© LEV V. RAZUMOVSKY[1], VIKENTIY L. RAZUMOVSKY[2]

[1]Dr. Geogr. Sci., Leading Researcher,
Water Problems Institute, Russian Academy of Sciences (Moscow)
[2]Post-graduate student, Water Problems Institute , Russian Academy of Sciences (Moscow)

razum@aqua.laser.ru, nethaon@mail.ru

UDC 574.5;561.26

RECORD OF THE RECENT ECOSYSTEM EVENTS IN LAKE KARAKEL ON THE BASIS OF REDEPOSITED DIATOM ASSEMBLAGES

SUMMARY. This study provides an analysis of data on diatom assemblages from bottom sediments in Lake Karakel (the Karachay-Cherkess Republic). The sediment cores for analysis were collected in the deepest parts of the lake. The method of graphical analysis of diatom assemblages was applied. We discussed perspectives of using this new method for paleoecological reconstructions. The results of isotopic dating were used. According to the structure of diatom assemblages we distinguished the periods of natural sedimentation in the lake. Several time intervals with the dominance of redeposited processes were established. Redeposited diatom assemblages are determined by characteristic variations of taxonomic proportions. In addition, we revealed the stages of lake ecosystem restoration after mudflows and other negative impacts. For these stages the main characteristic features in the taxonomic structure of diatom assemblages were distinguished. Our results are confirmed by other methods of lake sediment analysis (geochemical and lithological methods).

KEY WORDS. Diatom analysis, lacustrine sediments, redeposited assemblages, paleoecological reconstructions.

INTRODUCTION. Lacustrine deposits are traditionally used for paleoclimatic and paleoecological reconstructions. This is due to the fact that lacustrine sediments usually contain accurate chronology of the events of the past, which can be decoded with high temporal resolution. Nowadays, the information on the state of lake ecosystems of the Caucasus as indicators of global climate and environment change is very limited [1], thus, the conducted research is topical.

In assessing changes occurring in lake ecosystems, ecologists commonly use the method of diatom analysis. Diatoms (class Bacillariophyceae, division Ochrophyta) are the most common group of algae, which is well preserved in sediments due to the presence of silica cells (frustules). However, diatom analysis has significant untapped informational reserve. A well-developed method of graphical analysis of taxonomic proportions in diatom complexes can serve as a graphic confirmation of this fact [2-4].

Methodology of the research. Lake Karakel lies in the western mountainous province of the Greater Caucasus, in the Teberda valley. The lake is located at an altitude of 1,335 m above sea level; it is oval and elongated in the direction of the stretch of the valley. The lake is 280m long and 140m wide; the average depth is 6-11 m. According to G.K. Tushinsky [5], Lake Karakel was formed as a result of damming of glacial flows by moraine ridges.

Lake sediments were selected by the members of the department of glaciology of the Institute of Geography of the Russian Academy of Sciences in September 2010, in the central part of the lake, at the point where the greatest depths were observed (9.5 m). Sampling was conducted from a raft with the help of a lake borer [6].

As a result, two columns of sediments 100 mm in diameter, 110 and 140 cm in length were obtained; the columns complemented each other in the depth of selection. Thus, a single profile of bottom deposits of lake sediments amounted to the total length of about 180 cm. Since the upper unconsolidated part of the sediment (semisolid sapropel) could be lost during drilling, samples from the depth of 0-250 mm were additionally selected with the help of a box-corer.

Samples for diatom analysis were selected with the help of conventional methodology [7], at an interval of 1 cm. Samples were selected within the range of 0-48 cm (in the upper part of the section of lake sediments). Processing and manufacturing of permanent preparations, calculation and identification of the valves of diatoms were carried out according to standard procedures [7, 8].

It should be noted that the study of the samples of lake sediments was integral. A wide range of methods were applied: lithological, geochemical, isotopic and other methods [9], which were subsequently used in the comparison with the results of diatom analysis.

In addition to traditional methods of diatom analysis, a relatively new method of graphical analysis of taxonomic proportions in diatom complexes was employed [3, 4].

According to this method, graphs (or histograms) are originally built, in which the abscissa indicates the number of species taxa and lower ranks (hereinafter – taxa) which were identified in a sample of taxa; the ordinate indicates their relative abundance. Taxa are ranked in terms of relative abundance towards their reduction.

On the basis of numerous studies, in the Cartesian coordinate system were distinguished two types of graphs of natural, undisturbed structure of taxonomic proportions in diatom assemblages. Both types of graphs are characterized by smooth, proportionate contours. The first of them is in its outline close to the exponential dependence, and the second has a certain similarity with the logistic dependence [4, 10, 60-61].

There is a third type of graphs with a linear, angular shape which characterizes redeposited complexes [3, 135-136]. Loss and distortion of the initial contours are associated with post-mortem processes in which there is a redistribution of organosilicon shells of diatoms according to their size and massiveness.

Discussion of the results. All samples under analysis were presented in histograms of taxonomic proportions in the Cartesian coordinate system. The upper range (0-13cm) showed no noticeable distortion of taxonomic proportions in diatom assemblages. However, in other intervals a group of histograms of redeposited genesis was distinguished, as well as a histogram in which elements of redeposition of diatom assemblages could be traced.

Redeposited complexes are confined to the intervals of 22-23 cm, 23-24 cm, 28-29 cm, 32-33 cm, 33-34 cm, 37-38 cm, 43-44 cm. Diatom assemblages which contain noticeable elements of redeposition are located at the intervals of 36-37 cm, 41-42cm and 42-43 cm. A marked distortion of lifetime proportions, which is fixed at the intervals of 13-14 cm and 14-15 cm, is also likely to be connected with the processes of redeposition (Fig. 1).

Also highlighted was a group histograms, which were characterized by two features: a pronounced dominance of only one taxon and a reduction of the total number of identified taxa (16-17 cm, 21-22cm, 31-32 cm, 35-36 cm, 38-39 cm, 40 -41 cm). As a rule, these taxonomic proportions in diatom assemblages are typical of reservoirs with adverse environmental conditions associated with external impact of abiotic character (Fig. 1).

It should be emphasized that the findings and conclusions concerning the existing processes of redeposition were obtained prior to the opportunity to see the results of other types of analyses.

Reliable recognition and classification of redeposited complexes can be considered a sufficiently important result of diatom analysis. It is well known that identification of redeposited complexes in new sediments has always been extremely difficult.

The reason for this is as follows: due to the good preservation of the valves in the sediment and due to the presence of similar species, it is virtually impossible to "recognize" redeposited complexes. To date, only the method of graphical analysis of taxonomic proportions can help to reliably identify redeposited complexes of diatom algae.

According to the results of isotopic analysis, the age of the sediments at a depth of 54 cm corresponds to the age of 2,235 years (± 35 years) [9,11]. Consequently, the upper 48 cm of sediments, which were used for diatom analysis, were formed over the past 2,000 years.

Credibility (objectivity) of identification of redeposited complexes by means of the method of graphical analysis of taxonomic proportions was confirmed by the results of chemical and lithological analysis [9]. On a single profile we combined the intervals of redeposition processes received by means of diatom analysis and the intervals of the terrigenous component increase obtained by means of chemical analysis, and, as a result, the intervals identified by such different methods turned out to be virtually identical (Fig. 2). Moreover, a slight discrepancy in the location of redeposition intervals (diatom analysis) and terrigenous component increase (chemical analysis) only confirm the objectivity of the results. These minor differences can be attributed to the error which is associated with the sampling procedure for different types of analysis. Each group of experts analyzed core samples separately from each other. Naturally, if selection is carried out before core measurements, the error of 1 cm in the core area of 48 cm is quite acceptable. In this case, a full match of the results (in terms of intervals) might be suspicious.

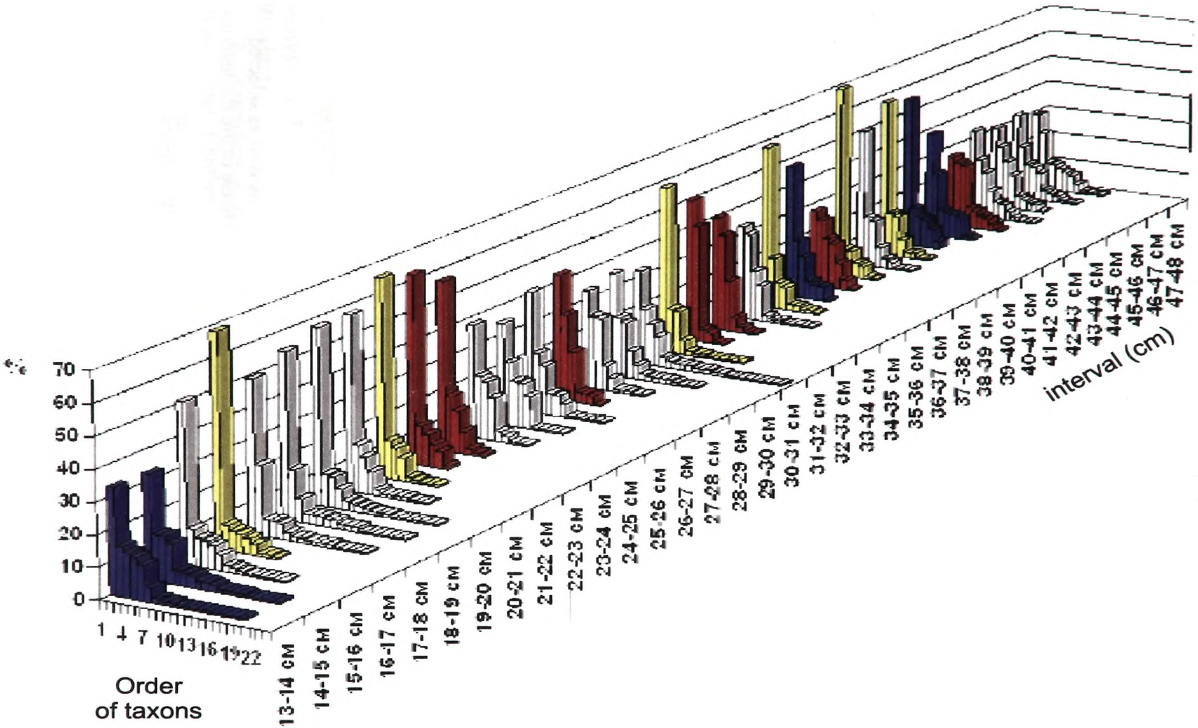

Fig. 1. Taxonomic structure of diatom assemblages of Lake Karakel:
■ — redeposited complexes; ■ — partially redeposited complexes;
■ — diatom assemblages with superdominance of one taxon

Another solid argument which confirms the presence of redeposition is the outline of subsequent intervals in the histograms (Fig. 1). In this case we are talking about a group of histograms where super-dominance of one taxon is noted. This sequence is not always observed, but it is manifested in the intervals of 21-22 cm, 31-32 cm, 35-36 cm and 40-41 cm, i.e. in four out of six cases in which prior redeposition processes were identified (Fig. 1, 2).

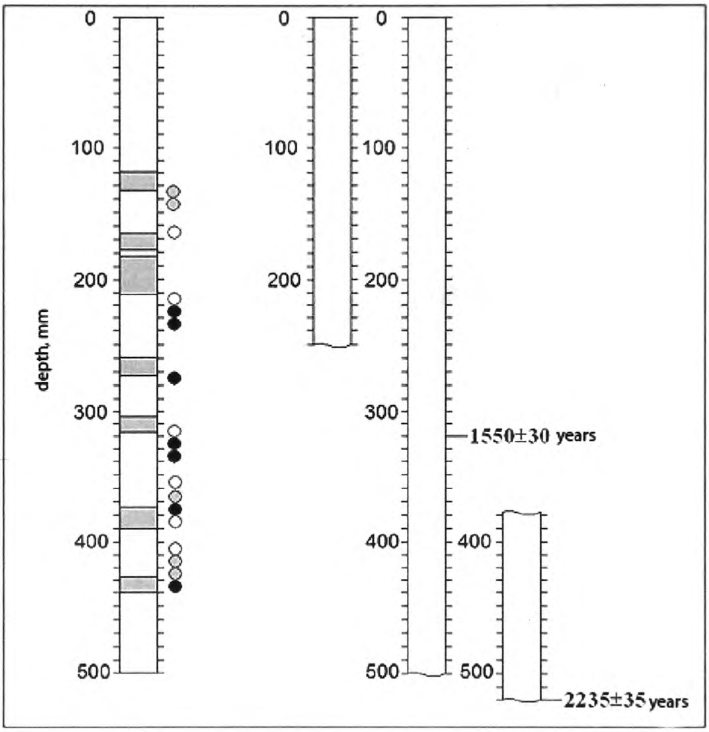

Fig. 2. A composite section of Karakel lake sediments (0-48 cm), as well as selected columns from which it was made up. Grey intervals indicate an increase in the terrigenous component in the sediments.

Note: • — location of redeposited diatom assemblages; ● — partially redeposited diatom assemblages; ○ — diatom complexes with the super-dominance of one taxon.

The fact that this sequence is not always recorded may be due to averaging of the results obtained by selecting samples for diatom analysis (a testing interval of 1 cm). Accordingly, if the average sedimentation rate comprises 0.22-0.23 mm per year [9], the averaging is approximately equal to 43.5-45.5 years. Of course, for such a period of time positive transformations may have already occurred in the lake ecosystem, the stage of predominance of one taxon followed by the redeposition stage as a result of mudslides may have ended and the lake's ecosystem might have recovered.

It is noteworthy that in the upper interval of the column (16-17cm) one can trace a stage of marked dominance of one taxon, which followed the stage of terrigenous component increase (18-19 cm). However, redeposited complexes were not identified in this interval (Fig. 2).

Conclusions. The opportunity to identify lacustrine redeposition processes using diatom analysis allows obtaining new reliable information for further paleoecological and paleoclimatic reconstructions. Reliability of redeposition processes identification in the course of analysis of taxonomic proportions in diatom assemblages was confirmed by other methods (lithological and geochemical), on the basis of which the conclusions concerning the mode and pace of sedimentogenesis in the lake were made.

REFERENCES

1. Moiseenko, T.I., Razumovskij, L.V., Gashkina, N.A., Shevchenko, A.V., Razumovskij, V.L., Mashukov, A.S., Horoshavin, V.Ju. Paleoecological studies of mountain lakes. *Vodnye resursy — Water Resources.* 2012. Vol. 39. № 5. Pp. 543-557. (in Russian).

2. Razumovskij, L.V. Water quality assessment based on the analysis of the structure of diatom assemblages. *Vodnye resursy — Water Resources.* 2004. Vol. 31. № 6. Pp. 742-750. (in Russian).

3. Razumovskij, L.V. *Ocenka transformacii ozernyh jekosistem metodom diatomovogo analiza* [Assessment of lake ecosystems transformation by means of diatom analysis]. Moscow, 2012. 200 p. (in Russian).

4. Razumovskij, L.V., Moiseenko, T.I. Evaluation of space-time transformations of lake ecosystems by diatom analysis. *Doklady akademii nauk. Obshhaja biologija — Reports of the Academy of Sciences. General Biology.* Vol. 429. № 3. 2009. Pp. 274-277. (in Russian).

5. Tushinskij, G.K. Modern and ancient glaciation of the Teberdinsky District// *Pobezhdennye vershiny* [Conquest of mountain peaks]. Moscow, 1949. Pp. 263–297. (in Russian).

6. Nesje, A. A piston corer for lacustrine and marine sediments. *Arctic and Alpine Research.* 1992. Vol. 24. № 3. Pp. 257-259.

7. Poljakova, E.I. *Diatomovyj analiz. Metody paleogeograficheskih rekonstrukcij* [Diatom analysis. Paleogeographic reconstruction methods]. Moscow, 2010. Pp. 126-160.(in Russian).

8. Battarbee, R.W. Diatom analyses // Handbook of Holocene Paleoecology and Paleobiology. Chichester: Wiley, 1986. Pp. 531-570.

9. Solomina, O.N., Kalugin, I.A., Aleksandrin, M.Ju., Bushueva, I.S., Darin, A.V., Dolgova, E.A., Zhomelli, V., Ivanov, M.N., Mackovskij, V.V., Ovchinnikov, D.V., Pavlova, I.O., Razumovskij L.V., Chepurnaja A.A. Drilling of sediments of Lake Karakel (the river Teberda valley) and prospects for reconstruction of the history of glaciation and Holocene climate in the Caucasus. *Ljod i Sneg — Ice and Snow.* 2013. № 2 (122). Pp. 102-111. (in Russian).

10. Shitikov, V.K., Rozenberg, G.S., Zinchenko, T.D. *Kolichestvennaja gidrojekologija: metody sistemnoj identifikacii* [Quantitative hydroecology: system identification methods]. Tolyatti, 2003. 463 p. (in Russian).

11. URL: http://www.radiocarbon.pl/