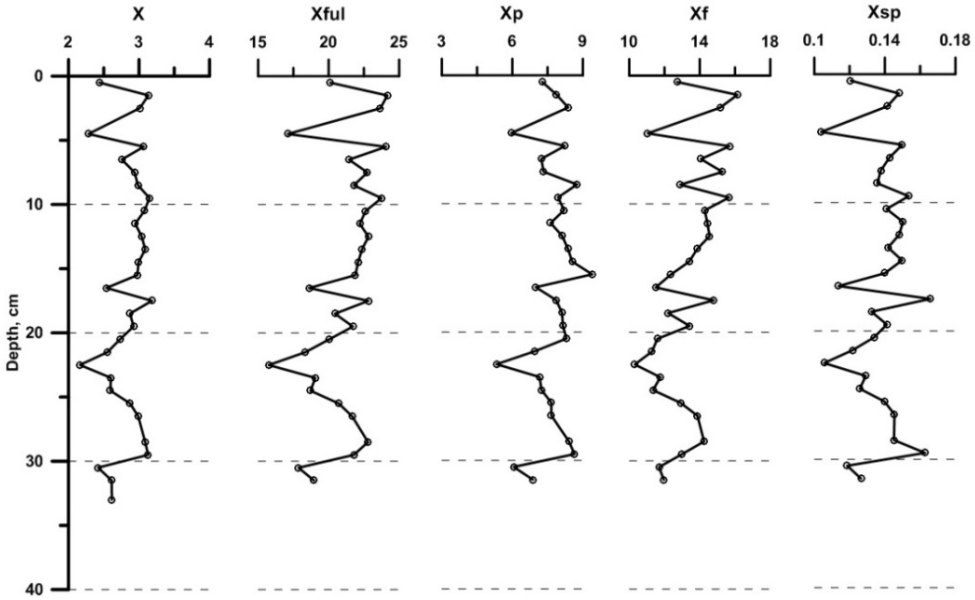

Figure-6. Variations of magnetic susceptibility values measured on MFK-1A (χ), magnetic susceptibility determined using coercimeter as the sum of components (χful), paramagnetic and diamagnetic (χp), ferromagnetic (χf), as well as superparamagnetic (χsp) components with depth.

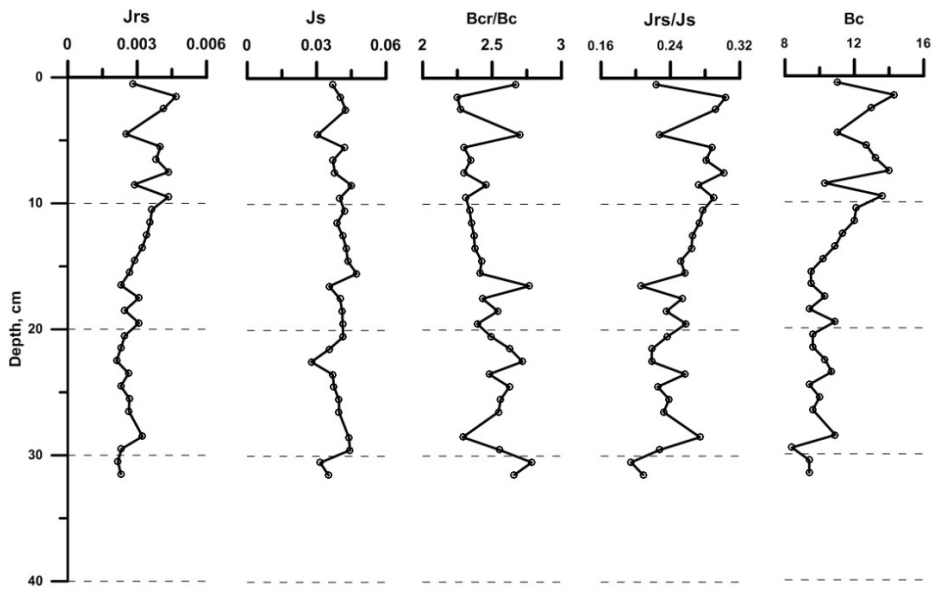

Figure-7. Variations of magnetic susceptibility and hysteresis parameters in Raifa lake sediments.

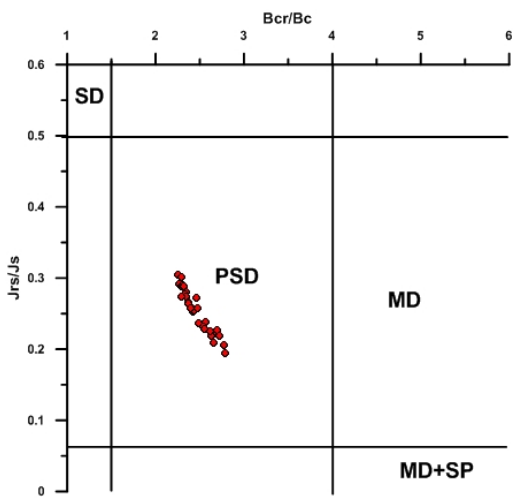

Figure-8. Day plot of the lake Raifa sediments.

The next important component is "BH" - (biogenic high) high-coercivity biogenic component, which includes mostly single-domain grains of magnetic minerals of biogenic origin, which are also a remnants of magnetotactic bacteria.

Modal values of PMCS component fall in the interval of ~ 68-94 mT in magnetization spectra (Figure-10). It should be noted that this component also presents in almost all samples, but its contribution to the magnetization of sediments rarely exceeds 20% (Figure-10).

We also highlight the component «D + EX» representing the sum of the component - «D» (detrital magnetite) detrital magnetite and «EX» (extracellular magnetite) extracellular magnetite - is a biogenic-induced grains, products of iron bacteria activity. In most cases, components «D» and «EX» overlap in coercivity, so they are treated as a single component. This component is represented by very small single-domain grains with low coercivity. This group is clearly seen in the lake samples by the normal magnetization spectra in a field range of ~ 5-24 mT.

The most high-coercivity component «H», having a bimodal distribution of PMCS in a field range of ~ 98-110 mT and 190-240 mT are represented by high-coercive grains. This component is present in the layers that are rich with clay material and may contain hematite and iron hydroxides. Magnetic grains of the components are likely to have allogenic origin, brought into the sedimentation basin with a water inflow and/or a wind.

The variations of PMCS for biogenic components BS and BH with depth are shown in Figure-11. The behavior of curves suggests relative constancy of sedimentation conditions, with slight variations of the coercivity for the components noted in the range of 8-12 cm, which may be due to rapid environmental changes.

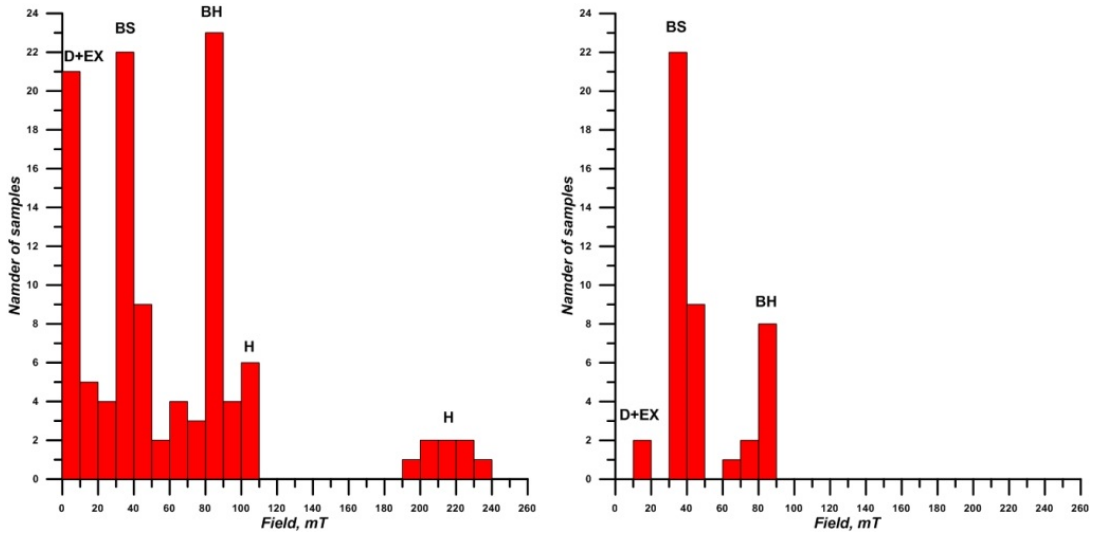

Figure-9. a) The histogram of PMCS distribution of ferrimagnetic components; b) The histogram of PMCS distribution of ferrimagnetic components with magnetization more than 10% of the total magnetization of a sample.

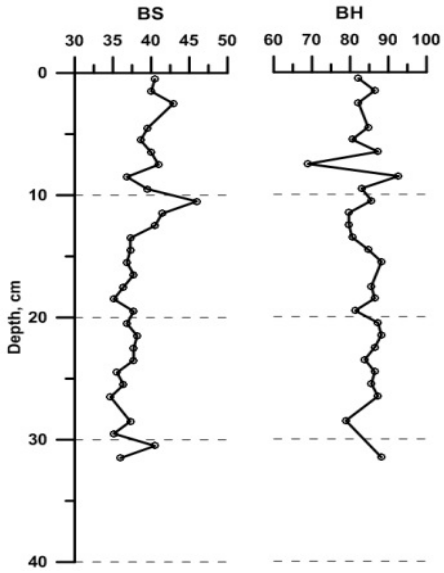

Figure-10. The variations of PMCS for biogenic components BS and BH with depth.

3.2.3. Cladocera analysis

Cladocera (Crustacea: Branchiopoda) are a key component of aquatic ecosystems, their community structure reflects a combination of the physical, chemical and biological characteristics of the ecosystem they inhabit [29].

The spatial distribution and abundance of freshwater fauna is regulated by environmental factors such as depth [30], pH [31], the development of aquatic vegetation [32] and predation pressure [33]. The temperature has a direct effect on the metabolism and the development of Cladocera and the indirect impact on the habitat conditions [34, 35].

The absolute dominant in the composition of Cladocera community in the investigated reservoir is *Bosmina* sp. (94.8%). Most of remains *Bosmina* sp. were presented by species *Bosmina longirostris*. Among the other representatives contributing to Cladocera community should be called *Daphnia* sp. (1.64%), *Chydorus sphaericus* (0.83%), *Alona rectangula/guttata* (0.52%). *Camptocercus rectirostris* (0.49%).

The opportunity to recreate the picture of events occurring in a reservoir is realized based on the preference data for environmental conditions encountered during the studies. Next let's specify the dominant species in the cladoceran community and their preferences to the existence conditions: *Bosmina longirostris* is a species, occurring in a wide variety of water basins, including slightly acid (pH> 5, 0), eutrophic and brackish (not present at a low salt content). It's developing in the plankton throughout the year, β - mesosaproben, lives in waters at an altitude below 500 m ASL [36]. *Chydorus sphaericus* is a small ball-shaped crustacean living in the coastal and open water, often near the water's edge, generally found within lakes with a high degree of eutrophication, β-mezosaproben. The temperature optimum for reproductive processes is at 7.1-7.9 ° C [37]. *Alona quadrangularis* - is an inhabitant of the bottom layers, growing in large quantities in summer. Apparently, monocyclic, development cycle ends in autumn. It's widespread in the Northern Hemisphere and can be found at an altitude up to 1370 m a.s.l. on various types of substrate. The species is very rare in acidic waters (at pH <5), mainly occur at pH 5, 6-7, 9. It gains weight in high conductivity waters at G>2, 0 mS/m [37]. *Alona guttata* - is an inhabitant of bottom layers and littoral vegetation of different water bodies. This species is year-round in southern regions and monocyclic "summer" form to the north. The population is cosmopolitan. *Camptocercus rectirostris* [36] - is a thicket dweller of swamps, lakes, reservoirs, floodplain water bodies. Monocyclic, the cycle

ARPN Journal of Engineering and Applied Sciences

ends in a second part of autumn. Spread in the northern hemisphere. The temperature optimum for reproductive processes is 9.7 °C [37]. *Disparalona rostrata* dwells in reservoirs located at an altitude below 300 m a.s.l, occurs on a rock bottom of water bodies, with pH 5.5-7.1 and conductivity> 3 mS/m [36]. *Pleuroxus laevis* - the species can be found among the vegetation and the bottom of the littoral area, at a height of 3 to 801 m a.s.l, in reservoirs with pH 4,3-8,3 (preferably pH = 5.5) and electrical conductivity of 0.8 to 46 mS/m [36].

According to the environmental conditions in different biotopes the encountered species mostly belong to the littoral-pelagic and littoral. Zoogeographic distribution of majority of the detected species and taxa classifies them as palearctic and cosmopolitan, universal.

The values of Shannon index, this indicator accounts for the number of species in the community, and the extent of their dominance [38], are within 0.13-0.48, which reflects the intensive water pollution. Index values less than 1.0 characterize extreme environmental conditions. Interpreting this index it should be taken into account that 2 to 8 of total 17 identified taxa were found in each layer of 31-cm lake sediment column. 9 taxa correspond to zooplankton analysis conducted by Derevenskaya O.U. *et al.* from 1983 to 2000; the water body belongs to the eutrophic type [39]. The values of Pielou's index are distributed in the range of 0.08-0.18 characterizing the community structure as distinct from evenness, each layer of the soil horizon can vary considerably according to the number and species composition of the freshwater fauna indicator groups.

The relative abundances of the most common cladoceran taxa of Lake Raifa are presented in Figure-12. The cladoceran stratigraphy was divided into three local faunal zones. All three zones are characterized be the dominance of *Bosmina* sp. The dominance of the cladoceran *Bosmina* sp. (Figure-12), a species associated with high nutrient status, suggests that the lake had high level of productivity. This is also indicated by the presence of *Chydorus sphaericus*, *Alona affinis, Alona rectangula/guttata, Camptocercus rectirostris*, since these taxa mostly occur in mesoeutrophic localities.

Zone I (29-31 cm). A total of 6 cladoceran taxa, of which 5 are in the family Chydoridae (chydorids), were identified from this zone. *Bosmina* sp. (87-91%) is the dominant species. *Daphnia* sp., *Alona affinis, Alona rectangula/guttata, Chydorus sphaericus, Camptocercus rectirostris* are present at lower abundances (6-1%).

Zone II (11-29 cm). *Bosmina* sp. increases to very high values (90-98%). In zone II *Alona rectangula/guttata* decreases to very low values and *Alona affinis* is completely absent from this zone. The other cladoceran remains occur mostly at very low abundance and sporadically.

III zone (3-11 cm) is characterized by the dominance of the same taxon *Bosmina* sp. A total of 11 taxa were found from this zone, but proportions of these taxa are low (3-6%). Cladoceran analysis revealed a higher species diversity of community in this part of the core (zone III).

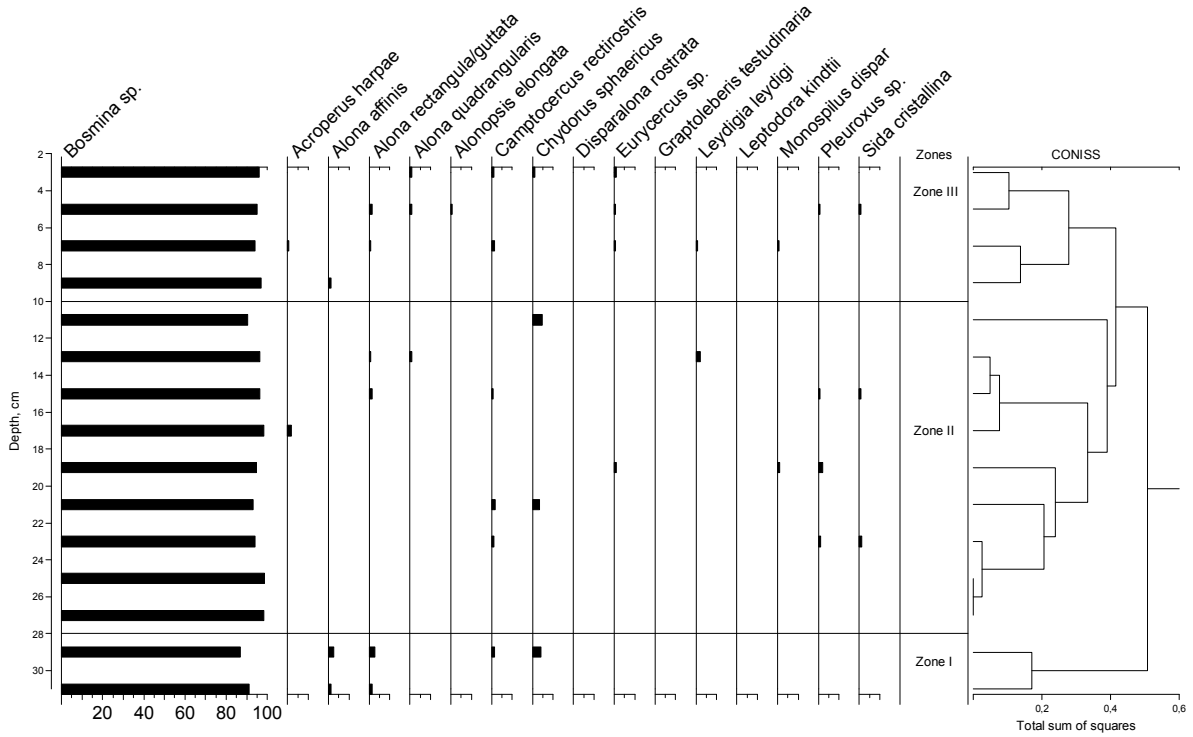

Figure-11. Relative abundance of the most common cladoceran taxa in Lake Raifa.

3.2.4. Dendrochronological study

The pine radial growth (Pinus sylvestris L.) is a good indicator of climatic shifts, as reflected in the works of other authors [40-43 and others].

Based on the model tree growth chronologies the summarized chronology of RAI has been obtained, the raw duration amounted to 139 years (Figure-13).

The obtained chronology can provide the years of minimum and maximum annual tree rings growth, as well as periods of increased and decreased growth (Table-3). Spectral analysis revealed that cycles with duration of 3-4 years have the highest density in the pine chronology.

The growth index correlation analysis was carried out to identify the major climatic factors affecting the pine growth in the study area with the air temperature and precipitation for the period from September last year to August of the current inclusive. There was detected a statistically significant positive response of the pine radial increment to the amount of July precipitation (r = 0.3, the level of significance <0.02). The positive relationship between growth of trees and the amount of precipitation in July indicates the importance of soil moisture in the middle of the vegetation period, which is especially important in the period of maximum growth of trees. These dendrochronological analysis results give a good idea of the weather conditions, which can cause expression or depression of growth of the pine forests reserve. Thus, the identified patterns can be used in the reconstruction of climate moisture in our region to instrumental weather observations. Therefore, further studies are required to extend the dendrochronological series into longer time-scales, involving subfossil timber located at the bottom of Raifa lake.

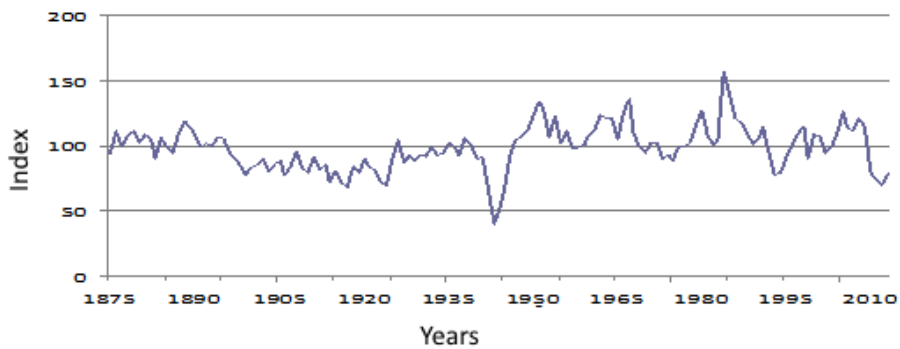

Figure-12. Long-term growth indices dynamics on the generalized RAI chronology of pine growth.

Table-3. The chronology of the years of minimum and maximum annual tree rings growth.

Years of max growth	Years of min growth
1888, 1926, 1951, 1967, 1984, 2005	1917, 1924, 1943, 1973, 1975, 1993, 2012
Periods of increased growth	Periods of decreased growth
1883-1888, 1924-1939, 1943-1951, 1994-2008	1895-1917, 1938-1944, 1951-1959, 1984-1993

4. CONCLUSIONS

It was revealed that stagnant geochemical environments played the dominant role in formation of chemical composition of sediments.

The formation of sediment was influenced by two main factors - the input of clay material and increasing the salinity of the lake. The following indices were defined as descriptive in reconstructive respect - Al, Sr, Mg, Sr/Ba, Al/Ca, V/Cr.

The presence of bromine in the upper part of the sediment (to a depth of 12.5 cm), suggests that this part was accumulating in a warming, increased salinity and bioproductivity growth conditions. The ratio V/Cr reflects reducing sedimentation conditions, as confirmed by the magnetic data.

The analysis of coercive spectra of samples from the lake bottom sediments revealed several magnetic components, among which there are two biogenic components with different magnetic rigidity, defined on the basis of a number of signs. Based on the data of thermomagnetic analysis it was found that the magnetically soft component is represented by magnetite, a magnetically hard probably by greigite.

Cladoceran analysis revealed a high dominance of one taxon (*Bosmina* sp.). The cladoceran stratigraphy was divided into three local faunal zones, but changes in structure of community were insignificant during the studied time period. Hydrobiological indices show eutrophication of the lake, allow classifying it as eutrophic or mesotrophic lake type.

The dendrochronological researches carried out on the territory of Raifa forestry revealed the years of maximum and minimum radial growth of pine. The established response of pine tree growth to the amount of

precipitation in July indicates the importance of soil moisture in the middle of the growing season, which is especially important in the period of maximum growth of trees. Subsequently, these data can be used to restore environmental changes and climate.

ACKNOWLEDGEMENTS

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University also by RFBR research projects No. 14-05-00785– a, No. 16-35-00452 and No. 15-05-04442 – a.

REFERENCES

[1] Unkovskaya E.N., V.V. Zharikov, S.V. Bykov, M.Yu. Gorbunov, M. Uman, N.G. Tarasova, O.V. Muhortova, O.V. Palagushkina, O.J. Derevenskaya. 2010. Plankton communities of Lake Raifa (Volga-Kama Natural Biosphere Reserve) I. Biodiversity plankton communities of different habitats of Lake Raifa. Izvestia Samarskogo nauchnogo sentra, Russian Academy of Sciences. 12(1) (5): 1453-1460.

[2] Bykova S.V., V.V. Zharikov. 2009. Ciliates of Lake Raifa (Volga-Kama biosphere reserve). Samarskaya Luka: regional and global environmental problems. 18(3): 121-131.

[3] Muhortova O.V., N.G. Tarasova, S.V. Bykov, T.N. Burkova, E.N. Unkovsky. 2011. Feature zooplankton phytophilic complex of Lakes Raifa and Dolgoe of Volga-Kama Natural Biosphere Reserve. Ecology and geography of plants and plant communities of the Middle Volga Region. pp. 346-352.

[4] Rysaeva I.A., Dvinskikh A.P. 2013. Features of macrocomponent composition of lake waters in the Raifsky area of the Volga Kama national natural biospheric reserve. «Vestnik AGU». 4: 88-94.

[5] Iassonov P.G., Nourgaliev D.K., Bourov B.V., Heller F. 1998. A modernized coercivity spectrometer /Geologica Carpathica. 49(N 3): 224-226.

[6] Kosareva L.R., Nourgaliev D.K., Kuzina D.M., Spassov S., Fattakhov A.V. 2015. Ferromagnetic, dia-/paramagnetic and superparamagnetic components of Aral sea sediments: significance for paleoenvironmental reconstruction. ARPN Journal of Earth Sciences. 4(1): 1-6.

[7] Kosareva L.R., Utemov E.V., Nurgaliev D.K., Shcherbakov V.P., Kosarev V.E., Yasonov P.G. 2015. Separation of Ferromagnetic Components by Analyzing the Hysteresis Loops of Remanent Magnetization Izvestiya, Physics of the Solid Earth. 51(5): 689-708.

[8] Sarmaja-Korjonen K., Szeroczynska K. 2007. Atlas of Subfossil Cladocera from Central and Northern Europe. Friends of the Lower Vistula Society. p. 84.

[9] Korosi J. B., Smol John P. 2012. An illustrated guide to the identification of cladoceran subfossils from lake sediments in northeastern North America. The Chydoridae. J. Paleolimnol. 48: 571-586.

[10] Frolova L.A. 2013. Cladocera. Biological indicators in paleobiological studies: atlas / Scientific Ed. L.B. Nazarova. Kazan: Kazan University Press. pp. 64-87.

[11] Kotov A.A., A.Y. Sinev, S.M. Glagolev, Smirnov N.N. 2010. Cladocerans (Cladocera). Determinant of zooplankton and zoobenthos in fresh waters of European Russia. V.1. Zooplankton / ed. V.R. Alekseev, S.Y. Tsalolihin. - M.: Association of scientific editions KMK. pp. 151-276.

[12] Flössner D. 2000. Die Haplopoda und Cladocera (ohne Bosminidae) Mitteleuropas. Leiden: Backhuys Publishers. p. 428.

[13] Grimm EC. 1987 CONISS: a Fortran 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. - ComputGeosci 113- pp. 13-35.

[14] 1993. Grimm EC TILIA 2.0.b.4 (Computer software). Illinois StateMuseum, Research and Collections Center, Springfield.

[15] Shiyatov S.G. 1986. Dendrochronology upper forest border in the Urals. M.: Nauka. p. 137.

[16] Shiyatov S.G. Dendrochronology methods. Part I. 2000. Fundamentals of dendrochronology. Gathering and getting tree-ring data / S.G. Shiyatov, E.A. Vaganov, A. Kirdyanov, V.B. Kruglov, V.S. Mazepa, M.M. Naurzbaev, R.M. Hantemirov. - Krasnoyarsk: Krasnoyarsk State University. p. 80.

[17] Rinn, F. 2005. TSAPWin - Time Series Analysis and Presentation for Dendrochronology and Related Applications, Version 0.53, User Reference / F. Rinn. - Heidelberg. p. 91.

[18] Bunn, A.G. dplR: Dendrochronology Program Library in R. 2012 R package version 1.5.6 / A.G. Bunn, M. Korpela, F. Biondi, F. Campelo, P. Merian, F.

Qeadan, Ch. Zang. URL: http://CRAN.R-project.org/package=dplR.

[19] Hammer O. 2003. Past – PAlaecological STatistics, ver. 1.04, 59 p. (http://www.folk.uio.no/ohammer/past).

[20] Anisimov M.A., Ivanova V.V., Pushina Z.V., Pitulko V.V. 2009. Lagoon sediments of Zhokhov Island: age, conditions of formation and significance for paleogeographical reconstruction of the New Siberian Islands. Proceedings of the Russian Academy of Sciences. Series: Geography. (5): 107-119.

[21] Shotyk W., Cheburkin A.K., Appleby P.G. et al. 1966. Two thousand years of atmospheric arsenic, antimony and lead deposition in an ombrotrophic bog profile, Jura Mountains, Switzerland. Earth and Planetary Scien. Letter. 145: 1-7.

[22] Li Yuan-hui. 1991. Distribution patterns of the elements in the ocean: A synthesis. Geochim. et. Cosmochim. Acta. 55: 3223-3240.

[23] Leonova G.A. 2009. Geochemical role of plankton of continental reservoirs of Siberia in the concentration and biosedimentation of trace elements - Doctoral dissertation author's abstract.

[24] Miko S., Mesic S., Prohic E., Pen Z. 2003. Trace element distribution in surface sediments of lake Vrana and topsoil of Cres island, Croatia. - Nat. Croat. 12(2): 93-111.

[25] Gorbatov E.S. 2013. Features of lake sedimentation during the formation of a ternary complex Shatursky Meshcherov. p. 26 (in Russian).

[26] Pashkova G.V., Ivanova E.V., Aysueva T.S., Shchetnikov A.A., Markova U.N., Finkelstein A.L. 2015. X-ray fluorescence determination of bromine in the bottom sediments of lakes for paleoclimatic studies. Analysis and control. T.19, №4. pp. 340-346.

[27] Egli R. 2004a. Characterization of individual rock magnetic components by analysis of remanence curves. 1. Unmixing natural sediments // StudiaGeophysicaetGeodaetica. 48(2): 391-446.

[28] Egli R. 2004b. Characterization of individual rock magnetic components by analysis of remanence curves. 2. Fundamental properties of coercivity distributions // Physics and Chemistry of the Earth. 29(13-14): 851-867.

[29] Frolova L. 2016. Subfossil Cladocera (Branchiopoda, Crustacea) in climatic and palaeoenvironmental investigations in Eastern Siberia (Russia) - International Multidisciplinary Scientific GeoConference, 2016. – Book 4. Energy and Clean Technologies, Conference Proceedings. II: 601-607.

[30] Frolova L.A., Nazarova L.B., Pestryakova L.A., Herzschuh U. 2013. Analysis of the effects of climate-dependent factors on the formation of zooplankton communities that inhabit Arctic lakes in the Anabar River basin. – Contemparary Problems of Ecology. 6(1): 1-11.

[31] Deneke R. 2003. Review of rotifers and crustaceans in highly acidic environments of pH values <3. Hydrobiologia. 433: 167-172.

[32] Quade H.W. 1969. Cladoceran faunas associated with aquatic macrophytes in some lakes in northwestern Minnesota. Ecology. 50: 170-179.

[33] Williams J.B. 1983. A study of summer mortality factors for natural populations of Chydoridae (Cladocera). Hydrobiologia. 107: 131-139.

[34] Frolova L., Nazarova L., Pestryakova L., Herzschuh U. 2014. Subfossil cladoceran remains from sediment in thermokarst lakes in northeastern Siberia, Russia. – Journal of Paleolimnology. 52(1): 107-119.

[35] Frolova L., Ibragimova A., Fedorova I. 2016. Stratigraphy of Cladocera in a core from A Yamal Peninsula lake (Arctic Russia). International Multidisciplinary Scientific GeoConference`. - Book 4. - Energy and Clean Technologies, Conference Proceedings. II: 579-587.

[36] www.nina.no.

[37] Nevalainen L., Luoto T. 2010. Temperature sensitivity of gamogenesis in littoral cladocerans and its ecological implications // J. Limnol. 69(1): 120-125.

[38] Shannon C.E., Weaver W. 1949. The mathematical theory of communication. - Urbana: Univ. Illinois Press. p. 117.

[39] Structures of zooplankton communities of lakes in Raifa part of Volzhsko-Kamaskiy Reserve and its buffer zone / Derevenskaya, O.Yu., Unkovskaya, E.N., Mingazova, N.M., Pavlova, L.R. 2002.

Transactions of Volzhsko-Kamskiy National Nature Reserve. Kazan. 5: 52-70.

[40] Bitvinskas T.T. 1974. Dendroclimatic research. L. Gidrometeoizdat. p. 172.

[41] Pugachev P.G. 1975. The dynamics of annual growth Pinus sylvestris. L. in Turgai basin due to climatic factors // Bot.zhurnal. 3: 401-412.

[42] Tishin D.V., Chizhikova N.A., Chugunov R.G. 2012. Assessing the impact of climatic factors on the radial growth of pine (Pinus sylvestris L) sphagnum bogs of the Volga-Kama Reserve. 2012, - Book of abstracts «Dendro 2012: perspectives of using tree-ring information for protection, restoration and sustainable use of tree vegetation. Materials of Conference. The Publishing House of the Moscow State University of Forest». (in Russian);

[43] Rigling A., Waldner P., Forster T. *et al*. 2001. Ecological interpretation of tree-ring width and IADF in Pinussylvestris on dry sites in the central Alps and Siberia. Can. J. For. Res. 31: 18-31.