



Original article / Оригинальная статья

УДК 540.4

DOI: <http://dx.doi.org/10.21285/2686-9993-2019-42-4-539-547>

Geochemical analysis of Lake Baikal sediments: review of the results of the Sino-Russian joint expedition at Lake Baikal as a scientific training project

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Abstract: The article presents the materials that have been collected, processed and prepared for publication by the students participating in the international Sino-Russian scientific educational field expedition “Baikal as the world’s pearl, 2019” organized by Nanjing University and Irkutsk Research Technical University. For the purposes of the field studies, samples of the recent sediments of different genesis have been taken. The further office studies have been conducted using the laboratory equipment of the training research divisions of the School of Earth Sciences and Engineering, and the School of Environment, Nanjing University. As a result of the factual material processing, the comprehensiveness of the data has been evaluated, and the directions for further studies have been defined, which will allow to deepen and expand the scientific concepts of the history of the paleogeographic and climatic conditions of the West Transbaikalia sediments formation. The work has been conducted under the supervision of Professor R.M. Lobatskaya (Irkutsk National Research Technical University) on the Russian side, and Professors Wei Li and Zhouchuan Huang (Nanjing University) on the Chinese side.

Keywords: practical training, sediments, sedimentation, geochemical analysis

Information about the article: Received October 17, 2019; accepted for publication November 19, 2019; available online December 30, 2019.

For citation: Yan Zini, Li Jinhui, He Zihui, Wang Zitong, Zhang Zhanao, Li Wei, et al. Geochemical analysis of Lake Baikal sediments: review of the results of the Sino-Russian joint expedition at Lake Baikal as a scientific training project. *Earth sciences and subsoil use*. 2019;42(4):539–547. <https://doi.org/10.21285/2686-9993-2019-42-4-539-547>

Геохимический анализ осадочных пород озера Байкал: обзор результатов китайско-российской совместной экспедиции на Байкале как учебно-научного проекта

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Резюме: В статье представлены материалы, собранные, обработанные и подготовленные к публикации студентами – участниками международной китайско-российской полевой научно-образовательной экспедиции «Байкал – жемчужина мира 2019», организованной усилиями Нанкинского и Иркутского национального исследовательского технического университетов. Для исследований в полевой период осуществлялся отбор проб из молодых осадочных отложений различного генезиса. Последующая камеральная обработка данных проводилась на лабораторном оборудовании учебно-исследовательских подразделений Школы геологических наук и инжиниринга и Школы окружающей среды Нанкинского университета. В результате обработки фактического материала оценена полнота данных и намечены направления для дальнейших исследований, которые позволят углубить и расширить научные представления об истории палеогеографических и климатических условий формирования осадочных толщ Западного Прибайкалья. Работа выполнена студентами под руководством профессоров Р.М. Лобацкой (Иркутский национальный исследовательский технический университет) с российской стороны, Вэй Ли и Чжоучуань Хуан (Нанкинский университет) – с китайской.

Ключевые слова: учебные практики, полевые исследования, осадочные отложения, седиментация, геохимический анализ



Информация о статье: Дата поступления 17 октября 2019 г.; дата принятия к печати 19 ноября 2019 г.; дата онлайн-размещения 30 декабря 2019 г.

Для цитирования: Янь Цзыни, Ли Цзиньхуй, Хэ Цзыхуй, Ван Цзытан, Чжан Чжанао, Ли Вэй [и др.]. Геохимический анализ осадочных пород озера Байкал: обзор результатов китайско-российской совместной экспедиции на Байкале как учебно-научного проекта. *Науки о Земле и недропользование*. 2019. Т. 42. № 4. С. 539–547. <https://doi.org/10.21285/2686-9993-2019-42-4-539-547>

Background

Lake Baikal which locates in Siberia is the oldest (25 Ma), deepest (1637 m) and largest (23000 km²) lake in the world. It has a lot of significant and special geological meanings. The Baikal region situates at the boundary between the Siberian plate and the outer Baikal plate. Its current basement structure is formed by a series of plate collision, fault and tectonic movement. The Baikal Rift Zone which is the result of so many tectonic movements is the second largest continental rift in the world with a length of 2500 km. These specific geographical environment and tectonic background of the Baikal region have a great influence on the local deposition and weathering processes and formed a unique deposition mode and weathering environment. The deposition mode and weathering environment are the focus of academic research for a long time and they have already become the focus of academic research nowadays.

Rare earth elements (REE) have some special physical and chemical properties so they always are used as tracers or feature elements to represent some geological processes in geochemistry field. The performance of REE has a particular response to geological processes such as deposition mode or weathering environment [1, 2]. Although these two processes in Baikal have been researched from long time ago the REE evidences still haven't been paid enough attention to. There are still a lot of space for us to attempt. This research intend to analyze the sedimentary material's relevant REE geochemistry feature in Baikal and referring former researches build a model which could explain the geological processes that are indicated by the REE evidences so we could use the evidences and the model to restore the deposition mode and weathering environment in Baikal

during the corresponding geological historical period.

Overview of Baikal deposition

The literature shows that the sediments in the practice area are composed of various genetic rock debris and unconsolidated quaternary materials. The formation of different kinds of unconsolidated sediments is based on the exogenic geological process such as various transport and accumulation conditions and weathering conditions in the region and the characteristics of bedrock. Geophysical studies show that the quaternary sediments are 10–12 m thick in large basins and no more than 5–7 m thick in small basins.

Residual deposit deposits are generally located in river channels with a small amount on slopes. The wide distribution of these genetic types reflects the neotectonics and rapid uplift in the region. River alluvium is formed in the basin of the largest river (Anga River, Sarma River, Kuchulga River, etc.). The section has a two-layer structure whose the lower part is the less rounded gravel and the upper part is silt and sandy clay.

The thickness of sedimentary fill in most of the rift basins ranges from 1500 to 2500 m. A maximum thickness of 7500–8000 m has been recorded recently in the South Baikal basin from multichannel seismic studies. It has been long noticed that the sedimentary infill of rift basins can be subdivided into upper and lower parts, differing in lithological and facial composition and corresponding to two evolutionary stages. The changes in velocity of tectonic movements, in climate and in relief, which are inevitably reflected in the composition and structure of both stages of sedimentary filling, surely occurred within each of the two main stages.

The lower sedimentary units are composed of Paleocene, Eocene, Oligocene,



Miocene and lower upper Neocene (possible) strata. Sediments mainly include sandstone, siltstone, mudstone, clay, diatomite, marl, etc. A lot of fine sediments are embedded in coal seam and diatomite and some lens of coarse sediments exist but are extremely rare. The upper sedimentary units are mainly composed of sediments of Pliocene, Pleistocene and Holocene and the sedimentary phases are basically corresponding to the present topography. The main sediments are sand conglomerate, pebble, megalithic sediments, conglomerate and fan deposit. At the marginal parts of the depressions the upper sequence overlies the lower one with well expressed angular unconformity above which the sediments are abruptly more coarse-grained. All this indicates about increasing of tectonic vertical movements during Middle Pliocene, 3–4 Myr ago [3–6].

The deposition rates in Baikal vary greatly in different space and time ranging from 3.23 cm/kyr to 17.29 cm/kyr. The average rate of last 800 years is around 0.036 cm/yr (Fig. 1) [7].

Programme status

Sampling method

After discussion, the sampling method is finally determined as follows.

First of all, when we are looking for the sampling site it is necessary to observe the section first, usually from a distance, so that

the basic properties and the sediment assemblage of the target section can be easily understood from a macro perspective. If it basically meets the research needs, a close observation will be made to confirm and record the stratification, color and material composition of the sediments in detail. At last, the depth of each layer will be measured and marked (in centimeters). Then we could begin sampling.

The deposition rate in Baikal region is firstly considered and after comprehensive consideration, it was determined that the section will be sampled with 10–15 cm intervals between each sampling point.

When sampling, the topsoil is first removed to eliminate possible biological effects and organic matter interference. Then the samples will be taken from the bottom up at a proper interval to avoid the upper sediments falling into the lower part in the selected section. If there is no proper existing section a test trench will be dug. The test trench should be 1–1.5 m long and 1 m wide, and as deep as possible. One side of the test trench should be dug as stair-step whose interval between each step should be 10–15 cm. The sampling should begin from the bottom up and from each step respectively. Each sample should take 2–3 g and get a double-backup. The samples will be sealed in plastic bags and be marked before being packed.

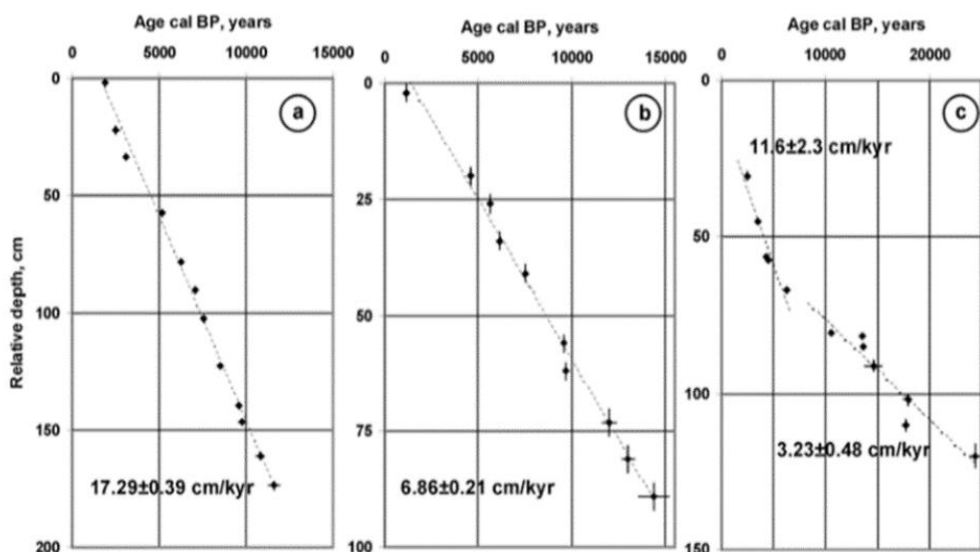


Fig. 1. Deposition rate in different regions in Baikal [7]
Рис. 1. Скорости осадконакопления в различных регионах Байкала [7]



As the main object of the research is to analyze the geochemistry feature of REE and REE is relatively stable in chemical properties there is no special requirements for samples' transportation and preservation. After putting the sample in the sampling bags, the air in the bags should be discharged. Then seal the bag, pack and transport them.

Sample information

During the expedition, we sampled in five locations representing different deposition modes and weathering environments. The sampling locations are shown in Fig. 2.

Nearby Kuchulga (SG1)

Location: 106°44'50.18"E, 53°2'54.79"N

Altitude: 497±8m

Many boulders of different sizes with good specificity can be seen near this location, which are the result of earthquakes and glaciation. Samples from here may indicate climate information such as quaternary glaciers. These samples were taken from the bottom to the top of the section at an interval of 10cm, and two groups were taken in parallel with 3 samples in each group.

Crust of weathering in Khuzhir Village (SG2)

Location: 107°20'43.11"E, 53°12'11.31"E

Altitude: 463±3m

This section is a weathering crust at Khuzhir Village, Olkchon island indicating chemical weathering (Fig. 3, 4). The sampling sites distribute tawny and white clay of 70–30 Ma. This area is in a tropical climate which means warm and oxidized. Then climate conditions changed after some time and the climate became colder, becoming a Mediterranean climate and forming white clay. Samples here may indicate climate change information. 10 samples were taken from the middle part of the section with a sampling interval of 10 cm.

Deposition section in Khuzhir (SG3)

Location: 107°20'44.64"E, 53°12'11.02"E

Altitude: 469±3m

The sampling site is at Khuzhir Village valley which is a crack generated by the uplift of Olkchon island. The water moves the unconsolidated sediments away to form a channel. Then the uplift continued and the water accumulated along the channel.



Fig. 2. Sampling points locations (label is the date of sampling)

Рис. 2. Расположение точек отбора проб (на этикетках указаны даты отбора)



Fig. 3. SG1 sampling location
Рис. 3. Расположение точки отбора SG1

The samples may contain characteristic information about the elements of lake water and some REE anomalies caused by the tectonic movement. The section was orange in color. We took samples from the top without plant roots at a 10 cm interval, with a total of 8 samples.

Deposition section in Zunduk (SG4)

Location: 107°25'31.77"E, 53°23'1.12"N
 Altitude: 471±8m

This samples were taken from a sedimentary section beside the lakeside at Zunduk (Fig. 5, 6). The section is in pale pink and the samples may contain information about the deposition mode of Lake Baikal. We took samples from the bottom to a point with a distance of 80cm to the top of the

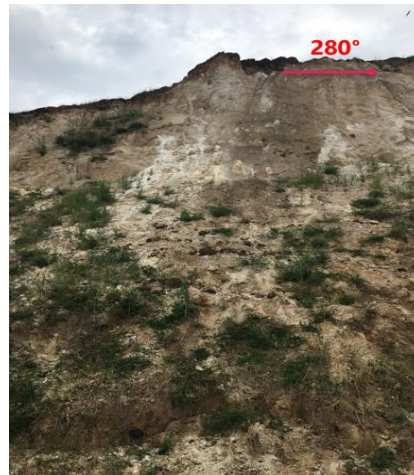


Fig. 4. Character of outcrop near the Kuchulga river
Рис. 4. Характер обнажения возле р. Кучулга

section, at a 10 cm interval between each of the 8 samples.

Southwest of Khoboy Cape (SG5)

Location: 107°43'08.09"E, 53°22'56.47"N
 Altitude: 485.7±12m

The sampling section is a weathering crust which located at the northeast corner of Olkchon island and the southwest of Khoboy Cape (Fig. 7). The weathering crust indicates chemical weathering and relevant researches show that it was formed in 3.5–3 Ma. The clay in different colors can be seen in the small scale area which is caused by the change of the chemical composition of the original rock. We obtained 7 samples from the pink clay with a 10 cm interval between each other.



Fig. 5. The deposition section in Khuzhir
Рис. 5. Фрагмент осадочной толщи в районе Хужира



Fig. 6. The deposition section in Zunduk
Рис. 6. Фрагмент осадочной толщи в районе Зундука



Fig. 7. The weathering crust in southwest of Khoboy Cape
Рис. 7. Кора выветривания на юго-западной оконечности мыса Хобой

Following research plan

This research will carry on sequentially by focusing on modern geochemistry analysis technologies, collected sedimentary samples from Baikal and how the REE geochemistry feature indicates the deposition mode and weathering environment. We intend to use ICP-MS, XRF and other modern geochemistry analysis technologies to detect the sedimentary samples from Baikal first to acquire the information related to REE. According to the preliminary research we need to acquire principal elements information and, certainly, REE data which includes: Σ REE, Σ LREE, Σ HREE, La content, Yb content, Ce content, Eu content and other necessary data [8–11]. What's more dating technology is also needed to determine the corresponding geological history period.

Although the relationship between the geochemistry feature of REE and the deposition mode and weathering environment has been widely studied, a systematic and complete interpretation model between them haven't been established. Another work of this research is to collected related literature widely so we could have enough existing work to analyze and obtain the

deposition mode information and the weathering environment information which are indicated by different REE geochemistry feature. Based on adequate analysis results we could establish a complete model which could be used to explain different REE geochemistry feature's meaning. We will use typical profile data in China to verify that model.

At the end based on the previous two achievements we will use the model with our data acquired from the samples of the Sino-Russian Joint Expedition to restore the deposition mode and weathering environment in Baikal during corresponding geological historic period.

The literature collection and collation work are in proper progress. The sample analysis should be thought carefully due to the possible improper preservation or other problems of the obtained samples. We now plan to use ICP-MS to analyze the first batch of samples so that we could preliminarily understand the content of REE in the samples and the reliability of the samples, and evaluate whether the samples have analytical value. If the data is reliable, much more following experiments will be carried on (Table).

Analyzing agenda details

Таблица полноты полученных данных для формирования цели их обработки

Batch	1	2	3
Sample code	SG3	SG2, SG4	SG5
Sampling location	Khuzhir	Khuzhir, Zunduk	Khoboy Cape
Analysis purposes	Evaluate sample storage status and obtain data	Obtain data	Obtain data



Acknowledgement

Even though the time has moved on, the moment when we first set foot on Lake Baikal seems like yesterday, with the beautiful singing, *the moon is so bright, how I yearn for it, at this fascinating night*, echoing in the ears. It has been nearly two mouths since we left Lake Baikal and the program is entering the experimental stage.

This July witnessed our encounter with Lake Baikal, the Siberian beautiful blue eyes, leaving a good memory of the summer. During the two weeks in Lake Baikal, we walked through 550 million years of Earth's history, learned to explore the story behind geological phenomenon and knew how to be down-to-earth, meditative and creative scientific researchers. We would like to extend our sincere gratitude to all the teachers and schoolmates who gives us support and encouragement. It is your tolerance and understanding that woven the unforgettable memory that belongs to us.

There is a person we must thank for her singly. We would like to say how grateful we are for the guidance and encouragement of Professor R. Lobatskaya, who always patiently answered our questions and gave us valuable advice on our program. She always

encouraged us to think out of the box to explore more possibility. Her rigorous academic and scientific attitude, optimistic and easy-going personality and professionalism are admirable, setting a good example for us. Her words that you most will be scientists in the future will forever inspire us forward.

Our deepest gratitude also goes to Professor Li Wei, our supervisor, who gives us constant guidance on research methods and experimental design and a lot of sincere encouragement. What's more, we would like to express our heartfelt gratitude to Professor Huang Zhouchuan for his guidance in the fieldwork and the help of implementing our program smooth development. We are also truly grateful for the help Professor Zhu Guorong and Professor Li Can gave us. Eventually we do appreciate our teammates of the program and everyone in the Sino-Russian Joint Expedition in Lake Baikal and Scientific Training team who made us feel at home even we were abroad and without their support and help our program can not go on wheels.

This is not the end. It is not even the beginning of the end. Remain our original aspiration and move forward bravely.

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Авторы заявляют об отсутствии конфликта интересов.

All authors have read and approved the final version of this manuscript.

Все авторы прочитали и одобрили окончательный вариант рукописи.



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