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Revisiting the paleolithic reindeer of Moldova: an in-depth analysis

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Abstract. This study examines reindeer remains from Paleolithic sites in Moldova, including re-description and reclassification of antler findings, and identifies a previously undocumented complete antler from Cosăuți. The antler from Duruitoarea Veche is determined to be from red deer (*Cervus elaphus*), consistent with the site's fauna. Using a t-test on talus samples, the study investigates body size variations between an older reindeer form from Duruitoarea Veche and Brînzeni 1, and the younger *R. tarandus constantini* from Cosăuți. Results show no statistically significant differences in body size, but confirm the larger cheek teeth in *R. tarandus constantini*. Reindeer from Rașcov 7 are reclassified as *R. tarandus* cf. *constantini*, with relatively large cheek teeth.
Keywords: reindeer, *Rangifer tarandus*, t-test, Late Paleolithic, southeastern Europe.

Reevaluarea renului paleolitic din Moldova: o analiză detaliată

Rezumat. Acest studiu examinează resturile de ren de pe siturile paleolitice din Moldova, incluzând redescrierea și reclasificarea descoperirilor anterioare de coarne și identificarea unui corn complet nedocumentat anterior de la Cosăuți. Cornul de la Duruitoarea Veche este determinat că provine de la cerbul comun (*Cervus elaphus*), în concordanță cu fauna sitului paleolitic. Prin utilizarea unui test t pe eșantioane de astragal, studiul investighează variațiile dimensiunilor între o formă mai veche de ren descoperită la Duruitoarea Veche și Brînzeni 1, și subspecia mai tânără *R. tarandus constantini* găsită la Cosăuți. Rezultatele arată că aceste diferențe în dimensiuni nu sunt semnificative din punct de vedere statistic. Totuși, testul t confirmă semnificația taxonomică a dimensiunilor dinților, deoarece aceștia sunt comparativ și relativ mai mari la *R. tarandus constantini* din Cosăuți. Un alt rezultat interesant este dimensiunea relativ mare a dinților observată la renii de la Rașcov 7, care sunt reclasificați în acest studiu ca *R. tarandus* cf. *constantini*.
Cuvinte cheie: ren, *Rangifer tarandus*, test t, paleolitic târziu, Europa de sud-est..

1. Introduction

Reindeer played a significant role as a faunal component during the Late Pleistocene period in the East-Carpathian region, emerging as a crucial game animal for Paleolithic hunters. The size of the reindeer's body was optimal, being large enough to attract the interest of Paleolithic hunters yet small enough to allow for the transportation of the entire

prey carcass to the butchering site. Consequently, all skeletal elements of Late Pleistocene reindeer are well-represented in archaeological assemblages. However, this specific type of accumulation of reindeer osteological material also led to the extreme fragmentation of reindeer remains found at Paleolithic sites, predominantly representing discarded kitchen refuse. Previous studies have extensively examined reindeer remains from late Paleolithic sites in Moldova [1, 2]. A biometric analysis was conducted, enabling the identification of three distinct forms of reindeer within the territory of the Republic of Moldova. The first form, presumably a forest reindeer, was found in "cave fauna" complexes dating back to 100-21 thousand years ago. The second form, relatively small in size, was discovered at Rașcov 7, approximately 19,300 years ago. Lastly, the third form was identified as the reindeer subspecies of eastern origin, characterized by relatively large cheek teeth, and attributed to the Siberian Paleolithic subspecies *Rangifer tarandus constantini* Flerov [1].

Investigations into sexual dimorphism among postcranial reindeer remains from various Paleolithic sites have revealed distinct demographic patterns. These patterns were interpreted as a consequence of diverse hunting strategies influenced by environmental conditions and the ecological characteristics of reindeer populations [2].

This article presents a comprehensive investigation comprising the description of new fossil remains, a critical reassessment of certain questionable specimens, and a statistical study focusing on selected reindeer remains. The primary objective is to validate the previously proposed conclusions and affirm observations pertaining to the biometric characteristics of reindeer samples obtained from diverse Paleolithic sites in Moldova. Through this rigorous analysis, we aim to enhance our understanding of the taxonomical diversity of fossil reindeer from Moldova, enabling us to elucidate the hunting practices and population dynamics of reindeer during the Late Pleistocene in the region.

2. Research Methods and Material

The fossil material examined in this study is housed in the Paleontological collection of the Institute of Zoology at the State University of Moldova, located in Chisinau. To ensure the reliability and accuracy of our findings, we employed appropriate statistical analyses that enable a robust comparison and evaluation of the reindeer samples collected from different Paleolithic sites in Moldova. In this study, we grouped together the remains of geologically older reindeer from the Paleolithic "cave assemblages" (Duruitoarea Veche and Brînzeni 1) for comparison with a "glacial maximum" reindeer sample (Cosăuți). Our research focuses on the analysis of new biometric data obtained from isolated lower fourth premolar (P_4) specimens of reindeer originating from several Paleolithic sites, namely

Brînzeni-1, Rașcov 7, and Cosăuți. These data are used to estimate and compare the size of reindeer dentition.

In addition to the lower fourth premolars (P_4), the third lower premolars (P_3) of reindeer exhibit a similar level of molarization. To distinguish between P_3 and P_4, we utilized the K-means clustering technique, which enables differentiation based on distinct crown measurements such as mesodistal length and labiolingual breadth. Crown measurements were recorded as maximum values; however, it is important to acknowledge that dental wear, particularly in heavily worn teeth, may introduce bias to the mesodistal length measurement. This consideration is taken into account during the biometric analysis and interpretation of results.

The biometric data concerning postcranial bones of fossil reindeer from Moldova, as well as data from modern reindeer used for independent t-tests, were adapted from a previous study by Croitor (2010). It is worth noting that the fossil reindeer samples exhibit varying male-to-female ratios. Therefore, we conducted independent t-tests separately for male and female samples to account for this variability. The data analysis was performed using the Python programming language in Jupyter Notebook.

Abbreviations used in the article: L, length; D, breadth; S, surface; DAP, antero-posterior measurement; DLM mediolateral measurement; dist, distal; br., brow tine; tr., trez tine; st., second tine; pt., posterior tine; bm., beam; cr., crown tine; pcr., posterior crown tine; plm., antler palmation.

3. Description

The taxonomic position and evolutionary affinity of Rangifer tarandus remains from the older cave faunas (Duruitoarea Veche and Brînzeni 1) require a reassessment of shed antler Nr. 290 from Duruitoarea Veche (Fig. 1). This particular specimen was initially identified as reindeer by David [3, Fig. 30, p. 147]. However, the morphological characteristics of this antler suggest that it actually belongs to the red deer species *Cervus elaphus*, which is also present in the fauna of Duruitoarea Veche. Unlike reindeer antlers, the surface of antler Nr. 290 exhibits a pearled texture rather than a smooth one. The antler is further characterized by consistently circular transverse sections of its beam (with an anteroposterior diameter of 43.0 mm above the brow tine and a lateromedial diameter of 41.8 mm) and tines. The brow tine displays a cylindrical shape and an additional spontaneous prong on its middle part, an uncommon feature. Notably, the bez tine is missing, and the trez tine differs from the flattened middle tine observed in forest caribou from North America. The main measurements of antler Nr. 290 are as follows: the anteroposterior diameter of the burr is 72.2 mm, the beam circumference above the brow

tine is 140 mm, the length of the basal tine is approximately 300 mm, the anteroposterior diameter of the antler above the burr is 67.7 mm, the lateromedial diameter of the antler above the burr is 48.0 mm, and the distance between the brow and trez tines is 260 mm.

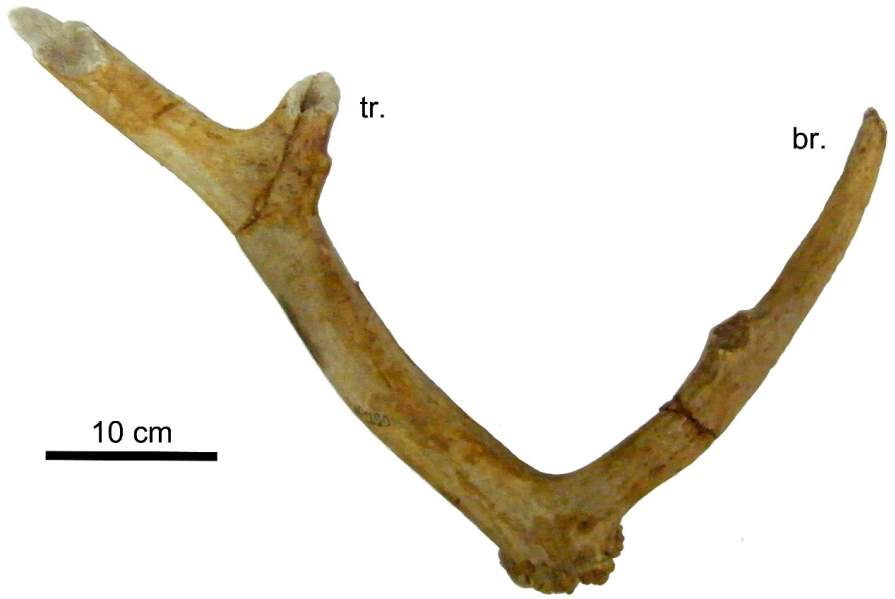

Figure 1. The left shed antler Nr. 290 of *Cervus elaphus* from Duruitoarea Veche originally described as reindeer antler [3].

Other fragments of antlers from Duruitoarea Veche and Brînzeni 1 exhibit less complete preservation but demonstrate typical morphology observed in reindeer: a remarkably smooth antler surface and a beam that is compressed more strongly from the sides, with the second tine located in close proximity to the basal tine, resembling the modern American barren ground caribou and Eurasian reindeer. The fragment of reindeer antler 30/1586 from Brînzeni 1 displays the longest distance between the basal and second tines, although this distance remains relatively small, measuring only 8 cm.

Unfortunately, the nearly complete antler of reindeer from Cosăuți has not been preserved. However, the provided photograph by Dr. Serghei Covalenco includes all the important features of the specimen (Fig. 2). The first basal tine, which exhibits strong asymmetry in reindeer and is often absent in one of the antlers, is not visible in the Cosăuți specimen and likely did not develop. The second tine terminates with a moderately developed palmation. The antler beam deviates caudally from the second tine ramification and displays a bowed shape. The posterior tine is well-developed. The distal portion of

the antler is characterized by a large hook-shaped posterior crown tine that points downward. The distal palmation of the antler is well-developed and bears four digitations. The antler from Cosăuți belongs to a large mature male; however, its distal palmation and crown tines are less developed when compared to the reindeer from Villestofte depicted by Aaris-Sørensen et al. [4].

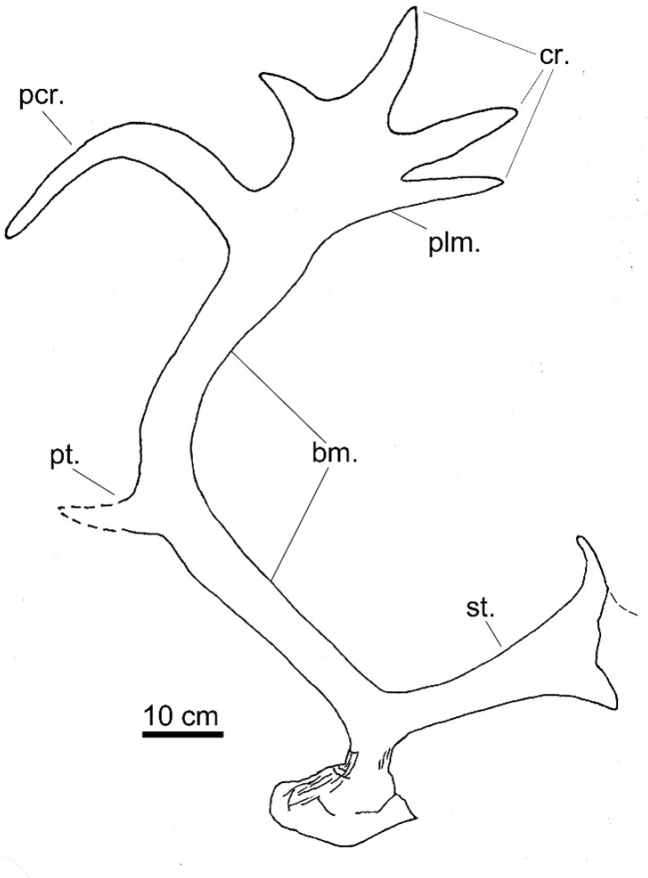

Figure 2. The almost complete antler of male reindeer *Rangifer tarandus constantini* from Cosăuți. The figure is based on photograph kindly provided by Dr. Serghei Covalenco.

During the statistical analysis of postcranial measurements in two forms of reindeer, we employed the Independent t-test since the studied reindeer populations are statistically unrelated. The postcranial measurements of the older form of reindeer from Duruitoarea Veche and Brînzeni 1 were found to be slightly larger than those of reindeer from Cosăuți [1]. However, there is a broad overlap in the data (Fig. 3, Tab. 1). The t-test comparing the

lumped sample of male reindeer talus from Duruitoarea and Brînzeni with the sample from Cosăuți indicated that the observed difference in body size is not statistically significant. The obtained T-statistic was 1.198, with a P-value of 0.248. Based on these results, we failed to reject the null hypothesis, which assumes no statistical difference between the compared samples. In other words, there is insufficient evidence to suggest a true difference in the distal breadth of the talus between the fossil reindeer males. The effect size, as indicated by Cohen's d value of 0.7, suggests a medium-to-large difference between the means of the two reindeer samples. The effect size provides information about the magnitude of the difference, regardless of statistical significance. Notably, the statistical difference in talus length was even less significant (T-statistic: 0.037, P-value: 0.971). Overall, the data does not provide strong evidence to support a true difference in the distal breadth of the talus between the two reindeer samples. While there may be a medium-to-large effect size, the statistical analysis does not support the presence of a significant difference between the means of the two samples.

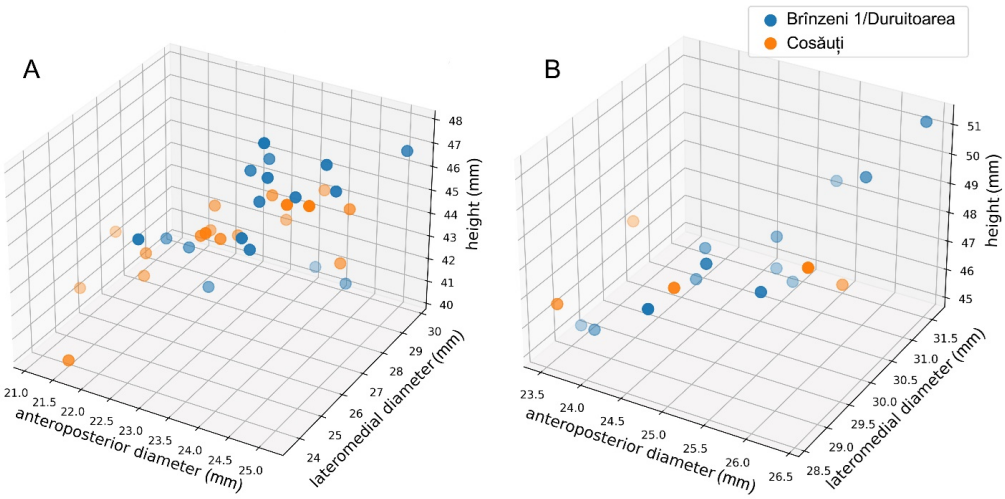

Figure 3. Measurements of tali of reindeer from the Paleolithic sites of Moldova: A, females; B, males.

Similar results were obtained in the statistical comparison of female distal breadth of talus: T-statistic: 1.668, P-value: 0.105, Cohen's d: 0.582.

To sum up, while there may be a moderate effect size and a moderate difference between the means of the two samples, the statistical analysis does not provide strong evidence to support a significant difference. To gain further insights into the obtained results of the statistical comparison of Paleolithic reindeer samples, we conducted a comparison

of small but informative samples of modern *R. tarandus tarandus* (n=4) and *R. tarandus terranovae* (n=4) from the Natural History Museum of London. The Student's t-test for metacarpal length yielded a T-statistic of 7.17 and a P-value of 0.00037, indicating a statistically significant difference between the metacarpal lengths of the modern reindeer samples. The comparison of distal talus breadths also revealed a statistically significant difference, with a T-statistic of 5.0457 and a P-value of 0.00234.

However, the statistical comparison of tooth size in Paleolithic reindeer from Moldova (Fig. 4, Tab. 2) yielded interesting results. The independent t-test for the length of the lower fourth premolar (P_4) between the samples from Cosăuți and Brînzeni 1 yielded a T-statistic of 3.379 and a P-value of 0.00222, suggesting a statistically significant difference between the samples (Fig. 4 A).

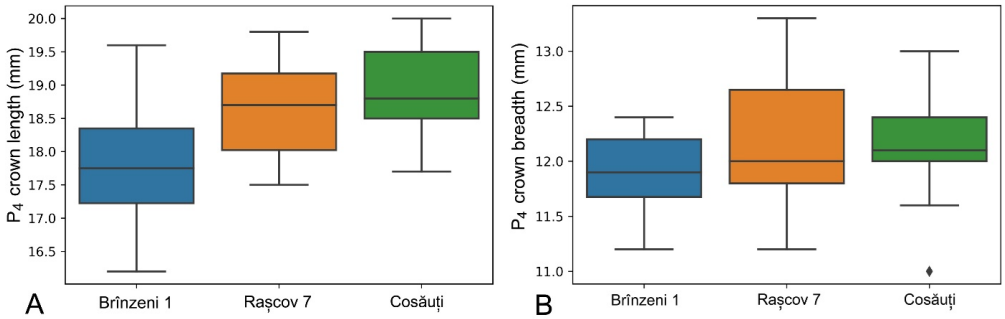

Figure 4. Boxplot showing range of measurements of lower fourth premolar (P_4) of Paleolithic reindeer from Moldova: A, crown length; B, crown breadth.

The independent t-test for P_4 between Cosăuți and Rașcov resulted in a T-statistic of 1.0635 and a P-value of 0.2932, indicating that the difference between the samples from Cosăuți and Rașcov is not statistically significant.

On the other hand, the independent t-test for P_4 between Rașcov and Brînzeni yielded a T-statistic of 2.7572 and a P-value of 0.0096, suggesting a statistically significant difference between the samples. However, the significant statistical difference only applies to tooth crown length. The independent t-test for P_4 breadth (Fig. 4, B) showed that the measurement differences among samples are not statistically significant: for the samples from Cosăuți and Brînzeni 1, the T-statistic is 1.4307 and the P-value is 0.1639; for the samples from Cosăuți and Rașcov, the T-statistic is -0.0342 and the P-value is 0.9729; and for the samples from Rașcov and Brînzeni 1, the T-statistic is 1.2322 and the P-value is 0.2268.

4. Discussion

The new data on antler material of reindeer from the Paleolithic sites of Moldova, combined with the t-test analysis of postcranial and dental remains, have provided valuable insights into the morphological characteristics of Late Pleistocene reindeer in southeastern Europe. Through the revision of shed antler Nr. 290 from Duruitoarea Veche, it has been determined that this antler actually belongs to red deer. Consequently, the assumption of the presence of a reindeer form in the Paleolithic of Moldova that evolved antler shapes similar to those of forest caribou from North America can be rejected. Instead, all known antlers of fossil and modern reindeer from Eurasia exhibit the characteristic antler morphology of barren ground American caribou, thereby confirming Geist's hypothesis [5] that the origin of Eurasian reindeer is related to barren ground caribou.

This type of antler morphology is also observed in the reindeer from Cosăuți. Although the complete antler of a mature male reindeer from Cosăuți is not preserved due to the extreme fragility of the specimen, it stands as the sole complete Late Pleistocene reindeer antler from Eastern Europe that reveals specific morphological characteristics. The most prominent features of the reindeer antler from Cosăuți are the large hook-like posterior crown tine and the development of palmation in the distal part of the antler. This particular shape of the crown part of the antler differs from the distal part of the antler in reindeer from Villestofte, which is characterized by elongated palmation and the development of several posterior crown tines of more or less equal size. It is worth noting that the Cosăuți variant of antler morphology is not documented in the extensive Paleolithic material (including archeozoological remains and Paleolithic art) from Western Europe, as summarized by Bouchud [6].

The reindeer specimens from Duruitoarea Veche and Brînzeni 1 were previously reported [1] as belonging to a large forest form. However, the t-test conducted in this study demonstrates that the postcranial measurement differences between these reindeer and those from Cosăuți are not statistically significant. It is important to note that many significant ecomorphological features of Paleolithic reindeer from Moldova remain unavailable. For instance, the length of metacarpals in reindeer from Duruitoarea Veche and Brînzeni 1 (represented by three specimens) closely resemble those of modern caribou from North America (Fig. 5 A). Unfortunately, a direct comparison of limb bone length between reindeer from Duruitoarea Veche, Brînzeni 1, and the reindeer form from Cosăuți is not possible. The only complete long bone available from the reindeer at Cosăuți is a tibia belonging to a female (Croitor, 2010). This tibia falls within the variation range of

modern *R. tarandus tarandus* (Fig. 5 B), suggesting that the reindeer from Cosăuți can be characterized as a short-limbed form.

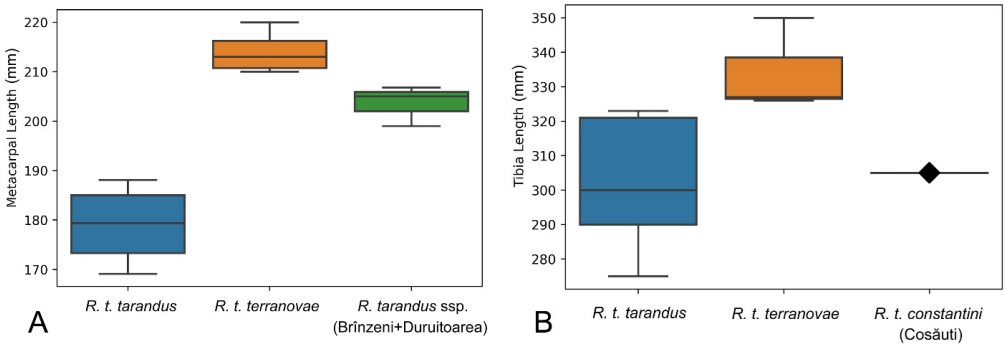

Figure 5. Lengths of Paleolithic reindeer long bones compared to modern reindeer subspecies: A, metacarpals; B, tibia. The data are adapted from Croitor [1].

Examining the dentition measurements provides interesting insights, as it reveals a statistically significant difference in tooth size, with larger teeth observed in the reindeer from Cosăuți compared to those from Brînzeni 1. The difference in P_4 crown breadth, however, is not statistically significant, although the mean value of the sample from Cosăuți is slightly higher than that of the sample from Brînzeni 1. Nevertheless, the difference in P_4 crown length is statistically significant, with the reindeer from Cosăuți exhibiting larger crown length. Therefore, the statistical analysis confirms the taxonomical significance of cheek tooth size, which is larger in the reindeer from Cosăuți identified as *Rangifer tarandus constantini* Flerov [1]. The increased size of cheek teeth is an adaptation to abrasive herbaceous forage in the Late Pleistocene tundra-steppe conditions. While there is no existing literature on tooth size dimorphism in ruminants, including reindeer, it was not possible to address the issue of tooth size dimorphism in this research due to the study's focus on isolated teeth without available sex identification. Nonetheless, the results indicating statistically significant larger cheek teeth in the reindeer from Cosăuți are consistent, as the total sample of reindeer comprises approximately 75% female remains. Therefore, the obtained results are not biased by potential sexual dimorphism in tooth size.

The conducted t-tests have enhanced our understanding of the systematic position of the reindeer from Rașcov 7, characterized by relatively large cheek teeth, which can be classified as *R. tarandus constantini*. Considering the broad range of variability observed

in the Rașcov 7 sample, I suggest referring to this reindeer form as *R. tarandus* cf. *constantini*.

5. Conclusions

The reevaluation of antler Nr. 290 from Duruitoarea Veche, originally attributed to reindeer, has revealed that it actually belongs to red deer (*Cervus elaphus*). Therefore, the assumption that reindeer from Duruitoarea Veche possessed antlers with a middle tine, similar to modern forest-dwelling American caribou, should be rejected.

All reindeer forms from the Paleolithic sites in Moldova are characterized by a distinct antler structure, with the second tine positioned close to the basal one. This antler bauplan represents the only recorded in Eurasia type of reindeer antlers that shows similarity to antlers of North American barren ground caribou.

The t-test conducted on talus samples of reindeer from the Paleolithic sites of Moldova did not reveal statistically significant differences in body size between the so-called "cave faunas" of Brînzeni 1 and Duruitoarea Veche and the Last Glacial Maximum reindeer from Cosăuți. However, the available material does not provide sufficient data on limb bone lengths, which are important ecomorphological characteristics of reindeer subspecies. Generally, reindeer from the "cave faunas" exhibit relatively long metapodials, similar to the metapodial length of modern forest-dwelling caribou, *R. tarandus terranovae*, from North America. Data on metapodial length in the reindeer from Cosăuți is lacking, but the single complete female tibia from Cosăuți falls within the variation range of modern tundra reindeer, *R. tarandus tarandus*.

The t-test conducted on P_4 crown length revealed the statistical significance of this characteristic, distinguishing the reindeer from the "cave faunas" from the reindeer form from Cosăuți, which is characterized by relatively larger cheek teeth. Therefore, large cheek tooth size serves as a reliable taxonomic character distinguishing *R. tarandus constantini* from Cosăuți from older reindeer forms, which are considered here as R. tarandus ssp. The reindeer from Rașcov 7 also exhibits relatively larger cheek teeth and is considered here as *R. tarandus* cf. *constantini*, given the broad range of individual variation observed in the Rașcov 7 sample.

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