«Red-colored» Pliocene soils of linear levelling surfaces in Western Cisbaikalia (Russia)

N V Vashukevich¹, G A Vorobieva², S L Kuklina²

¹ Ural State Agrarian University, 42, Liebknecht str., Ekaterinburg, 620075, Russia
² Irkutsk State University, 1, Karla Marksa str., Irkutsk, 664003, Russia

E-mail: vashukevich@urgau.ru

Abstract. This paper presents a comparative assessment of «red-coloured» Pliocene soils studied at the well-known paleontological sites of Tologoi and Udunga (Transbaikalia) and new objects - the sections of the Mikhailovka and Kholmushino quarries (Western Cisbaikalia). Studies of Pliocene sediments and soils in Baikal Siberia have quite a long history. «Red» Pliocene soils are sporadically found within the Baikal rift zone and on the Siberian platform - on fragments of the near-valley levelling surface at elevations of 70-120 m above the edge of the Angara River and its tributaries. A comparative assessment of the studied sections with similar age and morphology of the deposits of Transbaikalia showed that the deposits differ quite significantly in the content of rock-forming oxides. In particular, in the sediments of Western Cisbaikalia, a higher content of silicon oxide and a lower content of sesquioxides are observed, which might be evidence of worse conditions for heat and moisture supply in this region. An excess of the Clarke values characterizes the rare-earth elemental composition of the Pliocene deposits of Transbaikalia for La, Ce, Nd, Yb, while the deposits of the Western Cisbaikalia contain these elements in amounts lower than those of the Clarke ones.

1. Introduction
The Pliocene as the final section of the Neogene period of the Cenozoic era began 5.4 and ended 2.6 million years ago. This is the final stage of the global climate-cooling trend that led to the Quaternary ice ages. Current knowledge of the Pliocene global climate system remains very incomplete, due to the difficulties of obtaining well-dated paleoecology data.

In 2014, materials on the international project PRISM (Pliocene Research Interpretations and Synoptic Mapping) of the US Geological Survey were published [1]. The project aimed to interpret Pliocene materials for predictive assessments and a deeper understanding of global climate warming consequences. The project collected materials, including for Pliocene soils. The database contains 54 ground sections. The Eurasian territory represents two sections from Ukraine and one section from the Olkhon Island on Lake Baikal. The main problem is the lack of well-studied objects of Pliocene continental sediments, in contrast to their marine analogues.

Together with paleosols works, sedimentologists, geochemists, geomorphologists, specialists in paleomagnetic stratigraphy are actively studying Pliocene deposits [2, 3].

Therefore, information on the Pliocene sections is sufficiently presented in the literature. The works of the last four decades have a diverse focus, but mainly the soils of the Pliocene time are studied by specialists as the Hipparion Red-Earth Formation (namely the «Red Clay»). The most
significant studies of these deposits have been carried out for many years in the Loess Plateau region of China [4, 5]. A long history studies red clays in Europe, in particular in Hungary [6, 7].

In addition, studies of Pliocene sediments and soils in Baikal Siberia have a long history [8, 9]. «Red» Pliocene soils are sporadically found within the Baikal rift zone (Olkhon region, Olkhon Island) and on the Siberian platform - on fragments of the near-valley levelling surface at elevations of 70-120 m above the edge of the Angara River and its tributaries.

For the Lower and Upper Pliocene soils, the stratigraphic position is confirmed by data on the fauna of small mammals, malacofauna, and materials from paleomagnetic studies. During a significant part of the Miocene and Pliocene, red fersiallitic, vertisols, red-brown paleosols of a dry subtropical climate with a definite stratigraphic sequence were developed in the Baikal region.

At the top of the section, there are red-brown fissured paleosols, intensively carbonated in the roof (caliche). Its formation is associated with the pre-Late Pliocene hiatus. Mainly pale yellow slope sediments often interbedded with red-coloured pedo-sediments represent the subaerial sediments separating and underlying paleosols in the Miocene-Pliocene sections. Pliocene slope deposits are usually carbonated. This complex corresponds to the concept of red clay.

Among the paleosols of the Late Pliocene, from the bottom up the section, the following is noted: dark brown, a series of brown and reddish-brown soils, cryogenic gley and grey forest soils. Thus, in the second half of the Late Pliocene, subtropical brown soils disappear; they are replaced by soils of cold and moderately cold climates with syngenetic cryogenic deformation, indicating the existence of permafrost soils at the end of the Pliocene and a climate colder than the present one [10, 11].

On the territory of Transbaikalia, Pliocene soils have been studied at the paleontological sites of Tolgoi and Udunga. Red-coloured clays and loams with rubble, grit, carbonate concretions, fragments of humus interlayers were found at the foot of Mount Tolgoi. Attributed to the Upper Pliocene Tolgoi Formation, we found bone remains - *Hipparion, Rhinoceros*. The stratum of clays lies on the red-coloured alaskite granites of the Paleozoic age [12].

In the Udunga section, deposits of the Pliocene (Ruscinia) red-coloured montmorillonite-carbonate formation, which contain bone remains of the Udunga faunistic complex, were found. Bone remains are comb-toothed mastodon, Hipparion, thin-bodied monkeys. The clay layer lies on the Lower Paleozoic granites [13].

This paper presents a comparative assessment of red-coloured Pliocene soils studied at the well-known paleontological sites of Tolgoi and Udunga (Transbaikalia) and new objects - the sections of the Mikhailovka and Kholmushino quarries (Western Cisbaikalia).

2. Materials and methods
The Mikhailovka and Kholmushino quarries where the samples of Pliocene clays were taken belong to the Troshkovskoye refractory clay deposit. It is located 20 km from the city of Cheremkhovo (Irkutsk region) on the linear levelling surfaces in the interfluve of the Angara and Belaya rivers.

The sediments studied by us in the quarries are 2-3 m thicknesses of brown, red-brown and red-coloured loams and clays with horizons of carbonate nodules accumulation (figure 1), basically brownish with various shades of reddish and brownish tones of colour (5YR4/4; 5YR2. 5/2; 7.5 YR 3/2 according to the Mansell atlas).

The age of the deposits is recorded according to geological data. In the Mikhailovka and Kholmushino quarries, where the soil data studied, montmorillonite clays of Miocene age are extracted. The overlying sediments attributed to the Pliocene clays of the Troshkovskoye strata.

The samples were taken in the field (10 in total, 5 each from the section) were analyzed in the laboratory of the Limnological Institute of the Siberian Branch of the Russian Academy of Sciences. The main issues of sample preparation and analysis are set out in the work [14].

The prepared samples were measured on an Agilent 7500 ce ICP-MS quadruple mass spectrometer. Inert polypropylene injection systems are for aggressive samples. The measurements were carried out in the "hot plasma" mode (plasma generator power 1580 W) without a collision cell. A series of mixed standards is prepared from High-purity standards (Charleston, USA) ICP-MS-68A-A and ICP-MS-
68A-B multielement standard solutions used to calibrate the mass spectrometer. The calibration graph was built according to four standards: 0; 0.1; 10.0 and 100 ppb.

Figure 1. The Mikhailovka quarry: a - general view of red clay deposits, b - soil profile; sediments overlying red clay.

3. Results
Based on the conducted studies, it was revealed that the brown and reddish-brown soils of the Mikhailovka and Kholmushino quarries sections (Western Cisbaikalia) have more acidic pH values, lower content of carbonates, and higher content of humus and silt fraction than their studied counterparts do in the Pliocene soils Transbaikalia. In the sediments of the Tologoi and Udunga sites, a higher content of CaO, MgO, Na_2O, and K_2O was found, which might be associated with the aridity of the territory.

The ambiguity of the geochemical composition of the studied Pliocene deposits of different regions adjacent to Lake Baikal is well traced when considering the content and distribution of rare earth elements (REE).

Consideration of the nature of the lanthanides distribution curve is violated when considering the brownish-red-brown soils of the Western Cisbaikalia (Mikhaylovka). In them, the contents of La and Ce are similar, which is not typical of the logic of these elements distribution in other sediments and the bulk earth values in the earth's crust. Obviously, during the formation of these deposits, the geochemical conditions changed dramatically, both relative to the underlying strata and relative to the deposits of another region.

Geochemical lanthanides fractionation in soils was carried out by calculating the europium anomaly in both groups of Pliocene soils of the Pre-Baikal and Trans-Baikal regions.

In general, the indicator was positive for all soils. It is slightly lower in the soils of the Western Cisbaikalia. At the same time, it was previously noted that the rocks of the eastern coast, where the Angara-Vitim batholith is located, have a positive europium anomaly in the batholith granites (Eu/Eu* = 1.1-4.0), which is usually not typical of granites. On the west coast, there is no such thing in the rocks.

All this requires further more detailed studies, but it can be assumed that the processes of Pliocene soil formation on the initially different rocks of the western and eastern shores of Lake Baikal have reduced these anomalies.

4. Conclusion
Detailed paleosols studies of red-coloured Pliocene sediments and soils of the Mikhaylovka and Kholmushino sections were conducted for the first time. A comparative assessment of the studied sections with similar age and morphology of the deposits of Transbaikalia showed that the deposits differ quite significantly in the content of rock-forming oxides.

In particular, in the sediments of Western Cisbaikalia, a higher content of silicon oxide and a lower content of sesquioxides are observed, which might be evidence of worse conditions for heat and moisture supply in this region. An excess of the Clarke values characterizes the rare-earth elemental composition of the Pliocene deposits of Transbaikalia for La, Ce, Nd, Yb, while the deposits of the Western Cisbaikalia contain these elements in amounts lower than the Clarke ones.

References
[1] Pound M J, Tindall J, Pickering S J, Haywood A M, Dowsett H J and Salzmann U 2014 Late Pliocene lakes and soils: a global data set for the analysis of climate feedbacks in a warmer world Climate of the Past 10(1) 167–80
[2] Zhao G, Han Y, Liu X, Lü B, Chen Q, Zhang R, Ma J, Li H, Zhao J 2020 Causation and mechanism of magnetic susceptibility trend in Upper Miocene–Pliocene red clay deposits of the eastern Chinese Loess Plateau Palaeogeography, Palaeoclimatology, Palaeoecology 560 110014
[3] Junsheng N, Song Y and King J W 2016 A Review of Recent Advances in Red-Clay Environmental Magnetism and Paleoclimate History on the Chinese Loess Plateau Frontiers in Earth Science 4 27
[4] Nie J, Peng W, Möller A, Song Y, Stockli D F, Stevens T et al 2014 Provenance of the upper Miocene-Pliocene red clay deposits of the Chinese loess plateau Earth Planet. Sci. Lett. 407 35–47
[5] Qiansuo W, Song Y and Li Y 2020 Clay mineralogy of the upper Miocene-Pliocene red clay from the central Chinese Loess Plateau and its paleoclimate implications Quaternary International 552 148–54

[6] Kovács J, Varga G and Dezső J 2008 Comparative study on the Late Cenozoic red clay sediments from China and Central Europe (Hungary) Geol. Quart. 52 (4) 369–382

[7] Kovács J, Fabian S A, Varga G, Ujvari G, Varga G and Dezs J 2011 Plio-Pleistocene red clay deposits in the Pannonian basin: a review Quaternary International 240 35–43

[8] Mats V D, Lomonosova T K, Vorobyova G A and Granina L Z 2004 Upper Cretaceous–Cenozoic clay minerals of the Baikal region (Eastern Siberia) Applied Clay Science 24 327-336

[9] Mats V D 2013 Late cretaceous and cenozoic stratigraphy of the Baikal rift sediments Stratigraphy and Geological Correlation 21(6) 637-651

[10] Vorobieva G A, Mats V D, Shimaraeva M K 1987 Pliocene-Eopleistocene soil formation on Lake Baikal Russian geology and geophysics 9 20-28

[11] Vorobieva G A, Mats V D, Shimaraeva M K 1995 Paleoclimates of the Late Miocene, Pliocene and Eopleistocene of the Baikal region Russian geology and geophysics 8 82–96

[12] Ivanova V V, Erbaeva M A, Shchetnikov A A, Kazansky A Yu, Matasova G G, Alekseeva N V, Filinov I A, Kuzmin M I 2020 The Tolgoi key section (Upper Cenozoic, Transbaikalia): reconstruction of the peculiarities and depositional environment Russian geology and geophysics 61 (120) 1672-1691

[13] Kalmykov N P 2017 The location of Udunga (Western Transbaikal region, Russia): Geology and mammalian fauna of the Early Pliocene Otechestvennaya geologiya 2 76-82

[14] Zhuchenko N A, Chebykin E P, Stepanova O G, Chebykin A P, Gol'Dberg E L 2008 Microwave digestion of bottom sediments from Lake Baikal for the inductively coupled plasma mass-spectrometric determination of their elemental composition Journal of Analytical Chemistry 63(10) 943-949