

## A Mosasaur from the Cenomanian of Russia

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**Abstract**—The premaxilla of a mosasauroid lizard from the Lysaya Gora 3 locality in Saratov (Upper Cretaceous, Cenomanian) is described. To date, the oldest known mosasaur remains have been dated Turonian. The premaxilla is most similar in morphology to that of *Russellosaurus* from the Turonian of the United States; however, the absence of sufficient diagnostic characters only allows its attribution to Mosasauridae indet.

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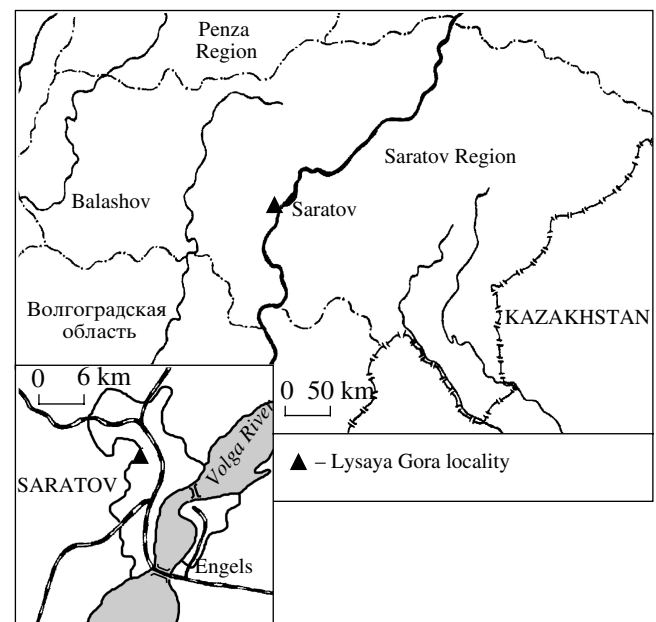
### INTRODUCTION

Isolated postcranial bones and teeth of sea lizards (mosasaurs) relatively frequently occur in the Campanian and Maastrichtian beds of European Russia and adjacent areas. To date, this region has yielded representatives of the genera *Mosasaurus*, *Tylosaurus*, *Dollosaurus*, *Plioplatecarpus*, *Platecarpus*, *Prognathodon*, and *Clidastes* (Storrs et al., 2000). In the earlier beds of Russia, mosasaur remains have not been recorded (Arkhangel'sky, 1997; Pervushov et al., 1999). Only recently, two mosasaurid vertebrae of one individual have been determined with certainty from the Lower Santonian beds of the Volga Region near Saratov (Arkhangel'sky et al., 2007). However, in Africa, Western Europe, and the Western Hemisphere, these Late Mesozoic marine lizards occur in earlier deposits dated Turonian–Santonian (Russell, 1967; Bardet, 1990; Lingham-Soliar, 1992, 1994a). The oldest known bone remains of Mosasauridae come from the basal Middle Turonian of the United States (*Russellosaurus coheni* and *Dallasaurus turneri*; Bell and Polcyn, 2005; Polcyn and Bell, 2005); the Turonian of Colombia (*Yaguarasaurus columbianus*; Paramo, 2000); the Lower Turonian of southern Morocco (*Tethysaurus nopcsai*; Bardet et al., 2003); and the Upper Turonian of Angola (*Platecarpus bocagei*; Lingham-Soliar, 1994a). Therefore, a mosasauroid premaxilla that was found in the Upper Cenomanian of Russia is of great interest. This specimen was found by the Saratov collector A.V. Lapkin in 1993 in one of the most thoroughly studied sections of this age in the Lower Volga Region, which is well known for a long time due to the material collected by Glikman (1953, 1955). This or a closely situated locality has yielded fragmentary remains of flying saurs of the family Ornithocheiridae (Glikman, 1953; Khozatsky, 1995; Averianov, 2004).

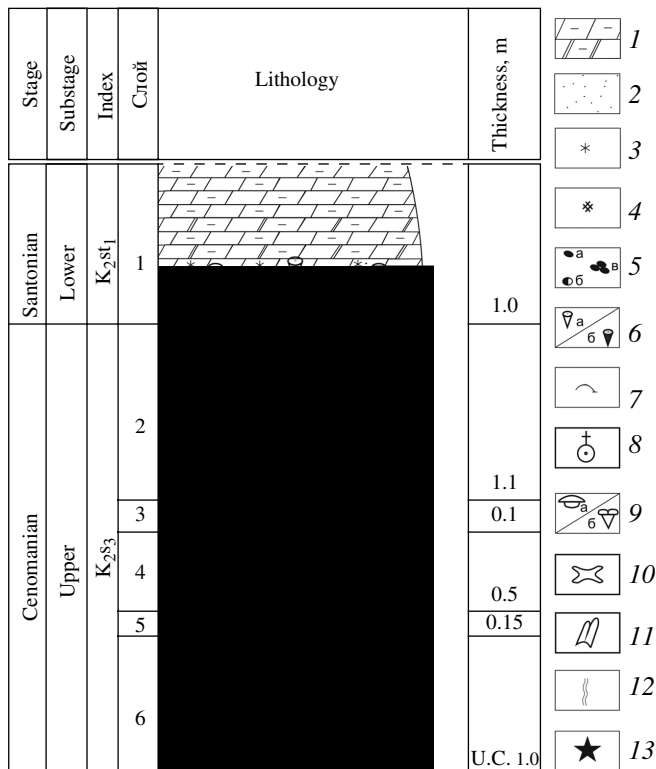
The specimen investigated is housed in the Paleoherpological Collection of the Zoological Institute of the Russian Academy of Sciences, St. Petersburg (ZIN PH).

### Geological and Taphonomic Characteristics of the Locality

The Lysaya Gora 3 locality is situated in the western part of central Saratov, in the eastern marginal area of



**Fig. 1.** Geographical position of the Lysaya Gora locality.



**Fig. 2.** Upper Cretaceous section of the Lysaya Gora 3 locality. Designations: (1) marl; (2) sand; (3) ferric hydroxides; (4) mica; (5) phosphorites of different generations: (a) simple sated phosphorites, (b) simple unsated phosphorites, (c) aggregates of sated phosphorites; (6) sponge: (a) autochthonous and (b) allochthonous burials; (7) bivalve shells; (8) remains of marine tetrapods; (9) teeth of cartilaginous fish: (a) sclerophages and (b) sharks; (10) pterosaur remains; (11) plates of chimaeras; (12) burrows of silt-eaters; and (13) level of the specimen in question.

the southern slope of Lysaya (Zavokzal'naya) Gora, 800 m west of the railroad station of Saratov 1 (Fig. 1). This is an abrupt western wall of an abandoned sand mine. This mine and a gully located 300 m to the north are Cenomanian beds, which yielded remains of marine and subcontinental vertebrates mentioned by the researchers of the 1950s–beginning of the 1980s (Glikman, 1953, 1955; Nessov and Khozatsky, 1977; Khozatsky, 1995). The absolute mark of the edge of the mine is 185 m.

The mine exposes the following sequence of the Upper Cretaceous beds (Fig. 2; described downward in the section) (after Pervushov et al., 1999, modified):

K<sub>2st1</sub> 1. Dirty gray, irregularly colored, with light and dark yellow, sandy marl. The psammitic component is inequigranular quartz–glauconitic. The upper part is denser due to irregular silicification. This site is rich in ferric hydroxide inclusions, phosphorite accumulations, and remains of large sponges. In the lower part, the rock is irregularly layered; upward in the section, fine lenses and punctated lamination are observed. This bed contains many phosphorite inclusions of vari-

ous generations, siliceous sponges, molds of mollusks and brachiopods, less often, ostracean shells, belemnite rostra, and teleosts. A significant number of strongly phosphatized invertebrate molds and infrequent strongly rounded remains of marine reptiles are redeposited from the Turonian and Coniacian beds, which have been disrupted in this structural zone, and from the underlying Cenomanian beds. Along the strike, fossils are either regularly scattered in the bed or form accumulations in some sites in the middle or upper part of the bed. Towards the foothill, the marl gradually passes into carbonaceous sand. Visually, the foothill surface falls in a layer with relatively regularly distributed small, isolated black and brown phosphorite inclusions. This bed has yielded unidentifiable remains of marine reptiles (Pervushov et al., 1999). It is from 0.5 to 1.0 m thick.

K<sub>2s3</sub> 2. Grayish green, irregularly colored, small–medium-grained and calcareous glauconite–quartz sand. The carbonaceous component decreases towards the sole. Phosphorite inclusions of several generations, which sometimes form from one to three levels of lenses and botryoidal accumulations, are irregularly scattered. The sole surface is distinct, rough. The bed is 0.9–1.1 m thick.

K<sub>2s3</sub> 3. Phosphorite horizon. A concentrated accumulation of phosphorite inclusions, which is relatively constant in thickness along the strike. Phosphorite inclusions are mostly black, weakly cemented, frequently irregular in outline. This horizon is relatively uniformly stained with ferric hydroxides. The sand layers overlying and underlying the phosphorite horizon are also regularly reddish yellow due to ferric hydroxides. The sole surface is rough, distinct. The bed is 0.08–0.1 m thick.

K<sub>2s3</sub> 4. Glauconite–quartz, small–medium-grained, poorly micaceous sand, irregularly colored with grayish green mostly at cavities and burrows. Scarce small black phosphorites are irregularly scattered. The sole surface is rough, indistinct. The bed is from 0.35 to 0.5 m thick.

K<sub>2s3</sub> 5. This is the level of phosphorite inclusions, varying along the strike and poorly concentrated in the shape of lenses and botryoidal accumulations. Inclusions are formed of yellowish white, glauconite–quartz, inequigranular (coarse-grained component is significant) sand; in places of accumulations of inclusions, cemented by ferric hydroxides. The ichthyofauna is represented by shark and ray teeth, jaw plates of chimaeras, abundant thin bones and scales of teleosts; in addition, reptile remains and scarce molds and shells of small invertebrates and coprolites are recorded. This interbed includes the majority of bones of marine reptiles and flying saurs. Mosasaur remains come from this bed. The bed is 0.05–0.15 m thick.

K<sub>2s3</sub> 6. White and light gray, with a greenish shade, glauconite–quartz, small–medium-grained, with infrequent coarse grains, sand. The cavities of variously ori-

ented burrows are filled with gray, slightly ferruginous sand. Apparent thickness is up to 1.0 m.

The majority of bones of marine reptiles (sea turtles and plesiosaurs) and flying saurs (Nessov and Khozatsky, 1977; Arkhangelsky, 1999; Pervushov et al., 1999; Averianov, 2002, 2004, 2007) come from a weakly outlined interbed of small isolated phosphorite inclusions (Bed no. 5). Skeletal elements are relatively well-preserved, phosphatized to varying extent, usually slightly rounded. Associations of bones of one individual sometimes occur.

In this case, burial places of bones in general coincide with the range of many marine and subcontinental organisms. Here, at the latest stages of Late Cenomanian sedimentation, there were conditions of coastal, shallow basin, which surrounded a gently sloping elevation located to the north and occasionally rising above the level of syzygial high tide. The southern slope of this upland, where the locality of Lysaya Gora 3 is situated, is almost flat, with weak ridges, composed mostly of sand, suggesting the presence of shallow-water conditions. The occurrence within the upper littoral and sublittoral of many diverse benthic and nektonic taxa provided the development of various food chains, in which an important role was played by fish, marine reptiles, and subcontinental vertebrates, in particular, flying reptiles. Vertebrate remains were probably preserved in the case when they were rapidly buried, overlain by psammitic matter. The usual occurrence of vertebrate remains at the level of lenses, accumulations, and even horizons of phosphorite inclusions is accounted for by the episodes of low sea level in this area, which was usually preceded by the importation of phosphatic matter impregnating bones, and the formation of troughs of flows oriented along the slope, which were rich in accumulations of heavy deposit fractions, i.e., phosphorite inclusions, in particular, biogenic inclusions. These accumulations contained both repeatedly reworked and newly deposited specimens. In addition to washing out from the deposits by coastal flows and shifts of draining troughs, an important role in the formation of these burials was played by gales. In this case, fossil and subfossil remains were relatively rapidly buried in transported psammitic substrate; as a result, many forms, in particular, well-preserved specimens, were buried.

The burial of marine invertebrates in Bed no. 5 is regarded as synchronous, irregularly scattered, lenticular, dominated by subautochthonous elements with disrupted shells. Bone specimens of vertebrates are also mostly in subautochthonous burials; teeth and dental plates of fish and some elements of larger vertebrates are not rounded.

The bone-bearing beds were dated by Zozyrev (2006a, 2006b) based on a complex study of Cenomanian deposits on the right bank of the Volga River near Saratov and the recognition of detailed regional stratigraphic units using the method of perspective correla-

tion. The Cenomanian Age of the terrigenous bone-bearing beds is established based on phosphatized molds of the gastropods *Buckmannina cenomaniensis*, *Calliostoma luneli*, *C. podolica*, *Solariella sobetski*, and *Margarites engelhardti* and the bivalves *Venus rothomagensis*, *Lucina tenara*, *Neitheia quinquecostata*, and *Amphydonte conicum* (the last two are index taxa of the Cenomanian of the southern Russian Plate) and on the correlation with many sections with similar relationships of intervals in the section within the same monocline in southern Saratov (Novouzenskoe, Usievich, Zaplatinovka, etc.).

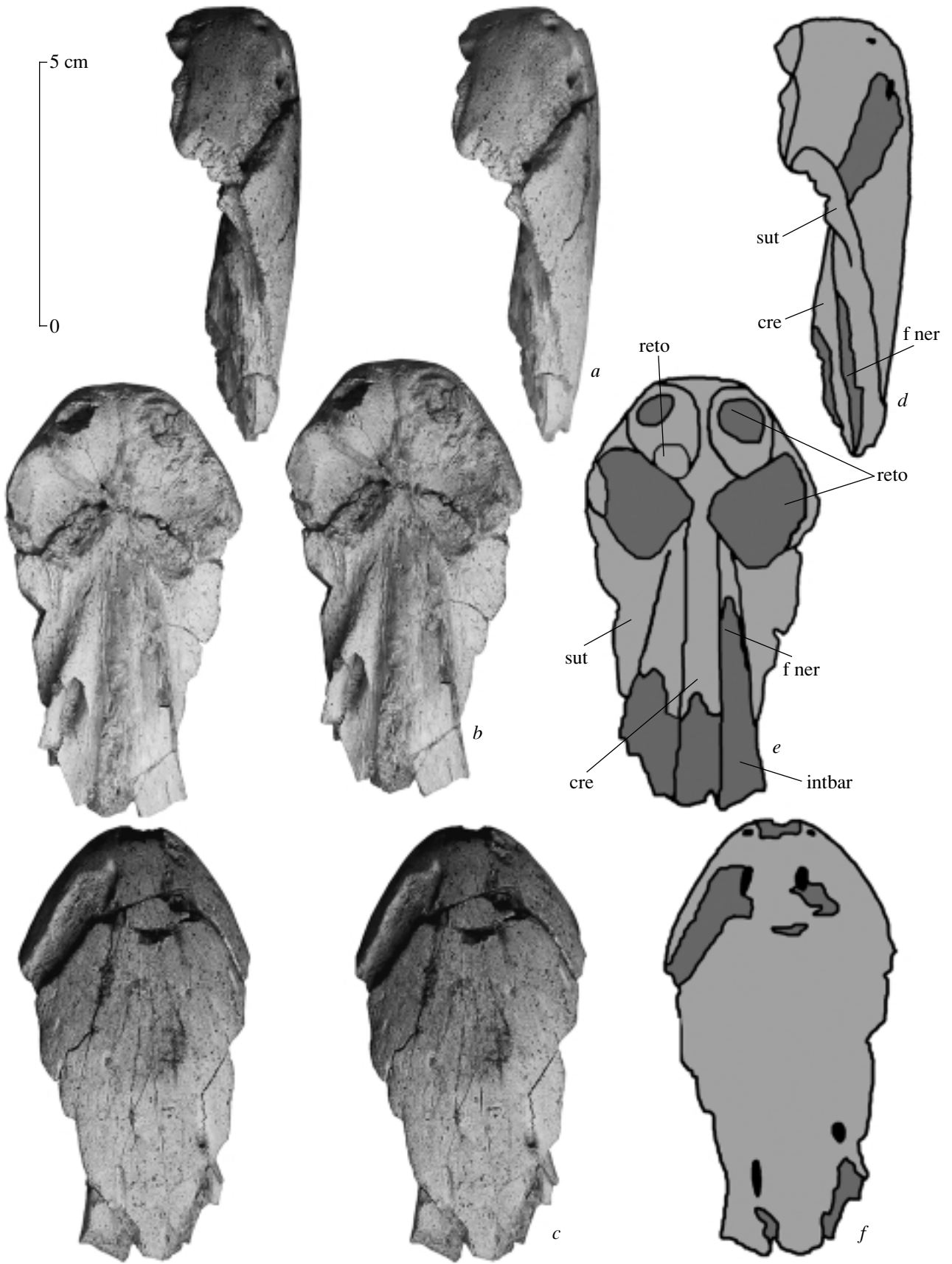
## DESCRIPTION

The material of mosasaur (ZIN PH, no. 84/90) is represented by a fragmentary premaxilla, with the preserved anterior part of the internarial bar, premaxillary-maxillary suture, and alveolar openings (Fig. 3).

The rostrum is undeveloped, the anterior wall of the premaxilla is positioned at an of 85° to the dorsal plane. The dorsal surface is strongly flattened, without a dorsal crest. In dorsal view, the anterior part of the bone is blunt. In the dentigerous part, the angle between the lateral walls of the premaxilla is 65°.

The premaxilla contains four tooth alveoli rounded in section and slightly anteroposteriorly extended. The anterior teeth are directed anteriorly at a small angle. The anterior alveoli are densely spaced, separated by a low longitudinal crest, 14 and 10 mm in diameter; both contain damaged tooth roots. The break shows the inner structure; the external cement layer has a more porous structure (2–3 mm thick); then, there is a 1.5–2-mm-thick dentin layer and, in the center, the pulp canal (4 and 3 mm in diameter). The posterior side of the right anterior alveolus has a distinct resorption mark. The posterior alveolar openings are much larger and deeper, without tooth remains. The anterior and posterior alveoli are positioned close to each other.

The preserved anterior part of the internarial bar is approximately 5 cm long. It is in the shape of an acute-angled triangle (the angle is 35°), which is located between the wings of the jaw bones. The ventral side of the internarial bar has a ventral median ridge, which extends from the contact area of the anteronasal septum and dentigerous portion; as the distance from the ridge origin increases, it gradually increases in size, with the maximum visible height of 5 mm, the width reaches 6 mm. Large foramina for the branches of the maxillary nerve ( $V_2$ ) are seen in the ventral surface of the anteronasal septum on the sides of the ventral median ridge. Several exits of this nerve are arranged irregularly on the dorsal surface of the bone; one foramen is just above a foramen on the ventral side and three are in the anterior part of the snout. The lateral margins of the internarial bar form a sutural surface for the articulation with the maxilla. This surface forms the posterolateral margin of the alveolus of the posterior tooth. At this



point, its surface is vertical. Posterior to the posterior tooth, the sutural surface becomes horizontal and occupies the entire lateral margin of the internarial bar. The maximum width of the sutural surface is 8 mm; and the maximum width of the premaxilla in the dentigerous part is 4 cm.

Specimen ZIN PH, no. 84/90 is assigned with confidence to the family Mosasauridae based on the presence of a suture between the maxilla and premaxilla. In Dolichosauridae, the articulation between these bones is of the hinged type. In the third mosasauroid group (Aigialosauridae), the character of contact between these bones remains uncertain.

The premaxilla in question should not be assigned to the subfamilies Mosasaurinae or Tylosaurinae because it lacks a rostrum. Among the Mosasaurinae, the rostrum is undeveloped in *Prognathodon*. However, the anterior teeth of this taxon are positioned at a much greater angle than in specimen ZIN PH, no. 84/90 (Lingham-Soliar and Nolf, 1989; Schulp, 2006). In addition, specimen ZIN PH, no. 84/90 differs from Tylosaurinae and from the mosasaurine *Clidastes* in the triangular rather than rectangular section in the longitudinal vertical plane of the base of the internarial bar (Russell, 1967; Schulp, 2006).

In the subfamily Plioplatecarpinae, the rostrum is poorly developed or absent. It is possible to compare the specimen in question to some species of this subfamily, the rostrum of which is reduced. Specimen ZIN PH, no. 84/90 differs from the genera *Plioplatecarpus* and *Platecarpus* in the nonreduced lateral walls, the weaker anteroposterior compression, the small incisure between the anterior tooth pair in place of the rostrum, and in the angle between the lateral walls of the premaxilla in the dentigerous part (Russell, 1967; Lingham-Soliar, 1994b; Holmes, 1996).

Specimen ZIN PH, no. 84/90 is similar to the premaxilla of the primitive plioplatecarpine *Yaguarasaurus columbianus* from the Turonian of South America in the shape in ventral and dorsal views, in particular, in the slightly blunted anterior edge and the angle between the lateral walls in the dentigerous part. However, the ventral side of the internarial bar of *Yaguarasaurus* has a weaker median ridge, the dorsal surface is more convex, and the internarial bar is thinner in lateral view (Paramo, 1993, 1994, 2000).

Early Turonian *Tethysaurus nopcsai* from Morocco also differs from specimen ZIN PH, no. 84/90 in the more convex dorsal surface (Bardet et al., 2003).

Judging from the description, ZIN PH, no. 84/90 is most similar to *Russellosaurus* from Texas. Both individuals lack a rostrum, have a high anterior nasal wall,

the end of the snout is strongly blunted, and the dorsal surface is flattened. The major distinction is the slightly blunter nasal part of *Russellosaurus coheni* (Polcyn and Bell, 2005). However, available material is insufficient to determine specimen ZIN PH, no. 84/90 more closely than Mosasauridae indet.

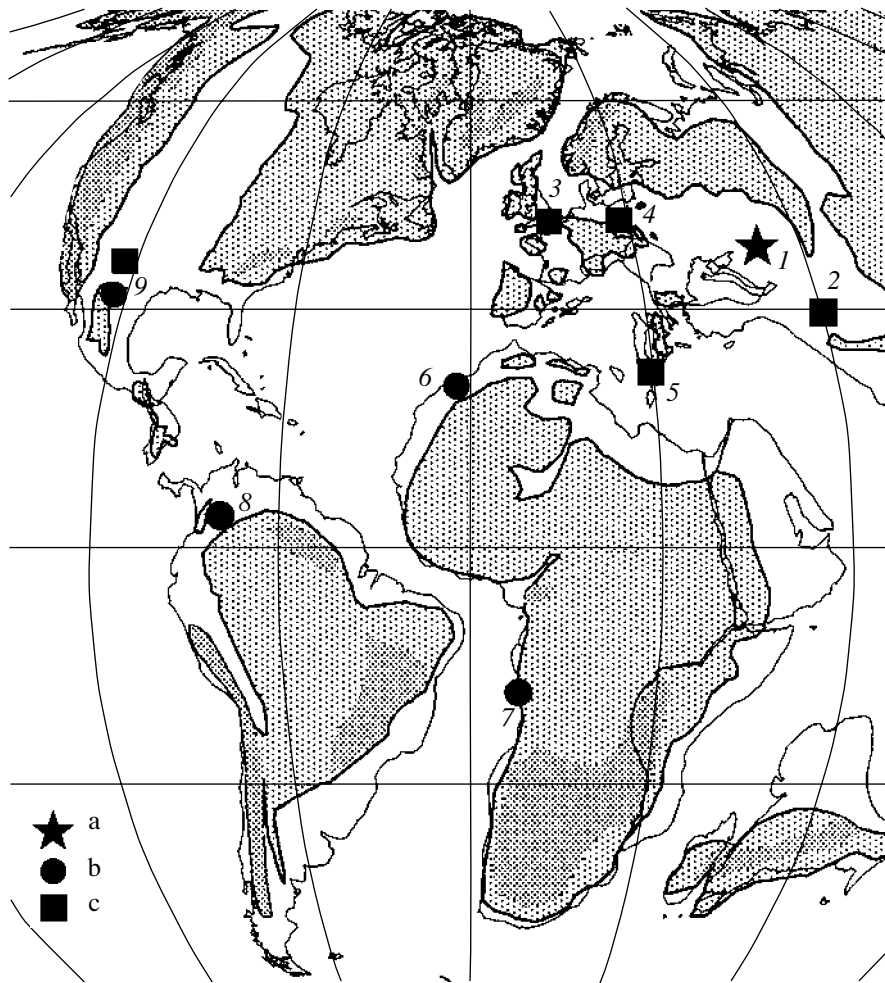
During the Cenomanian and Turonian, Mosasauridae (Aigialosauridae + Mosasauridae) and Dolichosauridae occurred from North America to Central Asia (Fig. 4). The latitudinal distribution extended from 45°N to 30°S. The data on this period are very scarce; therefore, it is impossible to indicate the area of the origin of mosasauroids (Jacobs et al., 2005a). Until the present study, the earliest known mosasaurs have been *Russellosaurus coheni* and *Dallasaurus turneri* from the Middle Turonian of the United States (Bell and Polcyn, 2005; Polcyn and Bell, 2005), *Yaguarasaurus columbianus* from the Turonian of Colombia (Paramo, 2000), *Tethysaurus nopcsai* from the Lower Turonian of Morocco (Bardet et al., 2003) and *Platecarpus bocagei* from the Upper Turonian of Angola (Lingham-Soliar, 1994a). The premaxilla under study belongs to the earliest mosasaur. Along with the earliest mosasaurs, the Cenomanian–Turonian beds have yielded dolichosaurs and aigialosaurs, such as *Dolichosaurus longicollis* from the Cenomanian of Germany (Diedrich, 1999), *Coniasaurus crassidens* from the Cenomanian of England (Caldwell, 1999) and the Upper Cenomanian–Turonian of North America (Texas) (Bell et al., 1982), the aigialosaur *Haasiasaurus gittelmani* from the Cenomanian of Israel (Polcyn et al., 1999; Dutchak, 2005), the dolichosaur *Aphanizocnemus libanensis* from the Middle Cenomanian of Lebanon (Dal Sasso and Pinna, 1997), and a dolichosaurid from the Turonian of France (Rage, 1989).

Dolichosaurs probably became extinct in the Turonian in connection with the competition with mosasaurs. At that time, mosasaurs occupied their adaptive zone, becoming the main marine predators of the Late Cretaceous (Jacobs et al., 2005b). In the terminal Cretaceous, mosasaurs are recorded throughout the world, up to the coast of the Antarctic. Taxa with narrow feeding specialization appeared (Schulp, 2006). In addition, a trend towards an increase in size developed; in particular, in the Cenomanian–Turonian, they were at most 3–4 m long, whereas, in the Maastrichtian, some species reached 15 m (*Hainosaurus bernardi*).

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**Fig. 3.** Mosasauridae indet., premaxilla: (a–c) stereophotograph and (d–f) explanatory figures; Lysaya Gora 3, Saratov Region; Upper Cretaceous, Cenomanian: (a, d) lateral, (b, e) ventral, and (c, f) dorsal views; light gray color shows preserved bone fragments; black color, exits of branchlets of the facial nerve. Designations: (av) alveolar opening, (cre) crest, (fnerv) branchlet of the facial nerve, (intbar) internarial bar, (reto) fossa of the replacement tooth, and (sut) premaxillary–maxillary suture.



**Fig. 4.** Localities of (a, b) mosasaurs and (c) more primitive mosasauroid lizards (dolichosaurs and aigialosaurs) in the Cenomanian and Turonian: (1) Saratov (ZIN PH, no. 84/90); (2) Kazakhstan (Averianov, 2001); (3) France (Rage, 1989) and England (Caldwell and Cooper, 1999); (4) Germany (Diedrich, 1999); (5) East Mediterranean (Dal Sasso and Pinna, 1997; Dutchak, 2005; Polcyn et al., 1999); (6) Morocco (Bardet et al., 2003); (7) Angola (Linghan-Soliar, 1994); (8) Morocco (Paramo, 1993, 1994, 2000); and (9) Texas (Bell et al., 1982; Bell and Polcyn, 2005; Polcyn and Bell, 2005).

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