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Chocolate clays of the Northern Caspian Sea Region: Distribution, structure, and origin

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ABSTRACT

The chocolate clays commonly comprise a part of the Lower Khvalynian sequence in the northern Caspian Lowland and in the Volga region. The mode of occurrence varies from continuous to patchy mosaic. All the clay deposits are confined to Pre-Khvalynian depressions of various origins. There are several sub-facies distinguishable within the chocolate clay facies: mono-clayey (typologic), stratified sandy-clayey and silty-clayey. Judging from specific features of lithology, geomorphic position, mode of occurrence, mollusc fauna composition, and radiocarbon dates, the chocolate clays represent a specific facies of the Lower Khvalynian sediments and cannot be considered as an individual stratigraphic unit.

1. Introduction

Among the Pleistocene marine deposits of the Caspian Sea, one of the most interesting facies are the “chocolate clays”. They are widely distributed in the Volga and Ural river valleys of the North Caspian Sea region in the form of sporadic or continuous covers.

The first description was obtained by Baer (1856) from outcrops near Enotaevka in the Volga River valley. Detailed description of a section that contained chocolate clays was first introduced by P.A. Pravoslavlev. The first researchers described chocolate clays as chocolate-brown slaty clays. A laconic and concise description of the chocolate clays was proposed by Shantser (1951): “… Chocolate clays represent horizontal bedding that contains alternation of thin dense layers, heavy clays and light silty clay”. These layers, especially clays, split into parallel platy parting.

Since K. Baer first mentioned the clays in 1856, they were discussed in a number of papers (Pravoslavlev, 1908; Britsyna, 1954; Priklonsky et al., 1956; Fedorov, 1957; Arkhipov, 1958; Vasiliev, 1961; Obedientova, Gubonina, 1962; Svitoch, Yanina, 1997; Badyukova, 2000; Chistyakova, 2001; Shantser, 1951; Leonov et al., 2002; Tudryn et al., 2013). In spite of long-term investigations performed by many specialists, numerous problems are still under discussion, including the topic considered below: are the chocolate clays to be considered as a specific formation or facies? To analyze the problem, the authors give attention to the spatial distribution, occurrence and structure, characteristics of the clay facies and lithology, color, and the type of fossil mollusc fauna.

2. Materials and methods of the analysis

All materials and data about chocolate clays have been obtained by field research expeditions in key sections of the North Caspian Sea Region and the Volga Region. A wide range of methods was used, such as lithological, mineralogical, geomorphological, malacofaunistic and radiocarbon. The key sections were minutely layer-by layer studied, fossils recovered from the sections were described, and ^{14}C dates were obtained.

3. Results

3.1. Spatial distribution of the chocolate clays

The chocolate clays are mostly confined to the middle and lower reaches of the Volga R. (Fig. 1), including the left and right sides of the Volga and Akhtuba valleys and the Volga R. delta, as well as the Kalmykia region adjoining the Volga valley. They are found also within a linear zone of depressions from the Kaisatskoe settlement to Elton and Verkhniy Baskunchak lakes, and in the Ural R. valley. The largest area of the chocolate clays is found in the Volga valley, on its 2nd terrace between the city of Samara and the Yenotaevka settlement. Farther east, on the Volga-Ural interfluve, typical chocolate clays practically disappear (Svitoch, 1968). The clays occur in the Ural R. valley and form the sedimentary cover of the Khvalynian plain.

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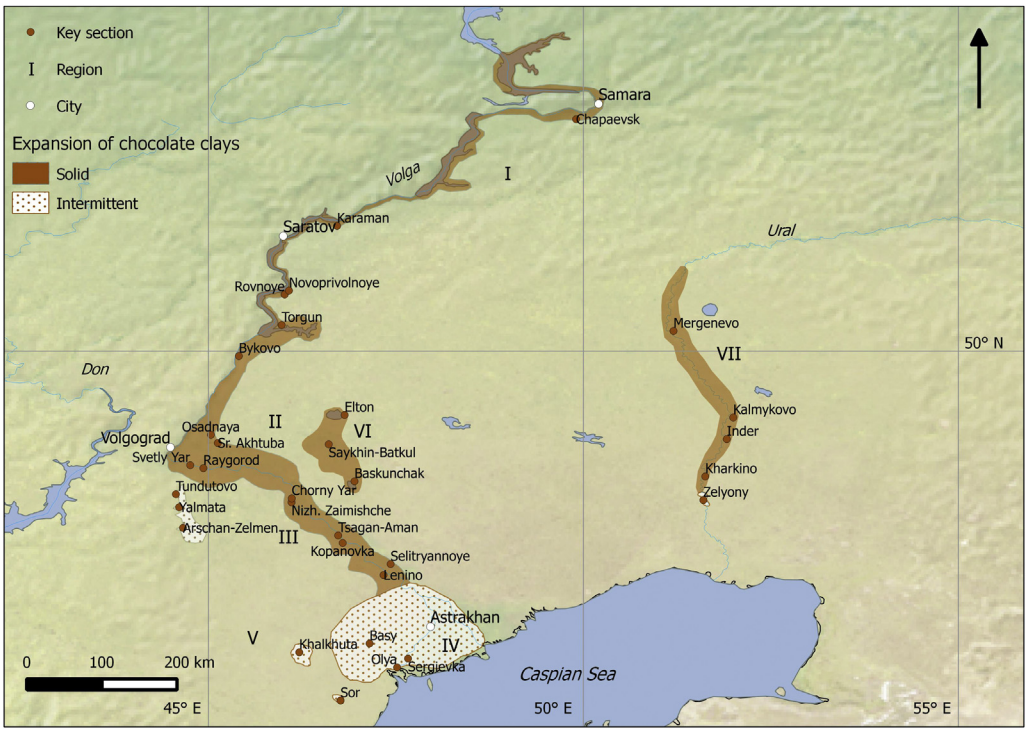

Fig. 1. Spatial distribution of chocolate clays in the Northern Caspian and Volga regions. (I – Middle reach of the Volga R, II – left side of the Lower Volga valley, III – right side of the Lower Volga valley, IV – delta Volga, V – Kalmykia, VI – Kaysatskoye – Elton – Verkhnyi Baskunchak, VII – Ural River valley).

In the middle reach of the Volga R., the chocolate clays were studied by Mazarovich (1935), Koptev (1966), and Obedientova and Gubonina (1962). The clays form a continuous mantle over the 2nd terrace of the Volga R. and of its large tributaries, such as Bolshoi Irgyz, Maly Irgyz, Yeruslan, and Bolshoi Cheremshan. They penetrate far into the interfluvial plateau along ancient erosional landforms. They are found in the Bolshoi Irgyz valley 70 km east of the Volga R. The zone of their occurrence in the ancient Volga estuary between the Caspian Lowland and the Zhiguli Heights is 2 to 30–40 km wide (Obedientova and Gubonina, 1962) and about 600 km long (from S to N). The northernmost point of occurrence of the chocolate clays is recorded at the Bolshoi Cheremshan River mouth. The chocolate clay interlayers are found in the sequence of the 1st terrace of the Volga within the reservoir area of the Volzhskaya hydro-electric power station (Obedientova and Gubonina, 1962). Over the greater part of the Volga valley in its middle reaches the top of the chocolate clays occurs at an altitude from 30–40 m to 25–20 m a.s.l. gradually lowering towards the Caspian Lowland (Vasiliev, 1961; Moskvitin, 1962; Obedientova and Gubonina, 1962).

The Khvalynian deposits in the middle reaches of the Volga are dominated by the chocolate clays that occur usually at the base of the sequence. In the north of the region (Chapaevsk (~28 m a.s.l., N 52°53′41.37″, E 49°38′04.43″), Maly Karaman (~30 m a.s.l., N 51°40′18.20″, E 46°50′13.54″) and Rovnoye (~15 m a.s.l., N 50°45′27.90″, E 46°01′41.38″) sections), the clays are overlain by stratified sands and loams. Farther south (Novoprivolnoye (~18 m a.s.l., N 50°48′08.03″, E 46°05′22.05″) and Torgun (~15 m a.s.l., N 50°17′33.04″, E 45°57′55.28″) sections), the Khvalynian sequence is more complicated, including several members of the chocolate clays in the upper part and at the base of the section. Typically, the index species of the brackish-water mollusc fauna are completely absent, while freshwater molluscs are found occasionally.

The Lower Volga region is known as the largest area of the chocolate clay distribution. They form the vast 2nd terrace of the Volga and occur in depressions of the Early Khvalynian plain on the Caspian Lowland. It was here, at the Chorny Yar (~–5 m a.s.l., N 48°01′55.47″, E 46°06′43.04″) section, that they were first described by Baer (1856). Later, they attracted an interest of many specialists (Pravoslavlev, 1929; Nikolaev, 1935; Zhukov, 1945; Kovda, 1950; Britsyna, 1954; Fedorov, 1957; Arkhipov, 1958; Vasiliev, 1961; Menabde et al., 1991; Svitoch et al., 1995; Svitoch and Yanina, 1997).

The deposits are exposed in picturesque erosional scarps on the left bank of the Akhtuba (the left distributary of the Volga R.) and on the right side of the Volga. The latter displays the section of the ancient Volga estuary filled with the chocolate clays and other marine deposits. The top of the clays is at 25–20 m a.s.l. in the north of the Caspian Lowland and descends gradually southward to –5 m at the Chorny Yar and Selitryannoye settlements and to 10 m below sea level at the head of the Volga delta. The depth of the Pre-Khvalynian erosion (which controls the thickness of the chocolate clays) in depressions averages to 2–4 m, although it may change over a small distance. For example, the clays are 10 m thick in the Svetly Yar (~5 m a.s.l., N 48°29′10.37″, E 44°46′36.42″) section, while 5 km south, at Raygorod (~6 m a.s.l., N 48°25′49.82″, E 44°57′41.10″), the thickness is reduced to 2 m, which suggests a considerable irregularity of the Pre-Khvalynian bed topography.

On the left side of the Lower Volga valley and its distributary Akhtuba, the chocolate clays are exposed in the sections of Bykovo, Osadnyaya, Srednya Akhtuba, and Selitrennoe. Their position and structure vary considerably from one exposure to another. At the northern localities of Bykovo and Srednaya Akhtuba (~15 m a.s.l., N 48°41′54.22″, E 44°54′33.26″), the sequence is dominated by the chocolate clays underlain or overlain with sands. In the middle part, interbeds of sand and silt with shells of index Khvalynian mollusks are common. In the south, the chocolate clays also include sand and silt interbeds with shells of index species *Didacna protracta*, mostly in the central part of the sections. Noticeable variations in the sedimentation environments occur from south to north.

On the right side of the Lower Volga valley, chocolate clay outcrops are found in abundance from Volgograd to Lenino settlement.

The region concentrates the most representative and best studied sections in the northern Caspian Lowland. The chocolate clays infill the estuary of the Pre-Khvalynian surface. The sequence displays local variations related to different environments of sedimentation. In the north (Svetly Yar, Raigorod localities) there are large members of massive chocolate clays separated by stratified sands and silts with abundant fauna of Khvalynian molluscs. Farther south (Chorny Yar, Nizhneye Zaimishche (~−4 m a.s.l., N 48°00′01.45″, E 46°06′35.96″)) the Khvalynian deposits are reduced in thickness, and the chocolate clays are overlain with sands including Khvalynian mollusc shells. Still farther south, within the area of Baer's mounds, the underlying Lower Khvalynian deposits consist commonly of interstratified layers of chocolate clays and sands. The sandy interbeds in the clays are noted for abundant and diversified mollusc fauna, indicative of a hospitable living environment.

The Volga delta is the southernmost area of the chocolate clay occurrence where they were primarily studied by Pravoslavlev (1926), Zhukov (1945), Krasnova and Rachkovslaya (Geology of the Volga River delta, 1951), Vasiliev (1961), Britsyna (1954), Menabde et al. (1991), Svitoch and Yanina (1997), and Kroonenberg et al. (2005). Unlike other regions in the Lower Volga region, the chocolate clays occur in the delta as individual patches in the core of the Baer's mounds. These are remains of the basal part of deposits underlying the mounds and are almost completely eroded in the inter-mound areas. That may account for the fact that the clays form low (1–3 m) elevations in the buried relief, though it is evident that the clays had been initially deposited in depressions of the Pre-Khvalynian delta. In the most complete sequences of Baer's mounds, the lower part of the Lower Khvalynian deposits is usually exposed, composed of chocolate clays with interbeds of well sorted sands containing various index taxa of Khvalynian molluscs. The upper part of the sequence mostly consists of rather thin layers of sand. The chocolate clays found in the basal part of the sections mark probably the deepest sites of the sea bottom at the initial stage of the Lower Khvalynian deposition.

There are some variations in the clay distribution over the Volga delta. The clays are found everywhere in the sub-steppe lakes (ilmens) in the west and east of the delta. Their base occurs at 24.3–34.3 m below sea level (Geology of the Volga River delta, 1951) and is noticeably tilted southward and towards the delta center. The inter-mound areas (where the chocolate clays were eroded) are greater in size in the eastern sub-steppe ilmens as compared with the western regions.

In the central portion of the delta, the Baer's mounds and the underlying chocolate clays are mostly eroded and persist only in western and eastern parts in the cores of rare mounds. The drilling data, however, indicate the presence of the chocolate-like clays on the semi-flooded areas of the foredelta (Kroonenberg et al., 2005). It is quite possible that their occurrence is controlled not only by location of the eroded mounds, but even more by the initial deposition of the clays in the Pre-Khvalynian distributaries of the Volga delta.

In common with the Volga delta, the Kalmykia region displays a mosaic pattern in the chocolate clays occurrence (Barbot-de-Marni, 1868; Nikolaev, 1962). Here they occur as deposits of small thickness in depressions varying in shapes and sizes, presumably the result of wind erosion and/or salt weathering. Hypsometrically, the clays are found at 10–15 m a.s.l. at the base of sediments infilling the depressions and up to −25 m under the Baer's mounds at the Krasinsky and Lagan localities. No chocolate clays have been found in the flat-bottom depressions. The latter are usually filled with shallow horizontally stratified formations composed of sands and clays. The clays are brown and contain an original assemblage of the Khvalynian molluscs (*Didacna subcatillus*, *D. cristata*). The chocolate clays are recorded in proximity to the Fore-Ergeny scarp, in deeply incised balkas and small river valleys at elevations of about 30–35 m a.s.l. They are also known from the section at the Vostochnyi Manych. In the key section of “Levyi Ostrov”, the chocolate clays occur at the base of the Khvalynian sequence and are overlain with stratified sands and sandy silts containing Khvalynian mollusc shells (*Didacna protracta*, *D. ebersini*, and others) (Svitoch et al., 2010).

In the northern Caspian Lowland, there is a system of depressions varying in form and size extending approximately from north to south for about 200 km. Among them\ are depressions related to salt tectonics (compensatory), lower segments of the Atelian Paleo-Volga, and lacustrine and lagoonal basins filled with the chocolate clays. Britsyna (1954) studied them in details at the sites of Saikhin – Batkul, Verkhniy Balykley – Vladimirovka, Verkhniy Baskunchak – Shungai, and Verkhniy Baskunchak – Loshchina. In the opinion of that researcher, the Khvalynian sediments in the region are typically three-layered, with chocolate clays occurring in the central part of the sequence. In the south, near Verkhniy Baskunchak, the chocolate clays are abnormally thick, in excess of 15 m. The sandy layers abound in Khvalynian mollusc shells attributed to index species *Didacna protracta*, and *D. cristata*. Unlike other regions where the chocolate clays are overlain with sands, the upper layer consists of gray-brown sandy loam and silts.

In the Ural River valley, in common with the Volga valley, the chocolate clays fill a large hollow, a part of the former estuary. The estuary extended beyond the limits of the Ural valley onto the adjacent Early Khvalynian plain. A series of key sections in the middle reaches of the river (Mergenevo, Kalmykovo, Kharkino) reveal the clays at elevations from 10 to 0 m a.s.l. Farther upstream the chocolate clays are recorded north of Uralsk town in the Kozhekharovsky and Chapaevo sections (Yakhimovich et al., 1986). In the lower reaches of the Ural R. (south of Zelyony) the chocolate clays are replaced with Khvalynian sands with characteristic fauna (Svitoch and Bratanova, 1998). Massive varieties of the chocolate clays are missing from the Ural R. valley. In widely distributed interlayed clays and sands, the clays usually compose the middle part of the sequence and are overlain with silts and sands with abundant mollusc fauna (*Didacna protracta*, *D. parallella*, *Micromelania caspia, Hypanis plicatus*, *Dreissena polymorpha*) of Khvalynian age. The Volga estuary considerably exceeded the Uralian bay of the Khvalynian Sea in area.

The chocolate clays are a few meters thick on average. The maximum thickness (9 m) was recorded at the northern side of Inder Lake, in a depression related to a salt dome (Yakhimovich et al., 1986).

3.2. Analysis

The chocolate clays of the northern Caspian Lowland and the Volga valley occur either as a continuous mantle, or as isolated patches (mosaic). The mantle-like occurrence is typical of the valleys of the Volga and its larger tributaries, the Ural valley in its middle reaches, and a chain of depressions east of the Akhtuba. There, the clays fill vast Khvalynian estuaries and large topographic depressions related to the salt tectonics.

Mosaic (patchy) distribution of the clays is typical of the Volga delta, Kalmykia, and presumably the right side of the Ural valley. Such a distribution may be original, inherent to depressions where the clays had been deposited (Kalmykia), or secondary, resulting from a partial erosion of the chocolate clay mantle, as is the case in the Volga delta where clays are commonly absent from inter-mound surfaces due to erosion. The chocolate clays had been completely eroded from most of the modern valley bottoms. That is true in particular of the Volga and the Ural rivers and their principal tributaries.

The chocolate clays are confined exclusively to topographic depressions. The depressions, however, may vary in origin, outlines and size. The largest are linear erosional landforms, valleys of the Volga and the Ural and of their large tributaries, hundreds of

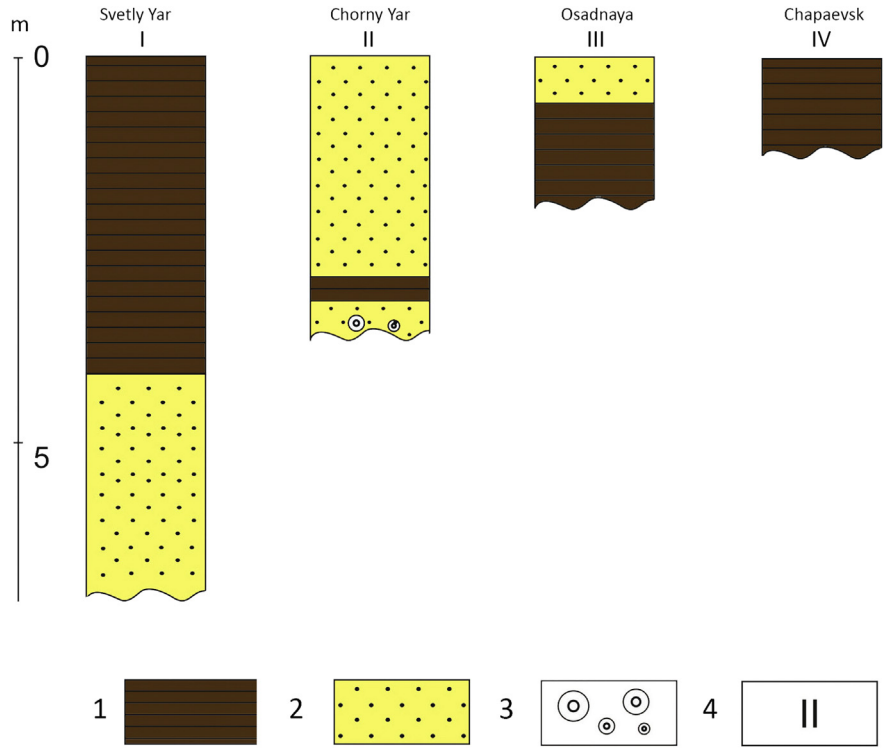

Fig. 2. Position of the chocolate clays with reference to the sequence of the Lower Khvalynian marine sediments: (I – in the upper part, II – in the middle part of the sequence, III – at the base, IV – all over the sequence); 1 – chocolate clays; 2 – sands; 3 – marine mollusc fauna, 4 – section location.

kilometers long and a few tens of kilometers wide. Vast fields of the chocolate clays are found within closed and semi-closed round depressions genetically related to salt tectonics. Some basins were initially lagoons and limans of the Early Khvalynian Sea. They are elongated rounded depressions, U-shaped in cross-section, with gentle slopes, 1–3 to 10–15 km wide, and a few meters (occasionally up to 20–30 m) deep.

Numerous, though limited in area, are patches of the chocolate clays occurring in lake and sor basins, in depressions eroded by wind, and in depressions within steppe paleo-channels. This distribution is typical of Kalmykia, the right side of the Volga valley and the Volga-Ural interfluve. Less common is occurrence in a somewhat elevated position, at the base of the Baer's mound (Olya, Basy, Lenino (~–15 m a.s.l., N 47°01′22.00″, E 47°19′15.51″), Sergievka, etc.). It is not inconceivable that in some cases this may have resulted from erosion of the overlying layers.

As a rule, the chocolate clays occur in the Lower Khvalynian sequence as a single lithological member of variable thickness, with two-layer occurrence (Torgun, Raygorod, Bykovo) less common. The Lower Khvalynian deposits exposed in Rovnoye, Svetly Yar, Novoprivolnoye, Olya, Basy, and Sergievka consist solely of the chocolate clays.

Stratigraphically, the chocolate clays fall completely within the range of the Lower Khvalynian interval. They contain two types of Khvalynian molluscs, the distribution of each being controlled by living environments. The mollusc shells are practically absent from the clays, with exception of scarce thin-valved *Monodacna caspia* and *Hypanis plicatus*. In sandy interlayers, however, shells are numerous and diversified in composition. Among them are species typical of the Early Khvalynian mollusc assemblage (*Didacna protracta*, *D. trigonoides*, *D. parallella*, *Dreissena distincta*, *Dr. polymorpha*, and others). It is noteworthy, that while all the finds are usually confined to a single sandy interlayer, the latter may occur in different parts of the clay member (Britsyna, 1954). There are some exceptions from the rule, such as in the key section of the Lower Khvalynian Tsagan-Aman (~–9 m a.s.l., N 47°32′04.36″, E 46°44′02.94″). In that section, mollusc shells occur in sandy interbeds distributed throughout the clay unit, which suggests highly variable environments during accumulation.

According to the ^{14}C dates obtained by Kh. A. Arsllanov in 2013 (Table 1), the period of the chocolate clay accumulation falls between 11 and 15 ka BP. Similar results, between 12 600 ± 130 and 13 240 ± 45 BP, were obtained by radiocarbon dating (Svitoch, 1997) and by AMS dating (Leonov et al., 2002).

Table.1Radiocarbon dates of the mollusk shells.

Lab. no	Sample	Depth, (m)	Material	Conventional ^{14}C age, year	Calendar age, year
LU-7032	Point 10, sample 1, Svetly Yar	2.4	Thin-valved shells	11 760 ± 150	13 650 ± 160
LU-7033	Point 10, sample 2, Svetly Yar	5.6	Thin-valved shells	11 790 ± 230	13 730 ± 270
LU-7034	Point 9, sample 3, Svetly Yar	9.7	Thin-valved shells	11 450 ± 210	13 340 ± 210
LU-7035	Point 14, sample 4, Cherny Yar	1.8	Thin-valved shells	11 890 ± 150	13 810 ± 170
LU-7036	Point 14, sample 5, Cherny Yar,	3.2	Thin-valved shells	12 690 ± 230	15 270 ± 570
LU-7037	Point 7, sample 6, Srednaya-Akhtuba	2.2	Thin-valved shells	11 680 ± 150	13 570 ± 160
LU-7038	Point 14, sample 7, Cherny Yar,	3.8	Thin-valved shells	12 790 ± 210	15 550 ± 590
LU-7039	Point 12, sample 2, Cherny Yar	1.5	Thin-valved shells	11 380 ± 210	13 290 ± 210
LU-7040	Point 12, sample 6, Cherny Yar	2.3	Thin-valved shells	11 650 ± 150	13 540 ± 160
LU-7041	Point 12, sample 10, Cherny Yar	2.9	Thin-valved shells	12 000 ± 140	13 980 ± 220
LU-7042	Point 12, sample 11, Cherny Yar	3.3	Thin-valved shells	12 360 ± 110	14 510 ± 260

Note: Calendar age is calculated using "CalPal" software, 2006, Universität zu Köln, B. Weninger, O. Joris, U. Danzeglocke (www.calpal.de).

The chocolate clay position in the generalized section of the Lower Khvalynian may vary over a wide range (Fig. 2). It have been identified as a stratigraphic horizon in the middle part of the section (Vasiliev, 1961; Britsyna, 1954; Fedorov, 1957), at its base (Obedientova and Gubonina, 1962), and at the top (Morozov, 1955).

The chocolate clays occur at the middle part of the Lower Khvalynian sequence and are underlain and overlain by sands with Khvalynian fauna. In the Lower Volga valley, the clays are often found at the base of the sequence, while in the northernmost part of their range the entire Khvalynian series is composed of the clays. On the whole, the clay horizon is discontinuous, being confined to depressions of the Khvalynian base and at various altitudes (occasionally as high as +40 m a.s.l.). Te chocolate clays cannot be identified as an individual stratigraphic horizon, as they do not bear index mollusc species and their position in the sequence may vary. The characteristics of the chocolate clays (lithology, fauna, structure and occurrence, color) determine them as a facies of the Early Khvalynian marine deposits, quite specific in its depositional environments unique to this basin (Shantser, 1951; Priklonsky et al., 1956; Moskvitin, 1962; Svitoch and Yanina, 1997).

Chocolate clays are light-brown and dark-brown mudrock with platy-prismatic structure that contain manganese and gypsum staining. X-ray diffraction and thermal analyses (Table 2) indicate the prevalence of clay minerals with polymineral structure (95–97%). Fractions that are less than 0.002 mm consist of illite 33–48%, kaolinite 16–33%, chlorite 8–23%, montmorillonite 3–28%, and mixed layers 4–12%. In general, all analyzed samples are relatively similar to recent terrigenous materials of the Volga river.

Table 2
Sample details and X-ray diffraction analysis of clay minerals (<0.002 mm).

No.	Section	Lithology	Level (cm)	Kaolinite	Illite	Chlorite	Montmorillonite	Mixed layers
GF-1	Middle Volga	Red clay	–	5	15	10	60	10
GF-2	Svetly Yar	Chocolate clay	200	29	40	9	7	15
GF-3	Upper Volga	Moraine clay loam	–	33	45	–	22	–
GF-4	Svetly Yar	Chocolate clay	300	33	43	8	8	8
GF-5	Svetly Yar	Chocolate clay	600	26	48	17	3	6
Obr.1–13	Svetly Yar	Chocolate clay	150	27	33	21	13	6
Obr.2–13	Svetly Yar	Chocolate clay	530	22	34	23	9	12
Obr.3–14	Svetly Yar	Chocolate clay	950	18	40	19	13	10
Obr.4–14	Novoprivolnoye	Chocolate clay	670	16	33	17	28	6
Obr.5–15	Torgun	Chocolate clay	150	25	38	22	11	4

The color is determined by oxide inclusions of hydrogoethite (FeOOH) and manganese. Hydrochloric acid extracts show iron sesquioxides in clays, Fe_2O_3 in particular (Priklonsky et al., 1956).

The composition of chocolate clays was compared to moraine clay loam of the Upper Volga region and Permian–Triassic red clays of the Middle Volga region. The data reveals significant difference between chocolate clays and Permian–Triassic red clays, and shows similar composition to clay minerals in moraine loam. This similarity suggests that intensive degradation of Valdai glacier ice sheet (15–12 ka) in the Upper Volga river basin could be a trigger for fluvioglacial and denudation processes as well as transportation of large quantities of fine-grained materials. These deposits subsequently filled the Early Khvalynian basin of the Caspian Sea and accumulated in lower depressions.

4. Conclusions

1. The chocolate clays are widespread in the Lower Khvalynian sediments on the northern Caspian Lowland. They occur as large areas near the Volga River valley and in its delta, in the adjacent part of Kalmykia; in depressions east of the Akhtuba, and in the middle reaches of the Ural River. There are also regions almost completely devoid of the chocolate clays, such are high terraces of the Volga (above the 2nd terrace level), a zone along the western margin of the Syrt elevations, as well as considerable areas of the Volga-Ural interfluve, vast lowlands in Kalmykia, and the area east of Inder Lake.
2. The chocolate clays may occur either as a continuous mantle, or discontinuously, in separate patches. A continuous, mantle-like occurrence is typical of valleys of the Volga and its large tributaries, of the Ural valley and a system of basins east of the Akhtuba. Mosaic distribution is characteristic of the Volga delta, Kalmykia, and the right bank of the Ural R.
3. The chocolate clays are confined to topographic depressions of different origin, configuration, and size. The largest are linear fluvial erosional landforms, the Volga and Ural valleys. Vast fields of the chocolate clays are found in closed or semi closed basins related to salt tectonics.
4. The chocolate clays are polymineral in composition and composed of kaolinite and illite. The “chocolate” color of the clays results mainly from the presence of iron oxides impregnating the entire clay series.
5. The chocolate clays are considered to be a single facies subdivided into three subfacies as follows: mono-clayey (typologic) layered; sandy-clayey; and silty-clayey.
6. The position of chocolate clays in the Khvalynian sedimentary sequence may vary considerably. They may also occur as several layers in a single section.
7. The chocolate clays yielded only rare shells of thin-valved molluscs (*Monodacna*, *Hypanis plicatus*). Brackish-water Khvalynian fauna was recovered in abundance from sandy interlayers in the clays.
8. Radiocarbon dating of the mollusc shells has shown their young age (12–15 ka BP).

The characteristics of the chocolate clays (spatial distribution, topographic position, mode of occurrence, mollusc fauna composition, along with radiocarbon dating) strongly suggest those clays to be an exotic facies of the Early Khvalynian marine sediments, so they cannot be rated as an individual stratigraphic unit.

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