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A discovery of limulid traces from the Lower Triassic deposits of the Orenburg region, Russia

Первая находка следов мечехвостов в нижнем триасе Оренбургской области, Россия

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КЛЮЧЕВЫЕ СЛОВА: ихнология, лимулиды, мечехвосты, триас, палеоэкология, тафономия, аналитические реконструкции.

ABSTRACT. The paper focuses on the first record of the limulid traces found in the Lower Triassic deposits outcropped in the Mansurovo locality, Orenburg region, Southern Cis-Urals, Russia. This new finding is determined as *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022. Comparative analysis of the studied ichnofossils shows that they are very similar both to the type specimens of *Selenichnites eotriassicus* Naugolnykh from the Lower Triassic deposits of the Volga River basin, and to the limulid traces *Selenichnites* sp. from the Jurassic deposits of Morocco. It is proposed that the traces *Selenichnites* cf. *eotriassicus* from the Mansurovo locality were left by a limulid ("horse-shoe crab") of the genus *Limulitella.*

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РЕЗЮМЕ. Статья сфокусирована на первой находке следов мечехвоста, обнаруженных в нижнетриасовых отложениях, обнажающихся в местонахождении Мансурово, в Оренбургской области; Южное Приуралье, Россия. Следы были определены как *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022. Сравнительный анализ изученных ихнофоссилий показывает, что они обладают значительным сходством как с типовыми экземплярами *Selenichnites eotriassicus* Naugolnykh из нижнетриасовых отложений, обнажающихся в бассейне р. Волги, так и со следами мечехвостов *Selenichnites* sp. из юрских отложений Марокко. Высказано предположение, что следы *Selenichnites* cf. *eotriassicus* из местонахождения Мансурово были оставлены мечехвостом, принадлежавшим роду *Limulitella* Størmer, 1952.

Introduction

One of the strongest aspects of modern paleontology is a possibility to obtain information about the organisms, which actually are not preserved as body-fossils but had left traces of their life activities. This aspect of paleontological studies is especially important for working with the near-coast shallow lagoon water deposits or lake/continental deposits. Ichnological data are extremely useful and helpful for proper studies of such paleoenvironments [Briggs *et al*., 1979, 2010; Laporte, Behrensmeyer, 1980; Fillion, Pickerill, 1984; Pickerill, 1992; Smith *et al*., 2003; Knaust, Hauschke, 2005; Lucas *et al*., 2005, 2006; Davies *et al*., 2006; Baas *et al*., 2013; Buhler, Grey, 2016; Gouramanis, McLoughlin, 2016; King *et al*., 2019] as for the many much broader paleoecological reflections [Seilacher, 1954, 1964, 1967].

The present paper deals with the first discovery of the traces, which were left by a xyphozurian arthropod, most probably a limulid assignable to the genus *Limulitella* Størmer, 1952 (see "Discussion" below). Similar traces were recently described from the Lower Triassic deposits outcropped in the Yaroslavl region, the close vicinity of the City of Rybinsk [Naugolnykh, 2022], but some morphological differences lead to describing the Mansurovo material in open nomenclature.

Material and methods

The material used as a basis for the present study was collected by E.A. Parkhomenko and D.S. Anikeev (Samara Paleontological Society, the City of Samara) in the field season of 2022, during two field trips fulfilled in October 9 and November 13. The specimens collected were transported to the Samara Regional Museum named after P.V. Alabin, where exact cop-

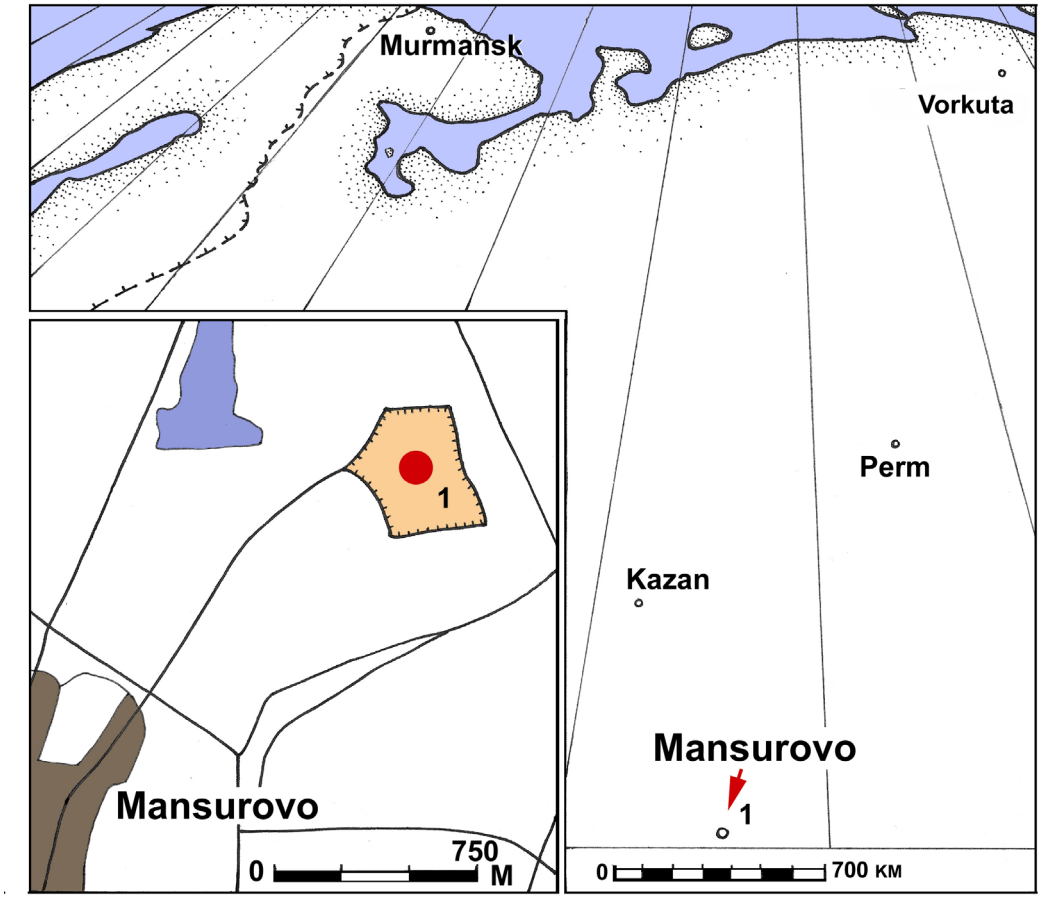

Fig. 1. Geographic position of the locality Mansurovo (1; marked by a red circle on left and by the red arrow on right image), where the traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 were found.

Рис. 1. Географическое положение местонахождения Мансурово (1; отмечено красным кружком слева и красной стрелкой справа), где были найдены следы *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022.

ies of the traces were made and sent for the measurements and detailed study to the first author of this paper (SVN).

The Mansurovo section is disposed at the south-western part of the Orenburg region nearby its boundary (Fig. 1). Stratigraphically, the Mansurovo locality belongs to Gostevskaya Formation of Ustmylsky Horizon of Lower Substage of the Olenek Stage of Lower Triassic [Uliakhin *et al*., 2023].

Paleontological characteristics of the Mansurovo locality includes following taxa: temnospondyl amphibians *Wetlugasaurus* cf. *malachovi* Novikov, 1990 and *Angusaurus* sp., thecodont *Tsylmosuchus* sp., prolacertilian reptile *Microcnemus* sp., ichnofossils of invertebrates *Taenidium* isp., *Rhizocorallium* isp., *Diplichnites triassicus* (Linck, 1943), tetrapod footprints *Rhynchosauroides* sp. and *Chirotherium*-type traces, roots preserved in situ [Uliakhin *et al*., 2023]. The taxonomic list of the Mansurovo paleontological assemblage is in good agreement with the recent knowledge of appearance of the Early Triassic vertebrate faunas of the Easter-Europe platform [Ivakhnenko *et al*., 1997]. Such assemblages normally include fish remains as well [Minich, Minich, 1998]. The taphonomic peculiarities of the Mansurovo locality allows to await finds of fossil fishes in this section during careful and systematic study of the deposits of Gostevskaya Formation there.

The best specimen with the limulid traces described in the present paper is a large slab (Figs 2, B, C; 3, A, B), representing a sedimentary/depositional surface with two distinct traces formed by the subsequently repeating crescent structures (see Description below). Two additional specimens of the same shape from the same locality were photographed in the field (Fig. 2, A, D).

In all the cases the traces listed above are preserved in the dense fine-grained sandstone of light greyish-yellow to ochre color. The depositional surface is more or less smooth, with the exception of the traces, which are preserved as natural relief as they were left by the moving animal. The only exception is a specimen (Fig. 2, D) with the trace, which is represented by the mold with positively expressed relief.

Paleoichnological description

Subphylum Chelicerata Heymons, 1901
Class Xiphosura Latreille, 1802
Order XIPHOSURIDA Latreille, 1802
Family Incertae sedis

Ichnogenus *Selenichnit*es Romano et Whyte, 1990

Selenichnites cf. *eotriassicus* Naugolnykh, 2022
Figs 2–4, 6.

DESCRIPTION. The best and the most representative specimen (Figs 2B, C; 3A, B; 4A, B) shows two traces left by

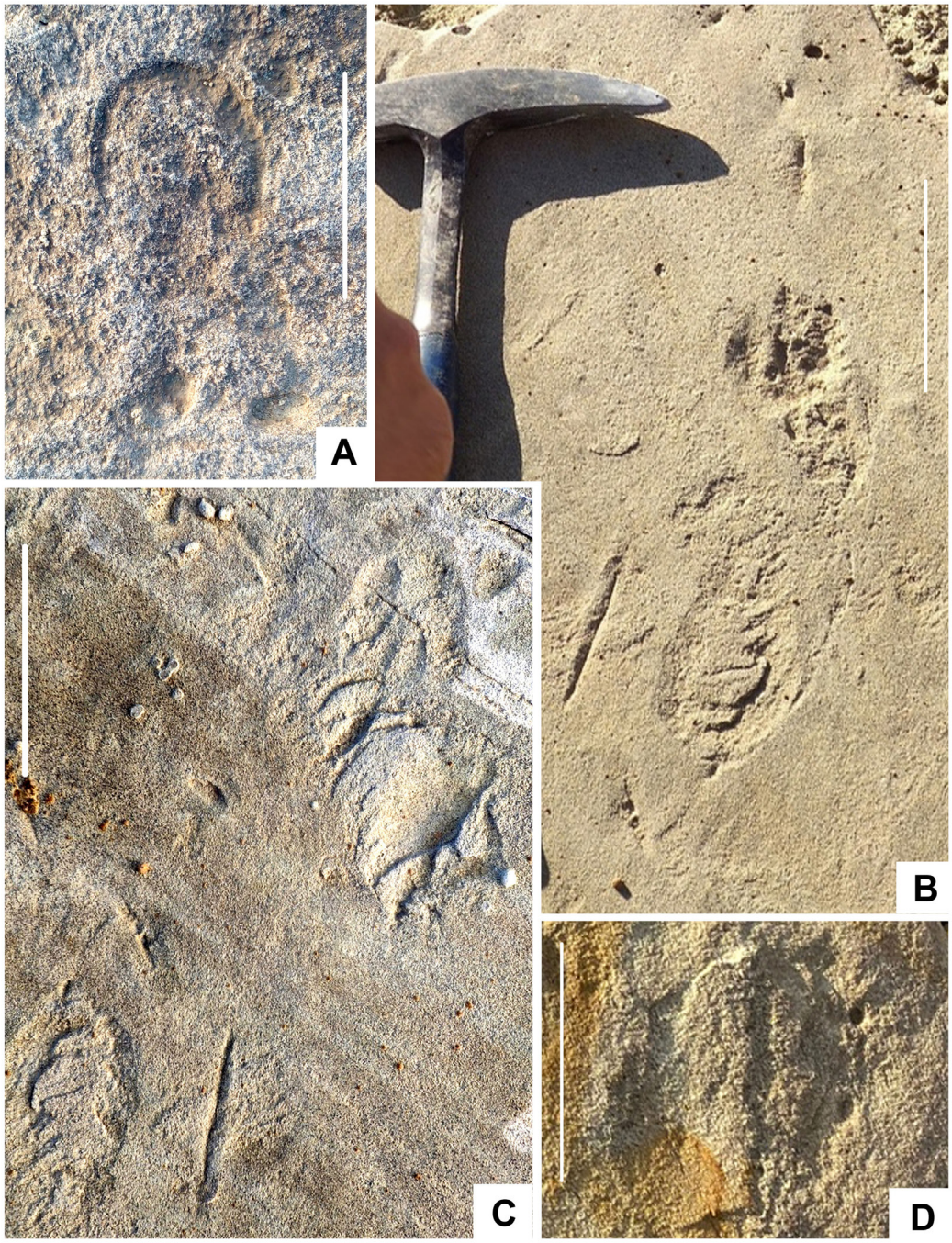

Fig. 2. The traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 at the locality Mansurovo. Scale bar is 10 см (A, B. C) и 5 см (D). The geological hammer is used as an additional scale on the Fig. B.

Рис. 2. Следы *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 в местонахождении Мансурово. Длина масштабной линейки 10 см (A, B. C) и 5 см (D). На фиг. B в качестве дополнительного масштаба использован геологический молоток.

two different individuals of different size and ontogenetic age, although basically with one and the same shape of the body. Both traces are disposed closely to each other and are orientated in almost one and the same direction. The distance between the traces is approximately 10 cm.

The larger trace is a semilunar/crescent imprint 9 cm wide, obviously left by the anterior part of an animal, which moved on the soft substrate. The posterior part of the trace is an unclear imprint of part of the animal body of smaller size and of trapezoid shape. There are smaller imprints of curved linear shape, which are disposed on the lateral areas of this trace. It is logic to suggest that these smaller imprints were left by moved legs of the animal. A small linear imprint 0.5 cm wide and 2 cm long is observed just after the posterior part of this trace. Most probably, this imprint was left by the caudal segment of the moved trace-producer.

The second trace preserved on the same depositional surface is a series of concaved semilunar/crescent imprints forming an

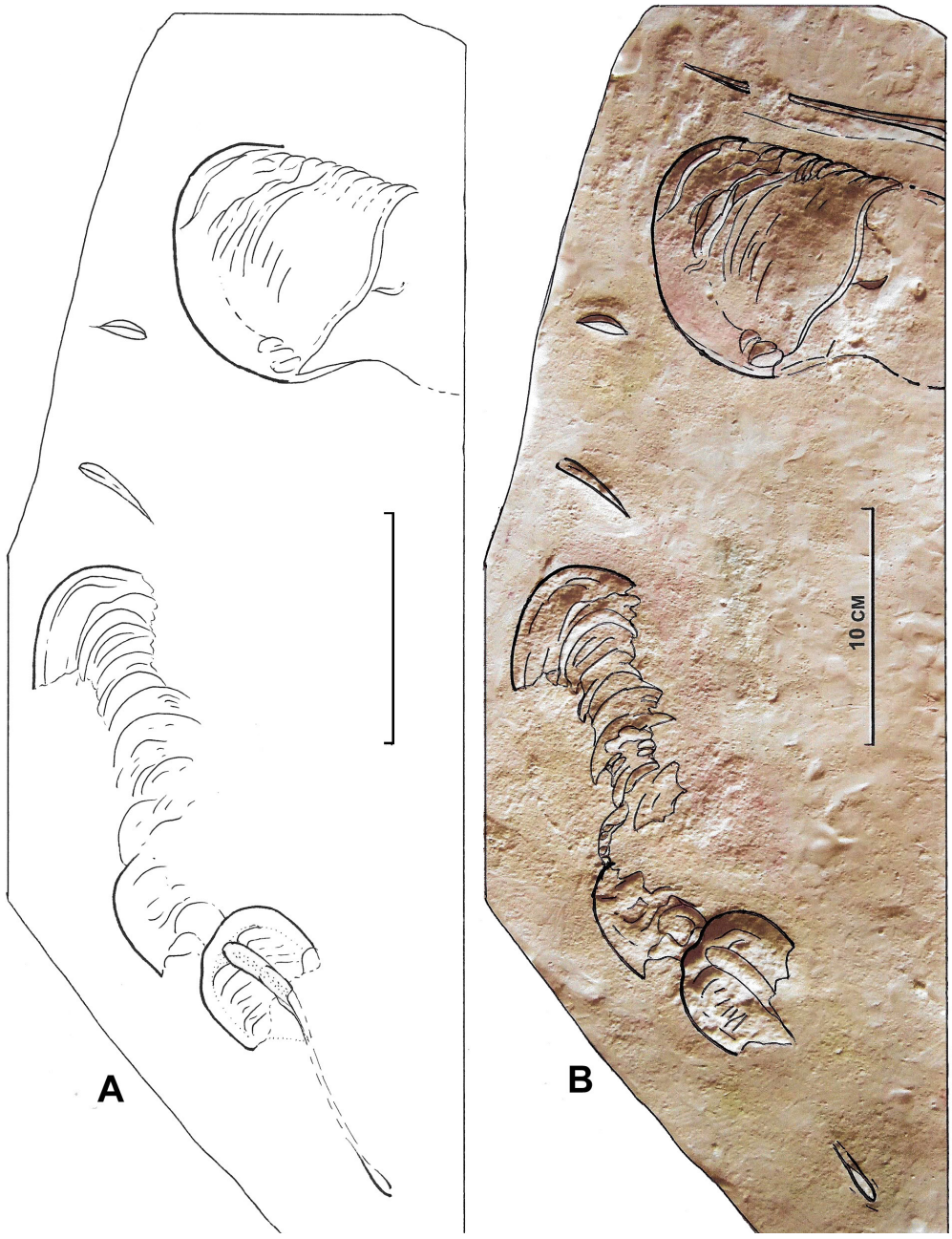

Fig. 3. The traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 at the locality Mansurovo. A — a line drawing; B — graphic line-tracing of the photo-image. Scale bar is 10 cm.

Рис. 3. Следы *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 в местонахождении Мансурово. A — графическая прорисовка; B — дешифровка фотоизображения по методике «line-tracing». Длина масштабной линейки 10 см.

undulating row. The almost complete trace of an animal, which might have lain on the soft substrate before starting its moving forward, is preserved in the beginning of the row (Figs 2B; 3A, B, lower part of the image; 4A, B).

Width of the crescent anterior part of this trace is about 5 cm, length is 5.2 cm. There is a distinct axial structure in the middle part of this trace. Two additional rows of linear imprints are observed aside of this structure. Each row consists of five prolonged structures perpendicularly to the axial structure. The left (as it is positioned on the Fig. 4A, B) row of the linear imprints is more distinct. According to our interpretation, these linear structures were left by walking legs of the trace-producer.

The long linear imprint is disposed just after posterior part of the body imprint. This linear imprint is disposed exactly in the same direction as the axial part of the posterior area of the trace (body imprint). There is no doubt that this linear imprint corresponds to caudal part of a moving animal, which was the producer of these traces. Length of the caudal trace is 4 cm, width is 0.8 cm.

Two additional specimens figured here on Fig, 2A, D demonstrate the same morphological features as that of the most representative specimens described above, although one of them (Fig. 2A) has no a distinct posterior part. Another one (Fig. 2D) has clear axial “rib” imprint exactly identical to the same structure of the specimen figured here on Fig. 4A, B.

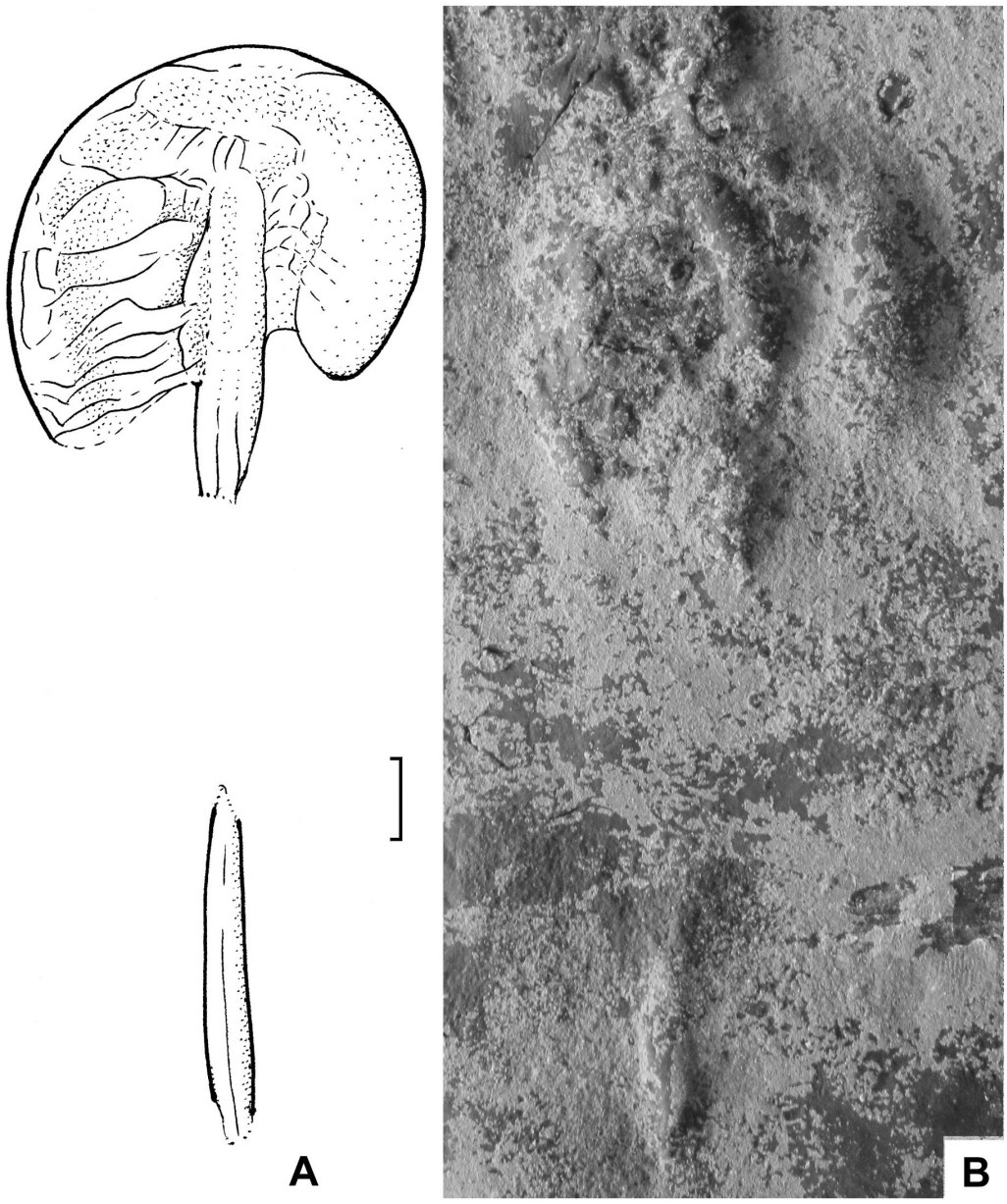

Fig. 4. The traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 at the locality Mansurovo. A — a line interpretative drawing; B — the photo-image. Scale bar is 10 cm.

Рис. 4. След *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 в местонахождении Мансурово. A — графическая интерпретационная прорисовка; B — исходное фотоизображение. Длина масштабной линейки 10 см.

MORPHOLOGICAL INTERPRETATION OF THE TRACES STUDIED. General shape of the traces studied, i.e. the anterior semilunar/crescent larger part, posterior trapezoid laterally segmented part and long and narrow caudal segment give possibility to express an opinion on the taxonomic assignment of these traces. Such pattern of the morphological features is quite diagnostic for the ichnogenus *Selenichnites* Romano et Whyte, 1990, widely used for attribution and description of the xiphosuran traces (see for details: [Romano, Whyte, 1990, 2013, 2019; Wang, 1993]). Moreover, the traces from Lower Triassic of the Mansurovo locality are almost identical to the traces described by one of the present authors (SVN) from the Lower Triassic deposits outcropped in the Tikhvinskoe locality, disposed in the City of Rybinsk area, Yaroslavl region, Russia (Naugolnykh, 2022), where these traces are associated with the fossil carapaces of the limulid *Limulitella volgensis* Ponomarenko, 1985 [Ponomarenko, 1985; Naugolnykh, 2009]. There is no question that the limulid traces from the Tikhvinskoe locality belonged to the horse-shoe crab *Limulitella volgensis*, because only one species of limulid is known in this locality, and only this single species was able to leave the traces of *Selenichnites eotriassicus* morpholohy. General shape of the limulid *Limulitella* body (Fig. 5) fits very well to the shape, size and proportions of the *Selenichnites* cf. *eotriassicus* from the Mansurovo locality (see, for instance, Fig. 4 here). Based on this assumption we can suggest that the traces from the Mansurovo

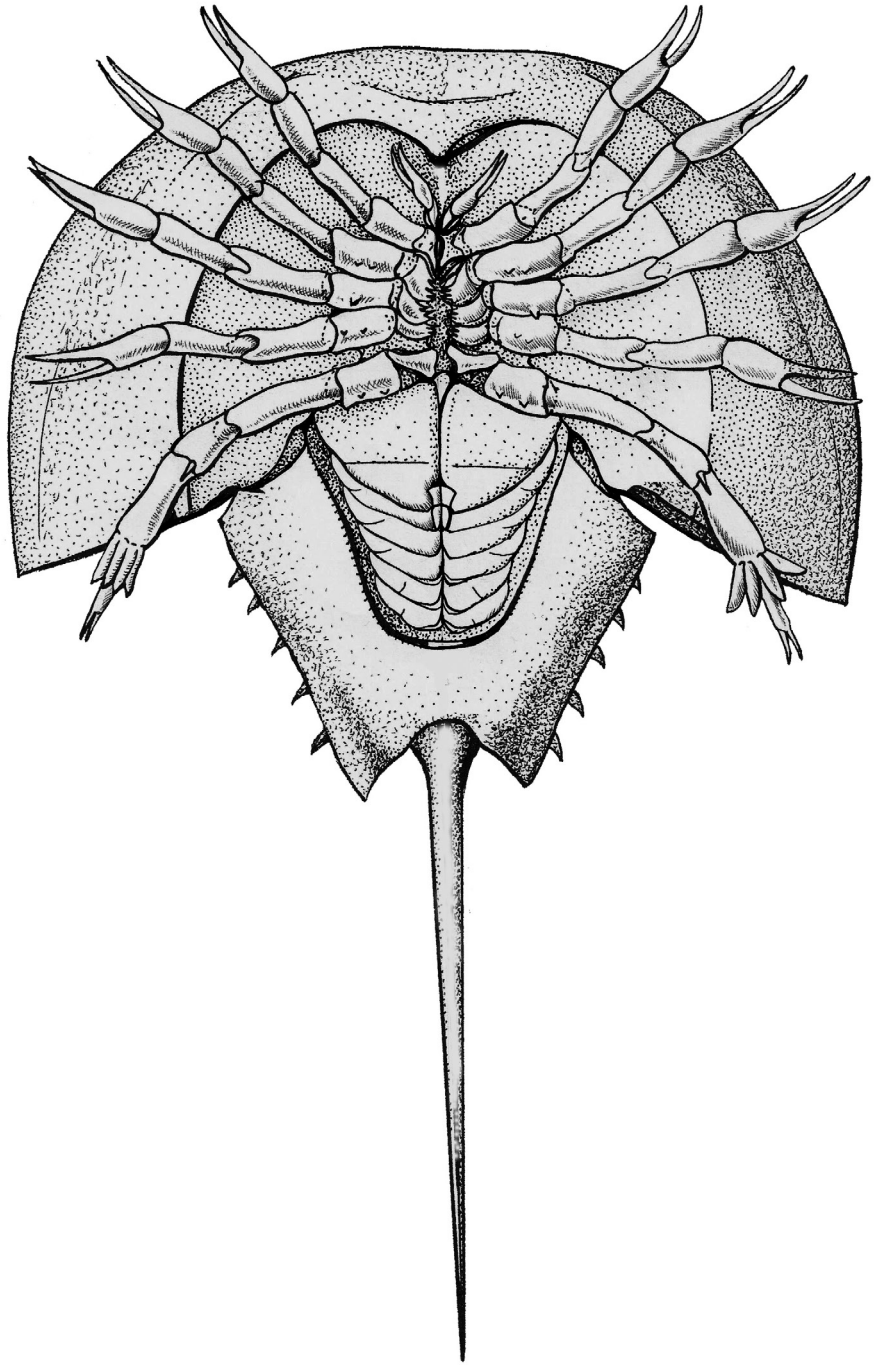

Fig. 5. A reconstruction of the abdominal (ventral) side of the horse-shoe crab *Limulitella volgensis* Ponomarenko, 1985, which left the traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022, Abdominal (ventral) side of the body is shown as integrative image after: Lankester, 1905; Davitashvili, 1936; Druschitz, Obrucheva, 1962. Length of the adult individual is about 15 cm.

Рис. 5. Реконструкция вентральной стороны мечехвоста *Limulitella volgensis* Ponomarenko, 1985, которому, возможно, принадлежали следы *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 из местонахождения Мансурово. Брюшная (вентральная) сторона тела показана как интегративное изображение по: Lankester, 1905; Давиташвили, 1936; Друщиц, Обручева, 1962. Длина взрослого экземпляра достигала 15 см.

locality described above were also left by a limulid of the genus *Limulitella*, although any limulid carapaces were not found in this locality yet. Very similar traces were reported from the Middle Jurassic deposits of the Skoura Syncline (Middle Atlas, Morocco), where they were also assigned to *Selenichnites* in open nomenclature [Oukassou *et al*., 2016].

DISCUSSION. The deposits of Gostevskaya Formation bearing *Selenichnites* cf. *eotriassicus* limulid traces can be interpreted as a result of sedimentation in the shallow water lagoon or lake, perhaps with the temporal ingression of marine waters. Such paleoenvironments were and still are typical for living conditions of xyphosurans, and be more taxonomically

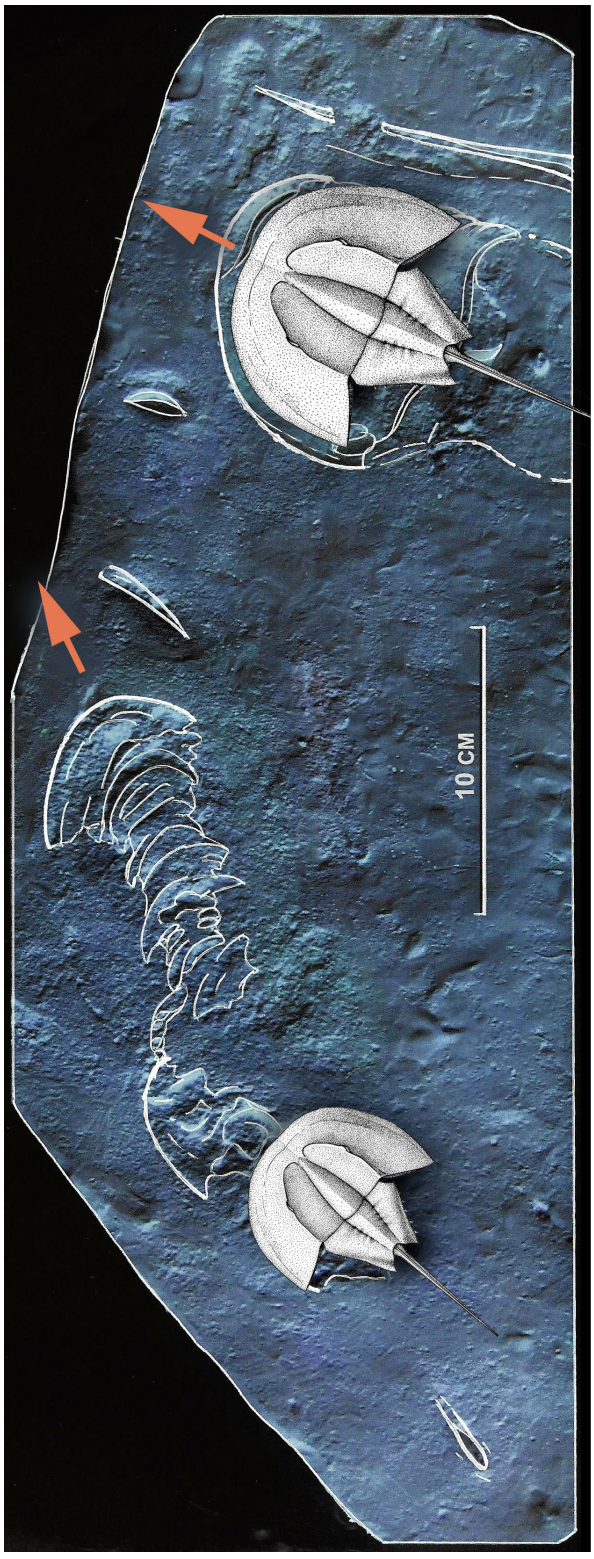

Fig. 6. Direction of moving of the horse-shoe crabs *Limulitella volgensis* Ponomarenko, 1985 and relation of their carapaces to the traces *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 (after the specimen from the locality Mansurovo). Scale bar is 10 cm.

Рис. 6. Направление движения мечехвостов *Limulitella volgensis* Ponomarenko, 1985 и соотношение панцирей мечехвостов со следами *Selenichnites* cf. *eotriassicus* Naugolnykh, 2022 (по образцу из местонахождения Мансурово). Длина масштабной линейки 10 см.

precise, the limulids, in geologic past [discussion see in: Bicknell *et al*., 2020, 2022, 2023; Naugolnykh, Bicknell, 2022] and even now. This or very similar types of paleoenvironments were characteristic of Triassic landscape in Western and Central Europe [Linck, 1943; Pollard, 1985; Knaust, Hauschke, 2005], and Eastern Europe as well [Strok *et al*., 1984; Lozovsky, 1987].

Regarding the main trends in modern paleoichnology, it should be noted that two basically different taxonomical approaches are present. The first one is based on the usage and further development of formal paleoichnological systematics, which is independent of the natural systematics of organisms. Various versions of such strictly formal systematics include both morphological features of the traces themselves, and type of activity or behavioristic peculiarities of the organisms (trace-producers), for instance, lying on the bottom, passive or active feeding or hunting, etc. Simultaneously, the taxonomic position of the organisms (trace-producers) left one or another type of the traces should not be taken in account for paleoichnologic/ichnotaxonomic decision.

The second approach includes, besides formal features for describing the ichnofossils, the data on taxonomic position of the organisms left the traces, which can be found or analytically induced during study and description of the fossil traces. Moreover, in many cases, such as study of echinoderms (Asteroidea and Ophiuroidea), bird or dinosaur footprints and so on, taxonomic assignment of the traces can be the main reason for their study. This approach can be successfully applied to the description of the traces *Selenichnites* cf. *eotriassicus* from the Mansurovo locality.

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