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LATE MIOCENE TURTLES OF GRYTSIV (WESTERN UKRAINE) WITH RODENT GNAW MARKS ON THE CARAPACE SURFACE

V. Yanenko[1,*] & O. Kovalchuk[1,2]

[1]*Department of Palaeontology, National Museum of Natural History, National Academy of Sciences of Ukraine, B. Khmelnytskyi st., 15, Kyiv 01054 Ukraine*
[2]*Department of Palaeozoology, Faculty of Biological Sciences, University of Wrocław, Sienkiewicza St., 21, Wrocław 50-335, Poland*
**Corresponding author*
E-mail: ornithologist.ua@gmail.com

V. Yanenko (https://orcid.org/0000-0002-1241-1929)
O. Kovalchuk (https://orcid.org/0000-0002-9545-208X)

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Late Miocene Turtles of Grytsiv (western Ukraine) with Rodent Gnaw Marks on the Carapace Surface. Yanenko, V. & Kovalchuk, O. — The paper describes a series of turtle remains from the Early Late Miocene of Grytsiv (Khmelnytskyi Oblast, Ukraine). This fossil assemblage was quite diverse and included representatives of four families (Emydidae, Geoemydidae, Testudinidae, and Trionychidae), most of which are described only to the family level due to incompleteness. The discovery of shell fragments, identified here as *Testudo chernovi*, is the earliest record of this species on the territory of Ukraine. Scratches on the nuchal of *T. chernovi* are interpreted as traces of gnawing or rasping and are described as a new ichnospecies, *Machichnus inrosus* isp. n. These traces are identified as gnawing marks of the rodent *Anomalomys grytsivensis*, as evidenced by the width of in lower incisors and the presence of two characteristic longitudinal ridges on their labial surface.
Key words: Reptiles, Testudines, diversity, ichnospecies, taphonomy, Europe.

Introduction

Turtles (Testudines) are well represented in the fossil record of Ukraine (Danilov et al., 2017 and references therein). The oldest remains assigned to this group belong to chelonioids and come from the Paleocene of Crimea (Zvonok & Danilov, 2019) and chelonioids and trionychids from the Middle Eocene deposits of Kyiv, Luhansk Region and the Crimea (Khosatzky, 1950; Chkhikvadze, 1990; Averianov, 2002; Danilov et al., 2011; Zvonok, 2011; Zvonok et al., 2013; Zvonok & Danilov, 2017, 2019; Georgalis & Joyce, 2017). There are no data on the presence of turtles in the Oligocene of Ukraine. The Quaternary fossil record of this group is rather poor and represented by the European pond turtle *Emys orbicularis* (Linnaeus, 1758), the testudinid *Testudo* (Syromyatnikova, 2023), as well as shell fragments described only up to the family level (e. g., Khosatzky, 1946 a; Korneyev, 1953; Tarashchuk, 1965; Kovalchuk et al., 2018 and others). In contrast, Neogene was a heyday for turtles as evidenced by the presence of many species described on a large number of remains, including almost complete shells. Neogene turtles have been reported from Miocene and Pliocene localities of Ukraine (Riabinin, 1918, 1945; Khosatzky, 1945, 1946 b, 1947, 1948 a, b, 1949 a, b, 1953; Bogachev, 1960; Pidoplichko & Tarashchuk, 1960; Telepneva, 1964; Tarashchuk, 1965, 1971 a, b; Chkhikvadze, 1982, 1983, 1989; Khosatzky, 1986; Orlov, 2005; Sinitsa, 2005; Joyce, 2016; Georgalis & Joyce, 2017; Kovalchuk et al., 2017; Syromyatnikova et al., 2019).

Turtle remains are fragmented, which makes them difficult to process. Many of them are described only to the family level due to the lack of reliable diagnostic characters. Type series of some Miocene and Pliocene turtle species from the territory of modern Ukraine also include isolated shell fragments and, to a lesser extent, other isolated skeletal elements. The validity of some of these nominal taxa is doubtful because of the poor preservation of their fossils. The temporal and geographical ranges of extinct species need to be clarified. The ability to compare new specimens with those of previously described species is limited.Another problem is that many turtle remains came from alluvial deposits, and therefore it is difficult to estimate their actual age properly.

Reptile remains (mostly snakes) from the Grytsiv locality in the western Ukraine have been thoroughly studied, and the results of these studies are presented in several publications (Zerova, 1987, 1989, 1992; Szyndlar & Zerova, 1990; Szyndlar, 1991; Ivanov, 1999; Szyndlar & Rage, 2002; Rage, 2013; Roček, 2019). At the same time, turtle shell fragments from this locality were only briefly mentioned by Korotkevich (1988) but have never been described in detail.

The aim of this paper is to revise the turtle remains from Grytsiv, to interpret the traces found on their surface in a taphonomic context, and to determine the species composition of turtles in this assemblage.

Geological setting

The Grytsiv (also known in the literature as Gritsev, Gritzev, Hrytsiv) locality (49°58′ N, 27°12′ E) is situated in the eastern wall of the limestone quarry exposed along the Khomora River, ca. 2 km west of the eponymous village in Khmelnytskyi Oblast, Ukraine (fig. 1). The fossil-bearing layer is confined to karst filling deposited at the coastline of the Eastern Paratethys (Korotkevich, 1988). Vertebrate remains were recovered from greenish clays and silts interlayered with early Bessarabian (= middle Sarmatian s. l.) algal reef carbonates lying on granitic basement (Korotkevich et al., 1985; Topachevsky et al., 1996). Based on a thorough revision of small-mammal fossils from Grytsiv, the age of deposits was estimated as early Late Miocene, MN 9 zone (Nesin & Nadachowski, 2001). This locality represents a taxonomically diverse fossil assemblage, which is one of the oldest Vallesian faunas in Europe (Nesin & Kovalchuk, 2021). The fossiliferous deposits of Grytsiv have a reversed polarity and correlate with the Chron C5r, ca. 11.146–11.056 Ma (Vasilyan et al., 2013; Kirscher et al., 2016).

Material and Methods

The studied sample consists of 65 shell fragments of different state of preservation. These specimens were collected in 1983, 1990 and 1991, and are housed at the Department of Palaeontology (NMNHU-P, collection AR) of the National Museum of Natural History, National Academy of Sciences of Ukraine (Kyiv, Ukraine). The identification of the fossils was accomplished using diagnostic features based on comparisons with extinct species deposited in the NMNHU-P collection as well as on data from the literature (Khosatzky, 1948a; Chkhikvadze, 1989; Danilov et al., 2017; Kovalchuk et al., 2022). In cases when identification to species level was not possible, the specimens were classified to higher taxonomic ranks. The systematics of turtles and taxonomic hierarchy follows Georgalis & Joyce (2017), Joyce et al. (2021) and Thomson et al. (2021). We used the standard anatomical orientation system for turtle shell. The osteological terminology for trionychid turtles adopted here is based on Gardner & Russell (1994), Scheyer et al. (2007), Vitek & Joyce (2015), and Georgalis & Joyce (2017). Description of trace fossils is presented according to Mikuláš et al. (2006), with references to Chumakov et al. (2013), de Araújo-Júnior et al. (2017), and Lindholm et al. (2023). A JEOL JSM-606 OLA scanning electron microscope was used for preparing SEM pictures.

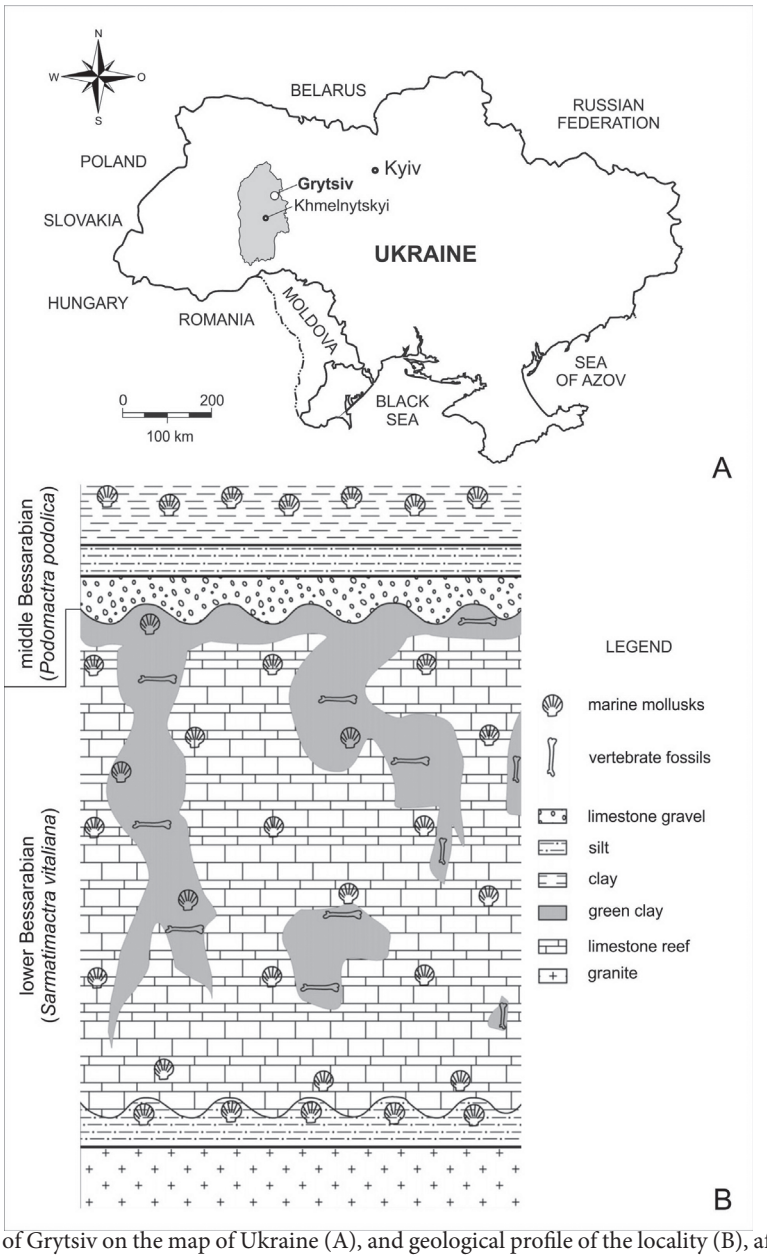

Fig. 1. Location of Grytsiv on the map of Ukraine (A), and geological profile of the locality (B), after Vasilyan et al. (2013) and Nesin & Kovalchuk (2021).

Systematic palaeontology

CLASS REPTILIA Laurenti, 1768
ORDER TESTUDINES Batsch, 1788
SUBORDER CRYPTODIRA Cope, 1868
FAMILY EMYDIDAE Gray, 1825 (sensu Joyce et al., 2021)
Emys Duméril, 1805
***Emys* sp.**

Material. Two marginal scutes NMNHU-P AR 402/1-2 (fig. 2, B), one vertebral scute AR 402/3, one xiphiplastron AR 402/4 (fig. 2, A), one abdominal scute AR 402/5, three fragments of costal plates AR 402/6-8.

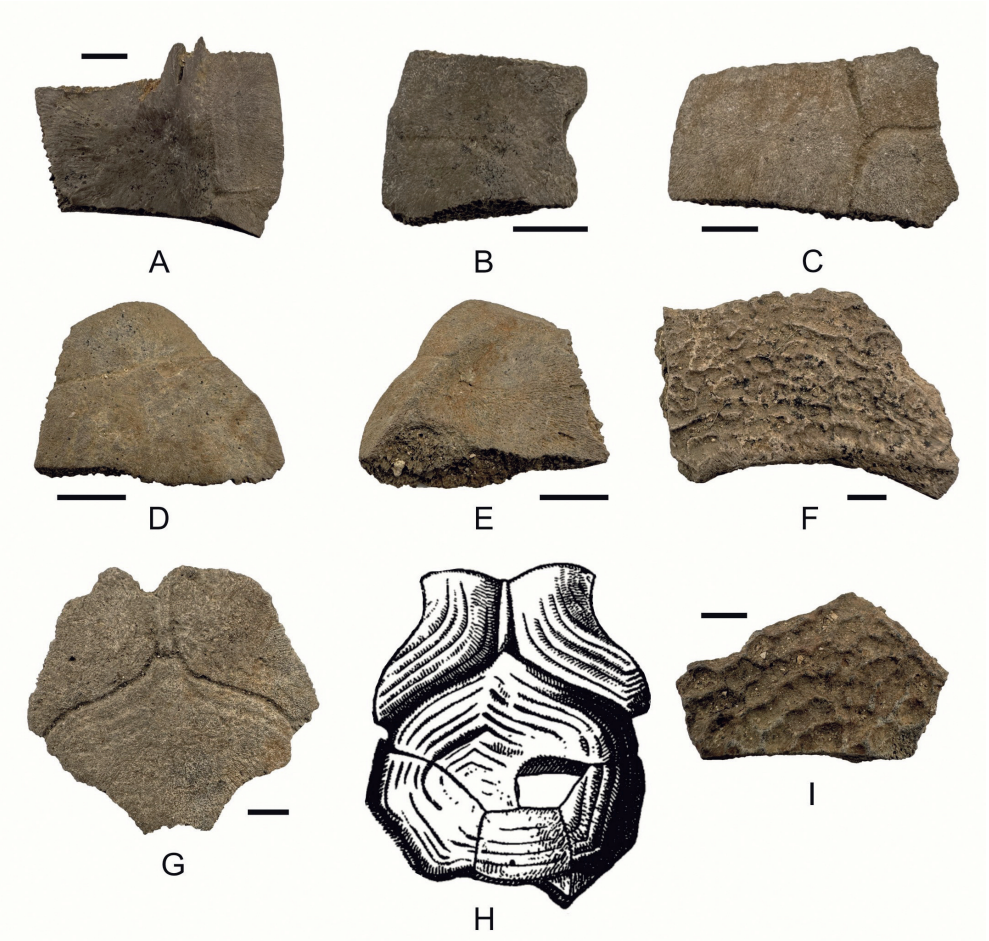

Fig. 2. Turtle remains from the late Miocene of Grytsiv: A–B — *Emys* sp., xiphiplastron NMNHU-P AR402/4 (A), marginal scute NMNHU-P AR 402/1 (B); C–E — *Melanochelys* cf. *M. moldavica* Chkhikvadze, 1983, costal plate NMNHU-P AR 403 (C), right xiphiplastron NMNHU-P AR 405 (D–E); F, I — Trionychidae indet., shell fragments NMNHU-P AR 401/1 (F), AR 401/2 (I); G–H — *Testudo chernovi* Khosatzky, 1948, nuchal NMNHU-P AR 406 (G), type specimen after Khosatzky (1948 a: fig. 1), modified (not to scale). Scale bars equal 5 mm in A–C, F–G and I, 10 mm in D and E.

Description. The surface of scutes and plates is smooth. The greatest length of the latter is 12 and 14 mm. The specimens are fragmented thus the width of the proximal and distal ends cannot be measured. The upper free edges of the xiphiplastron have wide and flattened borders. All the remains described belonged to a small-sized and/or juvenile individual.

Remarks. The presence of borders in xiphiplastron and morphology of other skeletal elements are characteristic for representatives of the genus *Emys* (Khosatzky & Redkozubov, 1989). During the late Miocene, two nominal species of this genus — *Emys sukhanovi* Chkhikvadze, 1983 and *Emys tarashchuki* (Chkhikvadze, 1980) – occurred in the territory of modern Ukraine (Danilov et al., 2017). The specimens from Grytsiv resemble those of *E. tarashchuki* in overall morphology, albeit the former are more gracile.

FAMILY GEOEMYDIDAE Theobald, 1868
Melanochelys Gray, 1869 (sensu Danilov et al., 2017)
Melanochelys moldavica Chkhikvadze, 1983
Melanochelys* cf. *moldavica

Material. One right xiphiplastron NMNHU-P AR 405 (fig. 2, D–E), one neural plate AR 404, one costal plate AR 403 (fig. 2, C).

Description. The posterior lobe of the right xiphiplastron is smoothly narrowed. The femoro-anal notch is weakly expressed. The short xiphiplastral processes are rounded and not bent posteriorly. The moderate anal notch is pointed. The transverse ridge on the upper surface of the caudal part of the xiphiplastron is moderately developed, and it is almost parallel to the posterior edge of the bone. The neural plate is wide, hexagonal, with a distinct bend of the medial keel. The fragments of costal plates are uniform in width.

Remarks. The right xiphiplastron from Grytsiv is morphologically similar to that in *Melanochelys moldavica* from the middle Sarmatian of Moldova (Chkhikvadze, 1983) except for the more pronounced transverse ridge on the upper surface of its caudal part. It further differs from the respective bones of the other geoemydid turtles (e. g., *Sarmatemys*, *Sakya* etc.) in having a much less developed femoro-anal notch and shorter xiphiplastral processes. Other skeletal elements (neural and costal plates) share general geoemydid morphology and we tentatively assign them to the same taxon.

FAMILY TESTUDINIDAE Gray, 1825
Testudo Linnaeus, 1758
Testudo chernovi Khosatzky, 1948

Material. Nuchals, NMNHU-P AR 406 (fig. 2, G), AR 407 (fig. 3, A).

Description. The anterior edge of the bones is slightly notched. The cervical scute is narrow, arrow-shaped and wedged on the inner side; its length reaches 11.0 mm. Lateral wings of the nuchal plate are not covered with pleural scutes. The midline length of the specimens AR 406 and AR 407 is equal to 31.6 and 36.1 mm, the greatest width — 38.0 and 46.2 mm, respectively. The length to width ratio is 0.83 (AR 406) and 0.78 (AR 407).

Remarks. The specimens are identical in morphology and shape to those of *T. chernovi* from the Early Pliocene of Ukraine (Khosatzky, 1948 a), although they are smaller and possess a shorter cervical scute. The nuchal of the closely related species *Testudo kuchurganica* Khosatzky, 1948 has a straight anterior edge and its lateral wings are covered with pleural scutes.

A series of characteristic scratches has been observed on one of the specimens considered (fig. 3, B–C). It was interpreted as traces of gnawing or rasping (Mikuláš et al., 2006) and described as a new ichnospecies below.

Machichnus Mikuláš, Kadlecová, Fejfar & Dvořák, 2006
Machichnus inrosus, isp. n.

Holotype. NMNHU-P AR 407, a series of scratches on the upper right margin of the turtle shell fragment (fig. 3).

Etymology. The ichnospecies name has Latin derivation ('in' means not enough, and 'rosus' means gnawen) and displays that a relatively small area of the turtle shell is affected by traces of gnawing or rasping.

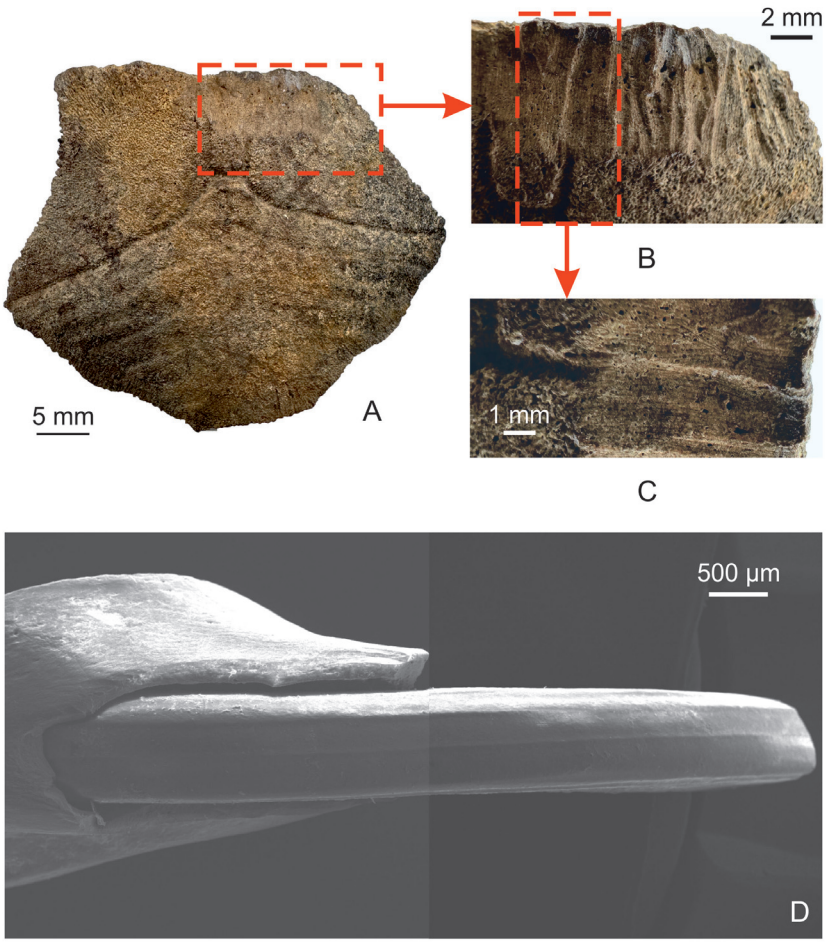

Fig. 3. The nuchal plate of *Testudo chernovi* NMNHU-P AR 407 from Grytsiv with gnaw marks (A); B–C — *Machichnus inrosus* isp. n., enlarged affected area (B) and a set of individual striae (C); D — combined SEM image of the mandible of *Anomalomys grytsivensis* Nesin & Kovalchuk, 2021 (NMNHU-P 22/2703) showing the labial surface of the lower incisor with longitudinal ridges.

Diagnosis. *Machichnus* consisting of narrow, subparallel grooves with a double longitudinal striation exposed on a small area of the substrate.

Description. There is a series of about 20 elongated shallow grooves on the surface of the nuchal of the *Testudo chernovi* carapace. The striae are uniform in shape, and they cover 10–12 % of the affected substrate. They are slightly arcuate in cross-section and bear two thin parallel furrows, one of which is located in the centre, and the other is shifted to the periphery. These furrows are traces of the longitudinal ridges on the lower incisors of a rodent, with which it gnawed (rasped) the turtle shell. The width of the striae is 1 mm, and the length of individual scratches reaches 8 mm.

Comparison. The new ichnospecies is similar in shape to those of the ichnogenus *Machichnus* Mikuláš et al., 2006 from the Early Miocene of the Czech Republic, although it differs from *Machichnus regularis* in having a greater length of scratches, while the width of individual striae is at the upper limit of values for the latter. On the contrary, *Machichnus multilineatus* is characterised by wider striae and longer traces. The area affected with scratches in *Machichnus inrosus* is much smaller than that in Early Miocene ichnospecies from the Czech Republic. *Machichnus bohemicus* Mikuláš et al. (2006) resembles *M. inrosus* in the length of traces but differs from the latter in the character of scratches and smaller

width of individual striae. Other members of *Machichnus* — from the Late Cretaceous of England (Chumakov et al., 2013), Neogene of the Atlantic Coastal Plain, USA (Lindholm et al., 2023) and the Late Pleistocene–Early Holocene of Brazil (de Araújo-Júnior et al., 2017) — substantially differ from *M. inrosus* in morphology and shape.

FAMILY TRIONYCHIDAE Bell, 1828
Trionychidae indet.

Material. Two shell fragments, NMNHU-P AR 401/1-2 (fig. 2, F, I).

Remarks. The available material is represented by bone fragments, the anatomic assignment of which is limited, as well all other known trionychid remains from Ukraine (Georgalis & Joyce, 2017). The external surface is covered by a plywood trionychid sculpture (see Scheyer et al., 2007) consisting of moderate shallow circular pits surrounded by ridges.

Testudines indet

Material. Fifty carapace fragments, NMNHU-P AR 408/1-50.

Remarks. All the specimens assigned to this category have different size and shared turtle morphology (see Danilov et al., 2017 for more details), although they are highly fragmentary to make any further identification.

Discussion

Composition of the Late Miocene turtle assemblage of Grytsiv

Turtle remains from Grytsiv analysed in this study are highly fragmentary. The poor preservation of the fossils together with the predominance of non-diagnostic skeletal elements complicates their identification that resulted in using open nomenclature for most of the taxa. Nevertheless, it was possible to identify representatives of four families — Emydidae, Geoemydidae, Testudinidae, and Trionychidae. Emydids and geoemydids are represented by *Emys* sp. (possibly *E. tarashchuki*) and *Melanochelys* cf. *M. moldavica*. Similar taxa have been reported from the late Miocene of Moldova (Chkhikvadze & Lungu, 1973; Chkhikvadze, 1983, 1989), Russia (Khosatzky, 1956; Titov et al., 2006; Tesakov et al., 2017) and Ukraine (Chkhikvadze, 1989).

Testudo chernovi was originally described from the Early Pliocene of Ukraine (Khosatzky, 1948a) and was also recorded in the Pliocene of Georgia and Moldova (Chkhikvadze, 1983, 1989). Later, the lower temporal limit for this species was dropped to the Pontian (Danilov et al., 2017). The finding of two nuchals identified as *Testudo chernovi* in the middle Sarmatian deposits of Grytsiv is the earliest known record of this species. Testudinids are well represented in the Late Miocene fossil record of Europe (e. g., Chkhikvadze, 1983, 1989; Georgalis & Kear, 2013; Pérez-García & Vlachos, 2014; Vlachos & Tsoukala, 2014; Pérez-García, 2016; Danilov et al., 2017; Kovalchuk et al., 2017; Garcia et al., 2020; Vlachos et al., 2020 a, b; Georgalis & Delfino, 2021; Pérez-García et al., 2022). The number of trionychid fossils from Grytsiv is limited. The recent revision of trionychid turtles from Europe by Georgalis & Joyce (2017) showed that all fossil trionychids from Ukraine can only be identified as Pan-Trionychidae indet. Nevertheless, other Neogene European trionychids have been identified to the genus level, with both genera *Trionyx* Geoffroy Saint-Hilaire, 1809, and *Rafetus* Gray, 1864, been present in the Miocene of Europe (Georgalis & Joyce 2017; Georgalis et al., 2020).

Interpretation of gnaw marks

According to Mikuláš et al. (2006), gnawing (rasping) traces consisting of parallel to subparallel, densely spaced grooves on fragments of turtle carapace were usually made by rodents. These animals may have rasped turtle carcass either to obtain cartilage and periost, rich in collagen and vitamins (as suggested by Mikuláš et al., 2006) or replenished the mineral (calcium) deficiency in this way similar to modern rodents (I. Zagorodniuk, pers. comm. 2023). In order to find out which rodent could make such traces on the surface of the *Testudo chernovi* shell fragment from Grytsiv, we examined all small mammal remains collected from this locality and having the same age. Based on the available data, this specimen could have been rasped by *Anomalomys grytsivensis* Nesin & Kovalchuk, 2021. Two mandibles with incisors of this rodent recovered from Grytsiv were available for comparison. Incisors of this species have the same width as individual striae (ca. 1 mm) and bear two characteristic longitudinal ridges on the labial surface (fig. 3, D). The traces of these ridges are clearly recognisable as tiny furrows in *Machichnus inrosus*. Considering that the remains of *Anomalomys grytsivensis* were found in the same layer as the carapace fragment, we suggest that the latter was gnawed by an individual of this species.

The lifestyle of anomalomyid rodents is not fully understood. Kowalski (1994) and Bolliger (1999) suggested that their hypsodont teeth with a simplified crown pattern were fossorial adaptations. According to Kalthoff (2000), small and narrow incisors of *Anomalomys* could not be used as a digging tool in the same way as those in mole rats. Moderate fossorial activity was inherent to *Anomalomys grytsivensis*, but it was unlikely prominent in their lifestyle (Nesin & Kovalchuk, 2021). The ultrastructure of tooth enamel in *Anomalomys* from Grytsiv differs structurally from that in Pliocene and Pleistocene representatives of the family Spalacidae (Nowakowski et al., 2018). It is more complex and probably reflects feeding on grass by anomalomyid rodents in Miocene steppe landscapes (Kowalski, 1994). The results of our study allow suggesting that they were able to replenish mineral deficiency in their diet by consuming cartilage and periost from animal carcasses.

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