

# A Record of *Clidastes propython* Cope (Squamata, Mosasauridae) in the Upper Cretaceous of the Saratov Region, Russia

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**Abstract**—A frontal of the mosasaur *Clidastes propython* from the Beloe Ozero locality in the Saratov Region (Rybushka Formation, Campanian Stage, Upper Cretaceous) is described. The investigated specimen differs from the frontals of other members of the genus *Clidastes* in the relatively straight lateral flanks. Reliable records of *Clidastes* outside America have previously been reported only from Great Britain, Sweden, and Germany. The new record from the Beloe Ozero locality expands the known geographical range of the species *C. propython* and genus *Clidastes*.

**Keywords:** *Clidastes*, Upper Cretaceous, Saratov Region, Russia

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## INTRODUCTION

Mosasaur remains in the Upper Cretaceous beds of Russia and adjacent areas are rather common; however, morphologically complete skeletons are extremely scarce. They include a skeleton of *Prognathodon lutugini* from the Campanian of eastern Ukraine (Yakovlev, 1905; Grigoriev, 2013) and also an incomplete skull of *Mosasaurus hoffmanni* from the Upper Maastrichtian beds of Penza (Grigoriev, 2014). The majority of known specimens are represented by isolated bones of the skull and postcranial skeleton.

Among cranial elements, the frontal, along with the quadrate and teeth, displays the greatest number of diagnostic characters. The frontal described in this work was found in 2013 in the Campanian beds of the Beloe Ozero locality of the Lysogorskii District on the Saratov Region. In this territory the Campanian Stage is correlated with the Rybushka Formation of the local stratigraphical scale. This locality has yielded many specimens of mosasaurs, plesiosaurs, pterosaurs, and others vertebrates (Pervushov et al., 1999; Arkhangelsky et al., 2007; Averianov and Popov, 2014).

On the dorsal and ventral sides, the bone was covered with a layer of dense sandstone hiding many diagnostic characters. Enclosing matter was removed using a dental drilling machine and air compressor (JUN-AIR i40-4B) with an air scribe (Paleo Tools ME-9100).

The specimen investigated is housed in the Paleoherpological Collection of the Zoological Institute

of the Russian Academy of Sciences, St. Petersburg (ZIN PH).

For comparison were used specimens from the Yale Peabody Museum of Natural History, New Haven, Connecticut, United States (YPM), and Geological Survey of Alabama Type Collection, Tuscaloosa, Alabama, United States (GSATC). The systematics in this study follows Palci et al. (2013).

## GEOLOGICAL AND TAPHONOMIC CHARACTERISTICS OF THE LOCALITY

The Beloe Ozero locality is situated 2.6 km southeast of the village of Beloe Ozero (Lysogorskii District, Saratov Region) and represents a natural outcrop of the Campanian beds (Rybushka Formation) in the right slope of an unnamed gully in its middle part (Fig. 1).

The Rybushka Formation has yielded fossils of invertebrates: the belemnites *Belemnellocamax mammillatus* and *Belemnitella mucronata*, the ammonite *Hoplitoplacenticeras* sp., the bivalves *Oxytoma psilomonica*, *O. tenuicostata*, *Cataceramus balticus*, *C. regularis*, and foraminifers of the *Brotzenella monterelensis* Regional Zone and *Cibicidoides aktulagayensis* Subzone (Olferiev and Alekseev, 2005; Seltser and Ivanov, 2010; Averianov and Popov, 2014). The formation corresponds in stratigraphical volume to most of the Lower Campanian (*Belemnitella mucronata alpha* and *Belemnellocamax mammillatus* regional mollusk zones) and basal Upper Campanian (*Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata* lone)

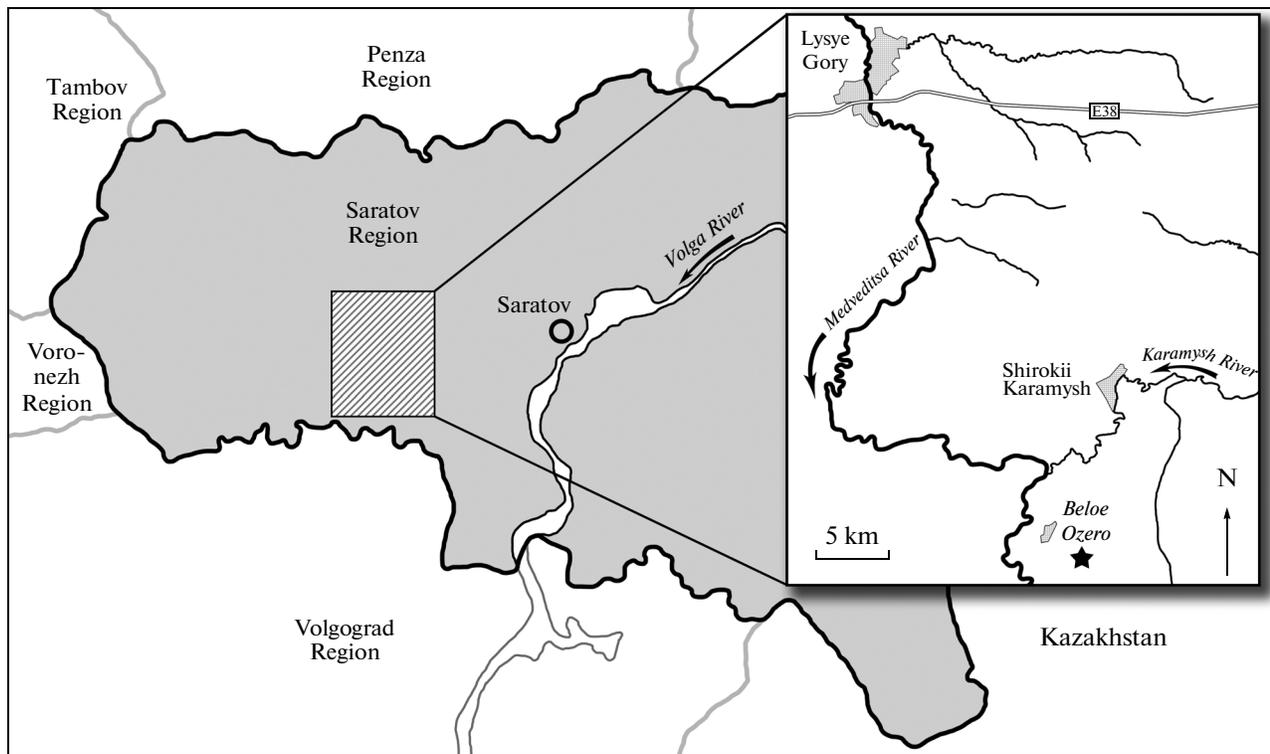


Fig. 1. Geographical position of the Beloe Ozero locality.

(Olferiev and Alekseev, 2005). Among vertebrate remains from the Rybushka Formation, bones of osteichthyans (*Enchodontidae*), shark teeth (*Cretolamna appendiculata*, *Squalicorax kaupi*, *Pseudocorax laevis*, *Archaeolamna kopingensis*, *Eostriatolamia* sp., *Heterodontus* sp., *Squatina hasei*, *Squatirhina* sp.), dental plates of the chimaeras *Ischyodus bifurcatus*, *Amylodon karamysh*, *Edaphodon* sp., *Elasmodus* sp. prevail (Averianov and Popov, 2014). This formation has also yielded abundant fossils of reptiles (plesiosaurs, mosasaurs, sea turtles, pterosaurs) and birds (*Hesperornis*). Beds 1 and 2 are tentatively dated Upper Campanian; Beds 3–6 are regarded as Lower Campanian.

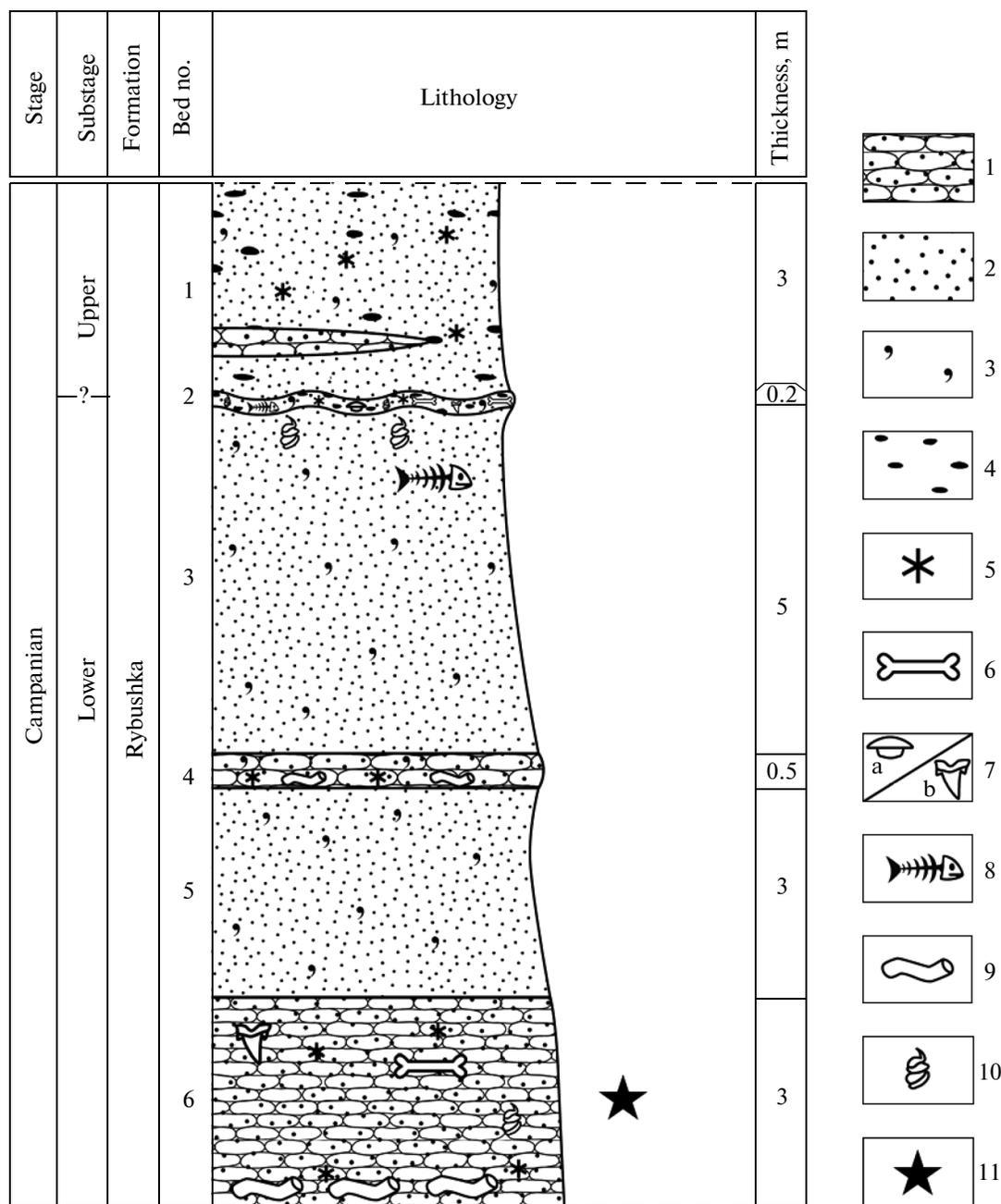
The Rybushka Formation is situated between a long-lived Voronezh island system and more deepwater sites of the Recent left bank of the Saratov Region, which are connected with the Caspian Depression. This territory was completely occupied by a shallow marine basin. All localities of marine and subcontinental vertebrates occur in the zones of Campanian coastal bands and island banks. They were formed due to consedimentary development of uplifted structures. Depending on the influence of water masses of different climatic zones and a complex relief of the sea bottom, this area accumulated siliciclastic matter and siliceous–clayey deposits (Pervushov et al., 2012).

A significant part of the section of the Beloe Ozero locality was buried under a thick, turf-covered talus.

Deposits of the Rybushka Formation are represented here by (downward in the section) (Fig. 2):

K<sub>2</sub> km<sub>2</sub> 1. Greenish gray, quartz–glaucconitic, medium-grained sand, in the upper part, the bed is strongly stained with chernozem; in the lower part, it is in places strongly compacted, sometimes to the condition of sandstone. Over the entire bed, dark brown phosphorite inclusions up to 2.5 cm in size and ferriferous inclusions up to 3 cm in size are regularly scattered. The boundary with the underlying bed is distinct, but uneven. The bed is up to 3.0 m thick.

K<sub>2</sub> km<sub>1-2</sub> 2. Phosphorite horizon. Brown and dark brown, poorly sabulous, irregularly shaped phosphorite nodules up to 3.5 cm in size. Small phosphorites (less than 1 cm) are usual. Along the strike, phosphorite inclusions are distributed nonuniformly, forming in places lenticular aggregations or, on the contrary, wedging out. In some sites, the horizon is nonuniformly stained with brownish red spots of iron hydroxide. There are also rare gray aleurite–carbonate pellets. The horizon is in places slightly cemented. Cementing matter is psammitic component of the overlying layer. The lower surface is uneven and pitted. The bed has yielded abundant shark teeth and vertebrae, fin spines and dental plates of chimaeras, remains of large sturgeons and clupeids, bones and teeth of reptiles (mosasaurs, plesiosaurs, turtles, pterosaurs); shark coprolites up to 8 cm long are particularly abundant. The bed is up to 0.2 m thick.



**Fig. 2.** Geological section of the Upper Cretaceous beds of the Beloe Ozero locality. Designations: (1) sandstone, (2) sand, (3) glauconite, (4) phosphatic and silty-carbonate pellets, (5) ferrugination, (6) tetrapod bones, (7) chondrichthian teeth: (a) rays and (b) sharks, (8) remains of bony fishes, (9) burrows of mud-eaters, (10) coprolites of sharks, (11) presumable level of find of the frontal (specimen ZIN PH, no. 5/48).

The underlying beds are covered by a talus, in places, with landslide deposits. The beds are described based on a series of trenches and grubbing.

$K_2$  km<sub>1</sub> 3. Gray-green, quartz-glauconitic, medium-grained sand. In the upper part, the bed contains subautochthonous, slightly phosphatized coprolites of sharks and small vertebrae of bony fish. The boundary with the underlying bed is uneven. The bed is 4–5 m thick.

$K_2$  km<sub>1</sub> 4. Light gray, glauconitic-quartz, medium-fine-grained, platy, sandstone gradually passing into the underlying bed. There are many subhorizontally positioned burrows of mud-eaters, stained with iron hydroxide. The lower surface of the bed is uneven. The bed is up to 0.3–0.5 m thick.

$K_2$  km<sub>1</sub> 5. Gray-green, quartz-glauconitic, medium-fine-grained sand. The bed is about 3.0 m thick.

K<sub>2</sub> km<sub>1</sub> 6. Gray–greenish, quartz–glaucous, cement siliceous sandstone; cementation is nonuniform. Glaucous grains are mostly black, form large clumpy structures about 0.5 × 1.0 m in size. The cracks are stained brown with iron hydroxide. The bed sole encloses abundant subhorizontal burrows of crustaceans 1.5–2 cm in diameter and up to 30 cm long, filled with the rock of the bed. The level of hard ground unpersistent along the strike is outlined at the bed sole. The bed contains slightly phosphatized vertebrae of a large shark and plesiosaur and also rare coprolites of sharks. The bed is about 2.5–3.0 m thick.

Downward along the slope, to the thalweg, there is a continuous talus completely covering the underlying 8-m-thick strata of Campanian deposits.

The thalweg is composed of variously rounded sandstone fragments from Beds 4 and 6 and also sand. It contains abundant molds of crustacean burrows, teeth and coprolites of fishes, and less frequent reptile bones.

The frontal described here was found in the thalweg; however, it is only slightly phosphatized and its surface has distinctive enclosing matter, so that it is possible to conclude that it comes from Bed 6. The absence of traces of significant rounding suggests that the specimens did not undergo essential lateral transportation; hence, this burial is assigned to the subautochthonous type.

## DESCRIPTION

Specimen ZIN PH, no. 5/48 is fused frontals, more than one-third of which is broken off anteriorly, as is judged from the position of the olfactory bulbs (Figs. 3, 4). The sutural boundary with the parietal is almost completely preserved and the canal of the olfactory tract is well preserved. On the dorsal side, there is a medial crest.

Since the anterior part of the bone is broken off, its exact proportions are impossible to estimate; however, it is evident that it not wide and short (the length-to-width ratio is less than 1.5 : 1 after Leblanc et al., 2012); it is more likely narrow and long (this ratio is 2 : 1).

The lateral flanks or wings are almost straight, slightly concave, with small prominence 25 mm apart from the posterior end. The lateral wings in the posterior part of the bone converge at an angle of 75°; after the ventral separation ridge, the angle becomes sharper, 28°. The posterior posteromedially directed lateral ends of the wings are round and form almost a right angle with a slightly displaced posterior bone margin.

On the ventral side, lateral to the ventrolateral descending processes (processus frontalis descensus) up to the bone edge, there are two deep paired depressions corresponding to contacts with the prefrontals. The sutural surfaces with the postorbitofrontals are shallower and have more uncertain borders compared

to that of the prefrontal. The anterior and posterior boundaries of these sutural surfaces are represented by notches (more pronounced posteriorly). The ventral separation ridge between the prefrontal and postorbitofrontal is 17 mm wide.

The boundary with the parietal is very well pronounced. It is represented by two plates located at the middle of the posterior bone margin and also sutural surface between the plates and on their sides. The plates originate from the bone edge on the dorsal side and converge close to the center on the ventral side. On the ventral side under the plates, there are incisures for connection with the parietal. Between these plates, there is sutural contact manifested by thin vertical interlocking ridges. Sutural contact on the plate sides is represented by extended longitudinal depressions. The plates are 20 mm wide and the sutural surface between them is 50 mm wide from above and 13 mm wide from below.

On the ventral side, close to the bases of the plates participating in sutural contact with the parietal, there are imprints of the cerebral hemispheres extending for 35 mm and gradually passing into two paired processes surrounding the canal of the olfactory tract. The processes closely approach each other (the distance between the processes is at most 2 mm) under the canal of the olfactory tract. They are 5 mm high and 25 mm long.

At the point of junction of the canal of the olfactory tract with the presumable area of the olfactory bulbs, the ventrolateral processes diverge at an angle of 45° and, then, again become parallel to each other. Closer to the split on the medial side of these processes, there are extended 10-mm-long and 5-mm-wide depressions. They are usually interpreted as paired parolfactory imprints of bulbs.

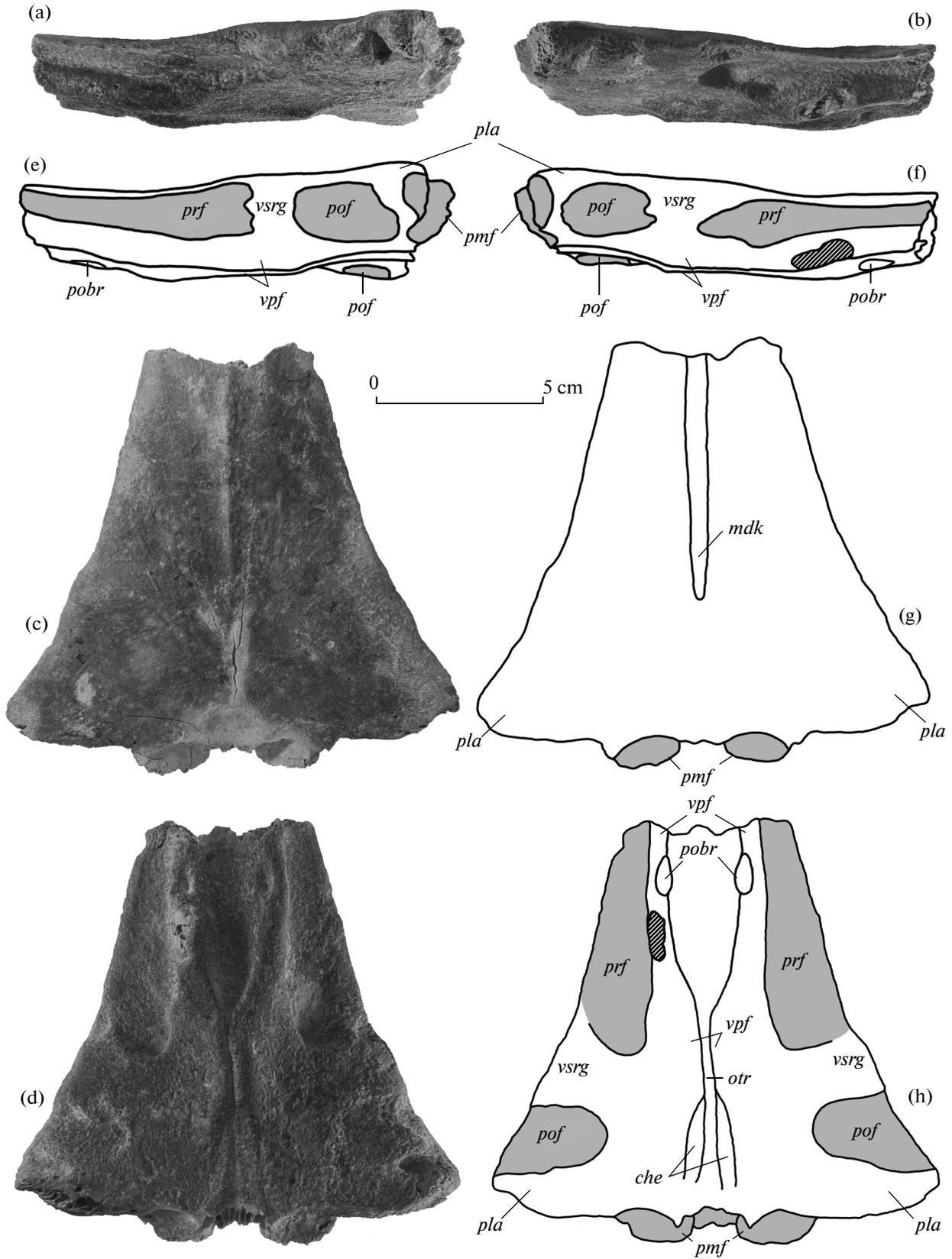
The dorsal medial crest is relatively low, but distinct; it begins at a distance of 40 mm from the posterior bone end, extends to the anterior broken edge, and reaches 1.5 mm of height.

The bone is 120 mm long and 130 mm wide.

## COMPARISON

The reconstructed proportions of the frontal (length-to-width ratio) is greater than 1.5 : 1, i.e., distinguishes this specimen from members of the genera *Globidens*, *Prognathodon*, *Mosasaurus*, *Tylosaurus*, and *Hainosaurus*, in which it is lower (Russell, 1967, 1975; Lingham-Soliar, 1992, 1995; Schulp, 2006). In the genera *Prognathodon*, *Mosasaurus*, *Plesiotylosaurus*, and *Plotosaurus* (Camp, 1942), the frontal enters the parietal by a long sutural crest embracing the parietal foramen, in contrast to a rather even connection observed in specimen ZIN PH, no. 5/48.

The sutural surfaces corresponding to the prefrontal and postorbitofrontal do not come in contact, indirectly suggesting that these bones lacked a contact at



**Fig. 3.** Frontal of *Clidastes propython* Cope, 1869, specimen ZIN PH, no. 5/48: (a, b, e, f) lateral, (c, g) dorsal, and (d, h) ventral views; (e–h) explanatory drawings; Saratov Region, Beloe Ozero locality; Upper Cretaceous, Lower Campanian, Rybushka Formation. Gray color shows sutural surfaces, hatching is damaged sites or splits. Designations: (*che*) imprint of cerebral hemispheres, (*mdk*) median dorsal keel, (*otr*) canal of olfactory tract, (*pla*) posterolateral wing of frontal, (*pmf*) posteromedial sutural surface for parietal, (*pobr*) paired parolfactory bulb recess, (*pof*) sutural surface with postorbitofrontal, (*prf*) sutural surface for prefrontal, (*vpf*) ventrolateral process of frontal, (*vsrg*) ventral separation ridge.

the margin of the frontal. This character distinguishes specimen ZIN PH, no. 5/48 from the genera *Tylosaurus*, *Platecarpus* (Russell, 1967), and *Taniwhasaurus* (Fernandez and Martin, 2009).

All members of the genus *Plioplatecarpus* (except for *P. marshi*) are similar in the structure of the wing ends of the frontal; they are sharp and directed posterolaterally (Russell, 1967; Lingham-Soliar, 1994; Holmes, 1996; Konishi and Caldwell, 2009). The medioposterior part of the frontal of *Plioplatecarpus* juts strongly inside and participates in the formation of the anterior wall of the parietal foramen (Russell, 1967). On the contrary, in specimen ZIN PH, no. 5/48, the posterior margin is straight and the posterior lateral ends of wings are round.

The wings of the frontal of the genus *Platecarpus* are sinusoidal (Russell, 1967), in contrast to almost straight lateral wings of the specimen described.

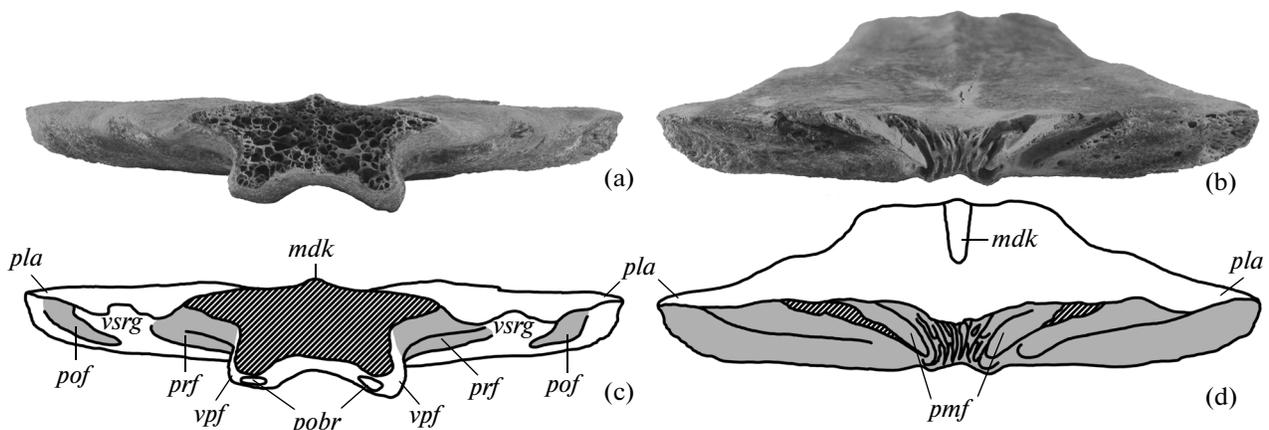
Specimen ZIN PH, no. 5/48 is most similar to the frontal of members of the genus *Clidastes* Cope, 1868. These bones are very similar in species of this genus, except for the lateral wing shape. In *C. propython*, they are straight, whereas in *C. liodontus* and *C. moorevilensis* (Leblanc et al., 2012) (Fig. 5), they are concave. Based on this character, the genus *Ectenosaurus* was excluded from comparison (Russell, 1967). Specimen ZIN PH, no. 5/48 is identical to the frontals of the specimens of *C. propython* figured by Cope (1875, pl. XVI, fig. 1) and Russell (1967, text-fig. 4B).

## DISCUSSION

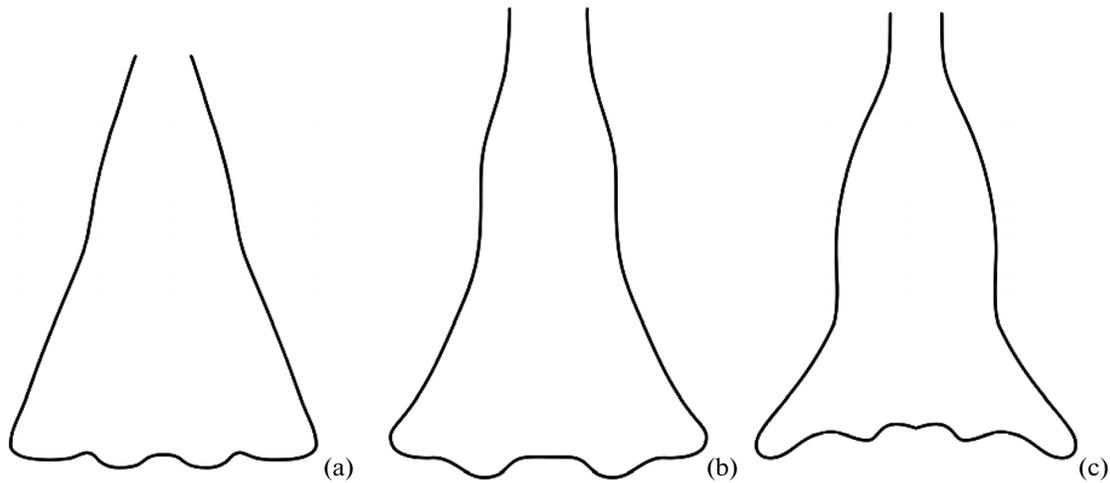
Until recently, reliable records of the genus *Clidastes* outside North America, where this genus is usual (Russell, 1967), have not been recorded. The European beds have yielded an anterior fragment of a dentary of *Clidastes* from the Turonian?–Campanian of the North Sea Basin of southern Great Britain (Milner, 2002); jaw teeth, pterygoid teeth, and vertebrae from the Lower Campanian of the Kristianstad Basin of southern Sweden (Lindgren, 1998; Lindgren and Siverson, 2004); and an anterior part of a premaxilla in articulation with fragments of jaw bones from the Upper Campanian of the Munster Basin in northwestern Germany (Diedrich and Mulder, 2004; Caldwell and Diedrich, 2005) (Fig. 6). In Africa and South America, *Clidastes* has not been recorded (Polcyn et al., 2008).

Some researchers assigned isolated mosasaur fossils from Russia, mostly teeth and vertebrae, to the genus *Clidastes* (Nessov and Yarkov, 1993; Yarkov, 1993; Pervushov et al., 1999; Storrs et al., 2000). Because of the absence in the cited publications of descriptions or substantiation of identification, it is possible to propose that specimen ZIN PH, no. 5/48 is the first reliable record of *Clidastes* in Russia.

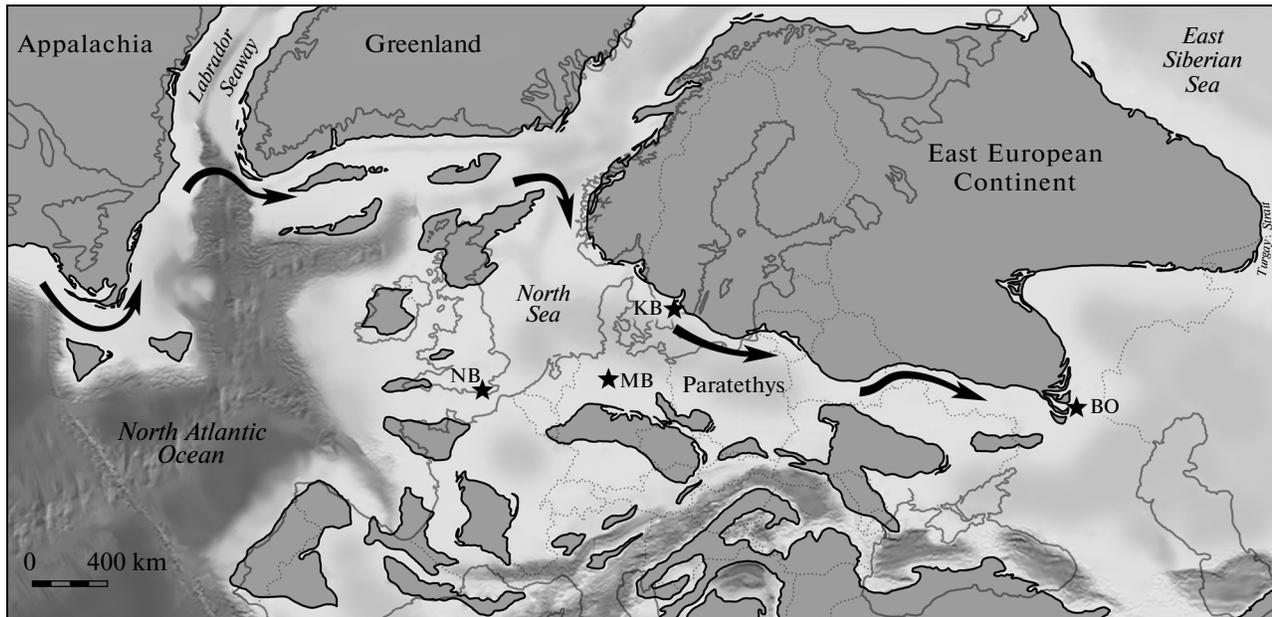
The results of the present study corroborate the hypothesis of Lindgren and Siverson (2004) and also Caldwell and Diedrich (2005) rejecting the endemism of North American *Clidastes* (Gulf of Mexico coast and Western Interior Seaway) and expand its range to Europe.



**Fig. 4.** Frontal of *Clidastes propython* Cope, 1869, specimen ZIN PH, no. 5/48: (a, c) anterior and (b, d) posterior views; (c, d) explanatory drawings; Saratov Region, Beloe Ozero locality; Upper Cretaceous, Lower Campanian, Rybushka Formation. Gray color shows sutural surfaces and hatching is damaged sites or splits. For designations, see Fig. 3.



**Fig. 5.** Schemes of frontals, dorsal view, not to scale: (a) *Clidastes propyhton*, (b) *C. moorevillensis*, and (c) *C. liodontus*. Frontals of *C. propyhton* (specimen YPM, no. 1368) and *C. liodontus* (specimen YPM, no. 1335) are taken from works of Cope (1875) and Russell (1967); *C. moorevillensis* is drawn based on a photograph of specimen GSATC, no. 218, provided by M.J. Polcyn.



**Fig. 6.** Paleogeographical map of oceans and continents in the Campanian (75 Ma), displaying a hypothetical migration pathway (shown by arrows) of the genus *Clidastes* from the Gulf of Mexico coast and Western Interior Seaway to Europe. Dark gray color shows dry land 75 Ma, semitransparent contours show outlines of modern continents and semitransparent dotted lines are boundaries of states. Relatively light color in the oceans shows shallow regions; darker color designates deepwater areas. Beds that have yielded fossil *Clidastes* described here: (KB) Lower Campanian beds of the Kristianstad Basin, southern Sweden (Lindgren, 1998; Lindgren and Siverson, 2004); (MB) Upper Campanian beds of the Munster Basin, northwestern Germany (Diedrich and Mulder, 2004; Caldwell and Diedrich, 2005), (BO) Lower Campanian of the Beloe Ozero locality, Russia, (NB) Turonian?–Campanian beds of the North Sea Basin, southern Great Britain (Milner, 2002).

It is plausible that the open northern Atlantic had become a natural barrier preventing migration through the ocean of relatively small mosasaurs, such as *Clidastes* or *Dallasaurus* adapted to warm subtropical seas (Russell, 1967; Nicholls and Russell, 1990; Polcyn et al., 2008). The temperature mode of oceanic waters apparently excluded a possibility of migration by the Arctic pathway through the territory

of modern central Canada. It is more probable that migration pathway to northwestern Europe was along the eastern coast of North America and southern Greenland (Lindgren and Siverson, 2004). This migration coincided with recession of the sea and ocean temperature, which began in the Late Coniacian and continued to the Maastrichtian (Polcyn et al., 2014).

At present, it is generally believed that the subfamily Mosasaurinae, which includes the genus *Clidastes*, was endemic to North America, at least, to the Campanian Time (Polcyn et al., 2008). It is noteworthy that the specimens referred to as *Clidastes* sp.?, coming from the Santonian beds of Great Britain (according to the text in phototable captions the author dated it Upper Turonian Age: see Milner, 2002, pl. 64, fig. 4), require a more thorough examination. These remains are a fragment of the anterior part of the dentary with two partially preserved tooth crowns. The assignment of this specimen to the genus *Clidastes* on the basis of the bone end slightly projecting beyond the anterior teeth is not justified, because this character also occurs in *Plesiotylosaurus* (Russell, 1967), *Eremiasaurus* (Leblanc et al., 2012), some members of the genus *Prognathodon* (*P. overtone* and *P. stadmani*) (Schulp, 2006), and some other mosasaurs. Nevertheless, even if mosasaurs from Surrey actually belong to the genus *Clidastes*, the theory about their migration to Europe from North America seems incorrect, since, if this were the case, members of this genus would have appeared in the Old World earlier. *Clidastes* described from the Turonian beds of North America (Martin and Stewart, 1977) were subsequently assigned to *Russellosaurina* (Polcyn et al., 2008). Therefore, the most ancient member of the genus *Clidastes* in the Western Hemisphere is *C. liodontus* from the Upper Coniacian beds of Kansas (Everhart, 2001).

The new specimen from the Beloe Ozero locality expands the known range of the species *C. propython* and genus *Clidastes* by more than 2000 km to the east, to the Russian Sea Basin.

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