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OLD MUSEUM COLLECTIONS AND STORIES THEY CAN TELL — NEW AMS-DATA AND STABLE ISOTOPES ($\delta^{13}C$ AND $\delta^{15}N$) OF *TRITICUM AESTIVUM* FROM THE TRYPILLIA SITES*

The archaeobotanical, nitrogen and carbon stable isotope analyses and direct ^{14}C AMS-dating were used to return the lost context to two cereal grain assemblages kept in the State Historical Museum. The archaeobotanical analysis of the selected grains defined their morphological character and assigned them to wheat species: *Tr. aestivum* subsp. *Aestivum* and *Tr. turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell. The data on the direct radiocarbon dating of five specimens are consistent with the chronology of Trypillia sites C1—C2, i.e. 4600—3600 calBC. We think that one of the assemblages can be linked to the lost collection of grains from the Khalepye village found during the excavations carried out by V.V. Khvoyka in 1895. The second assemblage comes from the Chernovtsy Museum, probably, originating in one of the Trypillia sites in the micro-region around the town of Chernovtsy. The analysis of the nitrogen and carbon isotopic composition of 15 wheat grains from Khalepye and Chernovtsy and wheat grains from other Trypillia sites as well as the southern Caucasus and northern Kazakhstan confirms this conclusion. Agricultural strategies that probably included use of organic fertilizers (animal manure) were known to the population that cultivated wheat found at Khalepye.

Key words: Trypillia culture, wheat grains, ^{14}C AMS-dating, stable nitrogen and carbon isotopes.

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СТАРЫЕ МУЗЕЙНЫЕ КОЛЛЕКЦИИ И ИСТОРИИ, КОТОРЫЕ ОНИ МОГУТ РАССКАЗАТЬ — НОВЫЕ ^{14}C УМС ДАННЫЕ И ИЗОТОПНЫЙ СОСТАВ ($\delta^{13}C$ И $\delta^{15}N$) TRITICUM AESTIVUM ИЗ ПОСЕЛЕНИЙ ТРИПОЛЬСКОЙ КУЛЬТУРЫ

Археоботанический анализ, анализ изотопного состава азота и углерода и прямое радиоуглеродное датирование методом ускорительной масс-спектрометрии образцов семян были использованы для восстановления утраченного контекста двух коллекций семян, хранящихся в Государственном историческом музее. Археоботанический анализ выбранных зерен определил их морфологические характеристики и отнес их к видам пшеницы: Tr. aestivum subsp. Aestivum и Tr. turgidum L. subsp. dicoccum (Schrank ex Schübl.) Thell. Данные прямого радиоуглеродного

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датирования пяти образцов согласуются с хронологией стоянок Триполья С1—С2, т.е. 4600–3600 лет до н.э. Мы считаем, что один из комплексов может быть связан с утраченной коллекцией зерен из села Халепье, найденной во время раскопок, проведенных В.В. Хвойка в 1895 г. Вторая коллекция происходит из Черновицкого музея, вероятно, с одного из трипольских памятников в микрорегионе вокруг города Черновцы. Анализ изотопного состава азота и углерода пятнадцати зерен пшеницы из Халепье и Черновцов и зерен пшеницы с других трипольских памятников, а также с Южного Кавказа и Северного Казахстана подтверждает этот вывод. Населению, выращивавшему найденную в Халепье пшеницу, были известны сельскохозяйственные стратегии, которые, вероятно, включали использование органических удобрений (животного навоза).

Ключевые слова: трипольская культура, зерна пшеницы, ^{14}C УМС-датирование, стабильные изотопы азота и углерода.

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Introduction

Archaeobotanical remains recovered from prehistoric sites provide unique evidence for spread of cultivated cereals in various regions. The Dniester-Dnieper interfluve inhabited by the Trypillia population since the 5th millennium BCE is one of the early farming centers in southeastern Europe. The first macroremains of cultivated cereal from the Trypillia archaeological context came from the excavations conducted by V.V. Khvoyka at the end of the 19th century (Khvoyka 1901; 1904); the total archaeobotanical collection of cereals recovered from all known Trypillia sites was rather small. The analysis of the assemblages of cultivated crops found at the Trypillia sites identified einkorn, emmer, bread wheat, naked and hulled barley, pea, vetch and lentil (Spengler 2015). Flotation of the occupation deposits was not carried out; for this reason, the cereal assemblages included separate charred grains and many researchers identified various cereal species analyzing imprints of grains on clay pots and plastering on the walls of houses (Yanushevich 1976; Pashkevich 2000; 2003). Today, the data on the role of cereals in the Trypillia subsistence economy are usually complemented with the results of occupation deposit flotation (Hofmann et al. 2019; Kirleis et al. 2024), phytolith analysis of the samples from the occupation deposits, the pottery organic residue in the houses at the Maidanetske mega-site in central Ukraine (Dal Corso et al. 2018) as well as pollen diagrams compiled from excavation trench sections at Trypillia sites such as Floreşti, Maidanetske, Ruseştii, and Druţa (Kremenetsky 1991: 74—95). Substantial increase in data on the macroremains of cultivated cereal grains from different Trypillia sites (Filopovic et al. 2024; Kirleis et al. 2024) in recent years has enabled our team to perform comparative analysis.

It should be noted that direct radiocarbon dating of grains from numerous European archaeological sites is an important methodological approach employed to study crop farming in prehistory. However, the radiocarbon results have revealed an issue relating to the archaeological context of such finds; absence of the clear context requires verification because of the intrusion of grains, seeds, and fruits from the upper layers into the occupation deposits of prehistoric settlements, resulting in errors in dating (Stevens, Fuller 2012; Pelling et al., 2015; Kirleis et al. 2024). For example,

based on the dating of grains, the historical and geographical contexts of broomcorn millet appearance in Europe have been revised and this crop has been removed from the list of Trypillia cultivated cereals (Motuzaite Matuzeviciute et al. 2013; Trifonov et al. 2017).

Besides, some recent papers have focused on the nitrogen and carbon isotopic composition of cultivated cereals, starting discussions of economic strategies implemented to increase the yield of the crops during the Trypillia mega-site period (Schlutz et al. 2023).

Stable isotope analyses of cultivated grains can be used to identify cultivation practices such as irrigation or its absence as well as manuring and crop rotation (Bogaard et al. 2007; Fraser et al. 2011; Kirleis et al. 2024). The study of the isotopic composition of the cultivated grains and the bones of domesticated animals from the Trypillia mega-sites (such as Maidanetske and Talianki) shows that during the Trypillia agglomeration period the people living at these sites raised animals in fenced intensive pastures, they collected animal manure and used it as fertilizer in the fields. This factor had an impact on the isotopic composition of the cereal grains found at these sites. The cereal seeds show very high values of nitrogen isotopes compared with the grains from other sites that preceded and succeeded the Trypillia agglomeration period (Schlütz et al. 2023). In our view, the comparative analysis of the isotopic data on the cereal grains from the State Historical Museum collection in Moscow could produce additional data for cultural attribution of the assemblages under study. Such aspects expand the possibilities of comparative analysis of assemblages from various sites.

The purpose of this study is to analyze the archaeobotanical collection of the State Historical Museum in Moscow, which, presumably, includes cereal grains from the Trypillia sites, conduct direct ^{14}C AMS-dating of the cereal grains, and identify stable carbon and nitrogen isotope ratios in order to verify the cultural contexts of these grains.

Therefore, the expanded dataset of cultivated cereal crops from prehistoric European sites, direct radiocarbon dating of charred grains from these sites as well as isotope values of macroremains greatly add to our understanding of when farming appeared in Europe and how it spread.

Background information on the cereal assemblages

The archaeological collection from '*the Kiev province, Kiev uyezd, area near v. Trypillia*' was officially acquired by the State Historical Museum (SHM) (then known as the Russian Historical Museum or RHM) on December 18, 1908 (SHM acquisition number 45427, Archaeological Department collection A86); it was registered in the Museum Records Department in 1939. This collection, consisting of pottery fragments and objects of plastic arts, was purchased from Khvoyka together with the collections of objects from other Trypillia sites and sites attributed to other archaeological cultures (e.g. the sites near Stratovka, Chernyakhovo, etc.) for 300 rubles (the Department of Collection Records in the State Historical Museum in Moscow). The museum documents do not make references to any archaeobotanical remains from Trypillia, which were, probably, included into the archaeobotanical collection of the State Historical Museum much later.

However, the Archaeological Department of the State Historical Museum still keeps paper-based catalog cards which specifically reference two archaeobotanical assemblages of cereal grains, one assemblage coming from '*the Kiev province, Trypillia village, from Khvoyka's excavations*', subsequently acquired by the Kiev Historical Museum, and the other assemblage which was transferred from the Chernovtsy Museum in '*the Bessarabia province (Chernovtsy region, Zastavna district, Doroshiltsy village'* [presently Doroshovtsy]. These archaeobotanical assemblages were not registered as part of the core Trypillia collections; instead, they were documented as museum auxiliary scientific collections. Later, the archaeological cereal grains (with 'wheat' and 'barley' labels) were included in the State Historical Museum permanent exhibition and put on display in Room 4 dedicated to the Bronze Age (Fig.1: 1); they were displayed in cabinets 6 and 17 that contained other exhibits associated with producing forms of economy. After the change of the exposition and reconstruction of the museum in the 1980—1990s, these archaeobotanical remains turned out to be stripped of their context.

To restore the significance and original contexts of the Trypillia archaeobotanical assemblages which had entered the collection of the State Historical Museum many years ago, we initiated a scientific study and, as a first step, examined the paper catalog cards to understand when and how these cereal grains ended up in the State Historical Museum. The results of our research are provided further in the text.

In 1895 V.V. Khvoyka, a famous archaeologist of Ukrainian Prehistory and one of the founders of the Kiev Museum of Antiquities and Art, now the National Historical Museum, conducted excavations on a hilly area of the Dnieper right bank between Kiev and the Ros river (in Zhukovtsy, Khalepye, Stayki, Veremye, Dolzhok, Scherbanevka, Trypillia and other villages) (Khvoyka 1901). During the excavations of one of the hills near the Khalepye village that encircled the area near Trypillia between Kiev and the Kanev *uyezd* (canton) (presently known as the Khalepye village located 5 km east-south-east of the Trypillia village, Obukhov district, Kiev region, Ukraine) a *'thick layer of ash, with roasted wheat grains lying in piles in some places'* was discovered on the floor of a room uncovered in an excavation trench (Khvoyka 1901: 773, Fig. 76). Understanding the importance of the find of charred grains at the Trypillia sites, Khvoyka presented his discovery to the 13th Archaeological Congress held in Ekaterinoslav in 1905 focusing specifically on these grains because, in his view, agricultural practices were important for subsistence economy of the local Trypillia population (Khvoyka 1907; Passek 1949).

According to Z.V. Yanushevich, along with the main collection of archaeological artifacts, the charred cereal macroremains found by Khvoyka at Khalepye were acquired by the National Historical Museum in Kiev (Yanushevich 1976: 103). Based on the information from the SHM paper catalog cards, the second archaeobotanical assemblage was kept at the Chernovtsy Museum in Moldavia. Subsequently, it was transferred to the State Historical Museum in Moscow.

The archaeobotanical assemblage in the National Historical Museum in Kiev was not investigated by K.A. Flyaksberg until 1930, she referred most caryopses to common wheat (*Triticum vulgare*), and some caryopses to hard wheat (*Triticum durum*). The subsequent re-examination of this archaeobotanical assemblage by D. Persidsky and O. Lypa revealed that it included various grains; on the whole, however, these archaeobotanists confirmed Flyaksberg's conclusion that the collection included grains of varying species (Yanushevich 1976). Yanushevich herself did not examine the collection because it had been lost during World War II when the building of the National Historical Museum in Kiev, including the room dedicated to the Trypillia culture, was destroyed and the collection of cereal grains that included grains from Khalepye was lost (possibly, moved away from the country) (Passek 1949: 21).

However, we think that the Trypillia archaeobotanical assemblage, presumably, from Khalepye, entered the collection of the State Historical Museum in Moscow before World War II. In the 1920s the exchange of archaeological collections among museums was a common practice in the Soviet Republics, its purpose was to demonstrate various aspects of ancient and medieval history across Russia by putting various items on permanent display at major museums in the country. We assume that the archaeobotanical assemblage labeled 'cereal grains from Trypillia' was a part of the lost cereal grain assemblage earlier kept in the collection of the National Historical Museum in Kiev and that the storage boxes of the State Historical Museum in Moscow also contained the cereal grains recovered by Khvoyka from the excavation trenches in Khalepye at the end of the 19th century. In addition to the grains, the boxes also contained small fragments of charred clay pots of the Trypillia type (Fig. 1: 3).

The box labeled '*cereal grains from Trypillia'* also contained a special package with an inscription '*for museum exhibits, library books, drugstores, etc.'* Such labels were made in 25,000 copies by a small print-shop in Odessa, Ukraine, which is indirect evidence that the Trypillia archaeological assemblage was transferred from Kiev to Moscow. Books, booklets and other printed materials dated from 1920s and labeled similarly are kept in many Russian libraries, for example, the Russian State Library.

However, we were not able to determine precisely what site the assemblage from the Chernovtsy Museum in Moldova had come from because there was no information in the published scientific literature.

The distribution map of the sites attributed to the Trypillia culture in the Dniester area in the Chernovtsy region shows several sites, e.g. Kadievtsy, Kudrintsy, Shipenitsy, etc. (Passek 1949: Fig. 1). The overview chapter entitled 'The Eneolithic of the Ukraine Right Bank and Moldavia' in the USSR Eneolithic Archaeological Book (Masson, Merpert 1982: 165—251) mentions Chernovtsy I (earlier period) and Chernovtsy II (later period) (Masson, Merpert 1982: Table 9). The distribution map of the Early Trypillia sites published in Volume 1 of The Ukrainian Soviet Socialist Republic Archaeology shows the Chernovtsy site (Bibikov, Zbenovich 1985: 192—193). It is likely that the second assemblage of the charred grains contained remains from the Chernovtsy site or a site ascribed to a similar tradition (Fig. 1: 2).

Fig. 2 contains the map showing the region where Khvoyka conducted his excavations in 1895 (according to Khvoyka 1901: Fig. 65), as well as the Doroshovtsy village and the Chernovtsy town from where, presumably, the second cereal assemblage derives.

These two archaeobotanical assemblages became the subject of this study. Its aim was to verify or reject the attribution of these two assemblages to the Trypillia culture.

Samples, approaches and methods

The archaeobotanical samples from the State Historical Museum were divided into two groups: (1) the samples (#1 and #2) from the *Context 1* Group that originated in the area around the Trypillia village not far from Kiev (presumably, Khalepye); and (2) the samples (#3) from the *Context 2* Group coming from the Chernovtsy Museum (the site has not been determined precisely).

The *Context 1* Group included 100 whole grains and thousands of tiny, charred grain fragments; the *Context 2* Group consisted of 30 grains.

The study was conducted in three stages: (1) we performed the archaeobotanical examination of two cereal collections; (2) to check our hypothesis based on the catalogue cards and the analysis of earlier publications that both cereal grain assemblages kept in the museum were from the Tripyllia culture, we conducted direct AMS-dating of the cereal grain samples; and (3) to verify the hypothetical archaeological context, we determined the nitrogen and carbon isotopic composition of the grains and compared these data with similar data obtained for archaeobotanical samples from other Trypillia sites as well as from an Eneolithic southern Caucasus site and an Early Iron Age/18th — 19th centuries site in the Kazakhstan.

To determine genus and species of the studied grains, we used a comparative and morphological method to examine the macrostructure of organisms without sophisticated equipment. Using a laboratory preparation needle, undamaged or slightly damaged grains that could be identified were selected (n=50). To identify the archaeological grains to genus and species, we used a reference dataset, which included grains from the plant botanical collection of the Department of Agriculture and Agroecology, Soil Studies Faculty, Lomonosov Moscow State University. This collection comprising grains and inflorescences of main cereal varieties, was created in 1953 and since then the Department of Agriculture and Agroecology has continued to add more grains to this collection. In addition to the examination of their morphological characters, the whole grains and slightly damaged grains were measured using dividers. Besides, the analysis also built on the work of N.A. Maysuryan (1954) and V.F. Dorofeev et al. (1979).

The photographs of the individual cereal grains were taken using a Zeiss AxioCam Erc 5s microscope camera and an Olympus BX51 optical microscope fitted with a Leica DFC420C digital microscope camera with magnification 50 and 100.

After describing the cereal grain assemblages, five grain specimens were selected for AMS-dating, namely, two samples, presumably, from Khalepye (*Context 1*) and three samples from Chernovtsy (*Context 2*). Two specimens were dated in the Institute of Geography, RAS (Russia), together with the University of Georgia (USA); two specimens were dated in the Isotoptech Zrt., Debrecen (Hungary), and one specimen was dated in the Poznan Radiocarbon Laboratory (Poland). Radiocarbon data obtained were calibrated with the OxCal software v4.4 (Bronk Ramsey 2017) and the IntCal20 calibration curve (Reimer et al. 2020).

To estimate the period interval for the two assemblages/contexts, two chronological models based on the sequence of the dates were produced. To this end, placing the data into the phase (using the Phase command in OxCal 4.3.2), we used two Bayesian models, one for each of the two contexts. The Start and End boundaries were determined using the values of the boundary medians (Boundary command) (Bronk Ramsey 2017).

The ^{14}C AMS dates were then compared with the new radiocarbon data microremains obtained from the Trypillia sites (Schlütz et al. 2023).

When analyzing the nitrogen and carbon isotopic composition, we assumed that the Trypillia agriculturalists developed at the very least two systems of agricultural practices, i.e. slash-and-burn agriculture (known as shifting cultivation in the steppe belt), and highly productive agriculture with the use of organic fertilizers (manuring). Different crop-growing systems had an impact on the nitrogen and carbon composition of the microremains (Schlütz et al. 2023; Kirleis et al. 2024; Larsson et al. 2024). Fifteen grains from *Context 1* and *2* were selected for the test isotope analysis.

The comparative analysis used published data on wheat samples from four Trypillia sites, i.e. Chechelnyk, Kosenivka, Maidanetske and Stolniceni 1 (Schlütz et al. 2023), the isotopic composition of wheat from Chobareti, which is a site dating to the Eneolithic—Early Bronze Age located in the southern Caucasus (Messager et al. 2015), and the Alekseyevskoye site located in the arid steppe in northern Kazakhstan (SHM collection) dating to the early Iron Age and the 18th —19th centuries CE.

The measurements of the nitrogen and carbon stable isotope ratios for the cereal grains were made at the Vernadsky Institute of Geochemistry and Analytical Chemistry (GEOKHI) of the Russian Academy of Sciences using a DELTA Plus XP isotope mass-spectrometer (ThermoFinnigan) linked to a Flash EA 1112 elemental analyzer. The temperature of the oxidation reactor is 1020 °C, the chemical agents used include granulated chromium oxide, and silver-plated granulated copper. The temperature of the reducer is 650 °C, and the chemical agent used is granulated copper. The isotope ratios are reported in permille notation relative to VPDB and AIR for δ^{13}C and δ^{15}N, respectively. Each sample was measured in triplicate and the standard deviation of repeated measurements was 0.2‰ and 0.2 to 0.3‰ for δ^{13}C and δ^{15}N, respectively. The δ^{15}N values were corrected (–0.5‰) for charring range as suggested in (Kirleis et al. 2024).

Results

Archaeobotanical analysis of the cereal grains

The examined samples are charred wheat grains; their state of preservation varies. The testa (seed coat) and the pericarp are gone completely or partially, which still makes it possible to identify the grains, in some cases, to the species (Fig. 3—4). Many of the grains burned rather quickly, as confirmed by the preservation of the grain form and fragile testa and pericarp. By contrast, some grains were subjected to relatively low temperature for a long time (they smoldered). At the same time, their form changed slightly, instead of being straight, the grains are ‘wavy’, with their pericarps preserved.

All examined grains were assigned to genus *Triticum* L. The genus identification is confirmed by a visible crease or a longitudinal furrow on the ventral side of the grain, a systematic characteristic of cereal grains, including wheat. The form of the grains is oval (barrel-shaped) and elongated with rounded or slightly acute apexes. The dorsal side is convex, tapering towards the base (embryo end), the embryo is identified in most cases. The W/H, L/H and L/W ratios of the grains correspond to those of modern samples.

The whole grains were identified to the species. Some grains are represented by longitudinal and crosswise grain fragments. Longitudinal fragments are usually halves of the grains that split along the furrow on the ventral side of the grain; longitudinal furrows are visible on some fragments. The crosswise fragments have preserved a rounded shape, a visible furrow, and their size is from ½ to ¾ of the grain size. The crosswise fragments have a varying form, i.e. a rounded form or a fairly pointed form.

Context 1 Group. The greater part of the samples examined can be identified as genus *Tr. aestivum* subsp. *aestivum* (Fig. 3: 1, 1.1, 2.2, 2.3, 2.4)**.** The measurements of the most grains vary from 0.25—0.4 cm (width) to 0.5—0.7 cm (length), which means that the length/width ratio is less than 2.0. The form of the grains is oval (barrel-shaped). There is a visible longitudinal furrow on the ventral side of the grain which is a systematic characteristic of the grains from the *Context 1* Group. The width of the furrow is approximately 1 mm. The dorsal side is strongly curved (convex), rounded, sometimes, laterally compressed in the middle. A rounded embryo which is more or less concave is visible at the grain base, with the grain tapering towards the base (Fig. 3: 1.1). The varying size of the grains may be explained by the fact that they developed in different parts of the spikelet and ear (spike). Usually, smaller size grains are produced either by upper florets of the spikelet or in the upper spikelet of the ear (spike).

Sample 2.4 is a grain with a slightly acute apex; a slightly acute base may be defined as a systematic characteristic of barley grains (Fig. 3: 2.4). However, barley grains have a pronounced elliptical, elongated form, the dorsal side is not convex. The grain tapers towards the apex and the base. These characteristics were not identified in sample 2.4.

The grains from the *Context 2* Group differ from the grains from *Context 1* (Fig. 4). Most are larger than the grains of *Context 1*, with slightly different morphological characters. The grains with up to ½ of their length gone measure 0.5—0.6 cm by 0.3 cm, which means that the whole grain can be more than 1 cm long. These grains have a distinctive form. They are longer, the grain base is split along the furrow (probably, because of high temperatures). The dorsal side is convex, the dorsal outline is sometimes hump-backed (Fig. 4: 3.3, 3.5, 3.7, 3.8).

Sample 3.1 is a grain different from the rest of the examined grains (Fig. 4: 3.1). It measures 0.8 cm in length, 0.4 cm in width and 0.35 cm in thickness, it means that its size is larger than that of other wheat grains. A vertical furrow is clearly visible on the flat ventral side. Compared with the other wheat grains, it is a bit narrower and laterally compressed. The embryo is located on the convex dorsal side of the grain. The form of the grain is elongated, the apex is rounded, the base is acute. The dorsal side is rounded, it is not convex, it does not have any pronounced ridges. The dorsal side of the grain was burnt to the endosperm, the seed coats (testa) are represented by fragments.

Based on these characteristics, the grain can be assigned to genus *Triticum*. Identification of species is somewhat difficult because the actual size and the color of the grain is not known; besides, we do not know if the grain was in the whole spikelet. However, relying on indirect traits (size, form, laterally compressed), we think that the grain should be assigned to *Triticum turgidum L.* subsp. *dicoccum (Schrank ex Schübl.) Thell,* known as emmer wheat and two-grained spelt.

The examined grains were identified as *Triticum* L., though their morphological characters are not uniform. The grains (Fig. 4: 3.5) can be identified as *T. turgidum* subsp. *durum (*Desf.). However, a strongly convex dorsal side of the grain is characteristic of both hard wheat and another grain species, which is *T. turgidum* subsp. *turgidum* (branchy).

The sample (Fig. 4: 3.7) has several large grains that exceed the hard wheat grains in size. Their size is 0.7—1.2 × 0.3 cm. The acute apex of the caryopsis and the convex dorsal side are characteristic of *T. turgidum* subsp. *turanicum* (Jakubz.) Á. & D. Löve, commonly known as Khorasan wheat.

Results of direct AMS-dating

Radiocarbon dates were obtained for all five grains. We used two Bayesian models, one for the *Context 1* Group (Fig. 5: 2) and the other for the *Context 2* Group (Fig. 5: 1), placing data into the phase (using the Phase command in OxCal 4.3.2). The Start and End boundaries were determined using the values of the boundary medians (Boundary command) (Bronk Ramsey 2017) (Tables 1 & 2).

Stable carbon and nitrogen isotope ratios for the wheat grains

The measurements of the nitrogen and carbon isotopic compositions of fifteen wheat grains are provided in Table 3. The $\delta^{15}N$ values were corrected (–0.5‰) for charring range as suggested in (Kirleis et al., 2024). For Khalepye grains the carbon isotopic values ($\delta^{13}C$) varied from -24.08 to -22.37‰; the nitrogen isotopic values ($\delta^{15}N$) varied from 4.38 to 7.54‰. For Chernovtsy Museum grains the carbon isotopic values ($\delta^{13}C$) varied from -24.28 to -23.38‰; the nitrogen isotopic values ($\delta^{15}N$) varied from 5.52 to 9.31‰.

Discussion

It was difficult to assign the studied cereal collection to the Trypillia culture in the absence of secure cultural contexts, and it was not clear how the collection had ended up in the State Historical Museum in Moscow. The study of the earlier published data on the cereal grain finds at the Trypillia sites and the preserved archival documents provided an opportunity to correlate the grains from *Context 1* with the archaeobotanical assemblage collected by Khvoyka during his excavation at Khalepye in 1895.

Back in the early 20th century, analyzing the subsistence system of the Trypillia population, Khvoyka came to the conclusion that charred grains of wheat, umbellate plants such as anise or dill, millet, barley, hemp and 'impressions of millet and wheat chaff' on clay plastering of the walls as well as milling stones and pestles could be used as evidence of farming by the Trypillia population (Khvoyka 1901: 812; 1904: 24). He noted that the finds of charred wheat grains at some sites such as the Khalepye village suggest development of agriculture (Khvoyka 1901: 774, Fig. 76). The archaeobotanical analysis of the cereal grains from *Context 1* revealed that this assemblage contained only wheat grains. These results coincide with the results of the grain examination in the 1930s published by Yanushevich (1976). Wheat grains were identified in the second assemblage from the Chernovtsy Museum as well (*Context 2*).

Under this study, based on the archaeobotanical analysis of all wheat grains from the collection of the State Historical Museum, all wheat grains have been assigned to *Tr. aestivum* subsp. *aestivum* and *Tr. turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell. According to the GRIN-Global Taxonomy based on Van Slageren's classification (1994), the identified wheat species are included in the group of naked tetraploids (2n = 28). The homeland of these wheat species is the Fertile Crescent.

The species T. turgidum subsp. *durum (*Desf.) and *T. turgidum* subsp. *turgidum* grow in similar environments. Both species have steppe ecotypes as well as ecotypes common in humid mountainous areas in the south of Asia Minor. *T. turgidum* subsp. *turanicum* (Jakubz.) Á. & D. Löve is a crop of oasis farming in the areas with dry and hot climate. The grains of this group of wheats could reach the studied area via trade or some other routes. Presumably, when wheat was grown as a grain crop, the purity of crop seeds was not maintained and seeds could be mixed during farming and storage. To give a definitive answer to the question on specific species the studied cereal grains belong to, modern analogies to the grains of these wheat species need to be subjected to high temperatures in similar conditions. In this case, comparison of the samples to identify specific species of grains will produce more correct results.

It can be inferred from our analysis that, based on the GRIN-Global Taxonomy, the grains of sample 1 (Fig. 3: 1, 1.1) belong to the domesticated free-threshing hexaploid wheat group (6x), i.e. *Tr. aestivum* subsp. *aestivum;* samples 3.3, 3.5 and 3.7 (Fig. 4: 3.3, 3.5, 3.7) belong to the domesticated free-threshing tetraploid group (4x); and sample 3.1 (Fig. 4: 3.1) belongs to the domesticated hulled tetraploid group (4x), i.e. *Tr. turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell. Gene flow between wild wheat *Triticum L.* and other grains such as *Aegilops sp. L.* produced one cultivated species and subsequently led to the emergence of modern high-yielding free-threshing wheat species with non-brittle rachis and grains. Further development and selection resulted in emergence of two wheat species groups: (1) tetraploid wheats (2n = 4x = 28), which includes *Tr. turgidum* L. as defined by Linnaeus and hexaploid wheats (2n = 6x = 42), and (2) *Triticum aestivum*

L. (2n = 6x = 42) as defined by Linnaeus; the second group includes both domesticated wheats with a brittle rachis such as *Tr. aestivum* L. subsp. *spelta* (L.) Thell. and wheat types with a non-brittle rachis, and naked grains, for example, *Tr. aestivum* L. subsp. *aestivum*.

The comparative analysis with the new archaeobotanical data from the Trypillia sites in Moldova and Ukraine confirms that wheat was one of staple crops of the Trypillia culture in this region during all stages of agriculture development. The identified wheat grains, presumably, from Khalepye and the Chernovtsy Museum are consistent with the Trypillia cereal assemblages from other sites that include emmer as a dominant crop, as well as *Tricicum monococcum* (einkorn) and *T. timopheevii* from Stolniceni (Kirleis et al. 2024).

In the earliest research of the Trypillia culture the remains of domesticated plants from 80 Trypillia sites in Moldova and Ukraine were examined, though, as has been mentioned earlier in the text, researchers mostly focused on the imprints of grains on pottery fragments and clay plastering, in many cases ignoring charred grains (Pashkevich 2000). Presently, because of the water-sieving programs conducted by many expeditions, the number of the archaeobotanical remains from the Trypillia sites has increased substantially (Kirleis et al. 2024). In recent years chaffed emmer wheat (*Tr. turgidum* L. subsp. *dicoccoides* (Korn. ex Asch. & Graebn.) Thell.), einkorn wheat (*Tr. monococcum* L. subsp. *monococcum*) and spelt (*Tr. aestivum* L. subsp. *spelta* (L.) Thell.), common naked barley (*Hordeum vulgare* L. convar. *coeleste* (L.) A. Trof.) and husked barley (*H. vulgare* L. subsp. *vulgare*) (Pashkevich 2000: 410) have been added to the Trypillia domesticated grain assemblages (Kirleis et al. 2024). The charred seeds of green peas (*Pisum* sp. L.) have been found at the Maidanetske site, whereas bitter vetch (*Vicia ervilia* (L.) Willd.) has been discovered at the Karbuna site in Moldova (Yanushevich 1976: 74; Pashkevich 1989: 137—138).

Several international projects focusing on the Trypillia mega-sites have used the water-sieving of occupation deposits as an obligatory procedure. Because of the taxonomic determination of the botanical carbonized remains from the Maidanetske mega-site located in the Southern Bug-Dnieper interfluve, cereal grains (*Triticum* sp., *Hordeum* sp.), pulses (Fabaceae) and awns of feather-grass (*Stipa* sp.) (Hofmann et al. 2019: 12—13) as well as *Triticum dicoccum (emmer), T. monociccum (einkorn), T. timopheevii (Timopheev's wheat) and others* have been added to *the Trypillia domesticated grain assemblages* (Kirleis et al. 2024); a single small grain of *Triticum* sp. has been uncovered at the Nebelivka mega-site (Chapman et al. 2020: 409).

The radiocarbon dates enabled us to verify the cultural attribution of the cereal grains from the State Historical Museum.

The radiocarbon data obtained for the two cereal grain assemblages (the Khalepye assemblage and, presumably, the Chernovtsy Museum assemblage) are consistent with the new AMS-dated grain of *Triticum* sp. from the Nebelivka mega-site (Chapman et al. 2020: 409), whereas using the chronological models, the Chernovtsy assemblage (*Context 2*) can be dated to an earlier interval, i.e. 4249/4050—4038/3889 BC (1σ) or 4023/3998—4145/3205 BC (2σ) and the Khalepye assemblage (*Context 1*) can be dated to a later period 3969/3676—3741/3491 BC (1σ) or 4449/3660—3760/3049 BC (2 σ).

These chronological intervals are correlated with the modern chronology of the Trypillia stages based on a rather large AMS-data dataset (Hofmann et al. 2019: 43) including new ^{14}C AMS dates of grains considered to be contemporaneous with Trypillia sites (Kirleis et al. 2024, Fig. 2). The analysis performed has verified the cultural attribution of the cereal grain assemblages kept in the State Historical Museum in Moscow and ascribed them to the Trypillia culture.

Analyzing the nitrogen and carbon isotopic composition of the wheat grains from *Context 1 and 2*, i.e. Khalepye and Chernovtsy, we suggested that this composition would reflect agriculture strategies employed by the Trypillia agriculturalists. The experimental growing of wheat, millet and other cereals as well as legumes and other crops in various conditions with the use of organic and nonorganic fertilizers shows that δ^{15}N in the grains reflects δ^{15}N in the soil on which crops are cultivated; the δ^{15}N values for agricultural crops can vary depending on the use of various technologies, such as irrigation, application of fertilizers and crop rotation (Bogaard et al. 2007; Larsson et al. 2024). When grown in the same conditions, various crops tend to demonstrate similar δ^{15}N values, despite minor differences among varieties; possible differences

between the carbon isotopic composition of the modern samples and that of archaeological samples can be caused by the Suess effect or more carbon in the atmosphere owing to anthropogenic activities as well as water conditions (Larsson et al. 2024; Kirleis et al. 2024).

The precise locations of the two assemblages of the microremains from the State Historical Museum are not known. However, we believe that both assemblages are attributed to the Trypillia culture. In our case, the nitrogen and carbon isotopic composition of several wheat seeds from two sites (Khalepye in case of *Context 1* and Chernovtsy in case of *Context 2*) could be similar to that of the wheat grains from other Trypillia sites, which reflects similar growth conditions and, at the same time could be different from the nitrogen and carbon isotopic composition determined for wheat grown in other natural and climatic as well as economic conditions.

The new data on the nitrogen and carbon isotopic composition of fifteen wheat grains, presumably, from Khalepye and Chernovtsy, were compared with those obtained for wheat grains from other Trypillia archaeological sites, i.e. Chechelnyk, Kosenivka, Maidanetske and Stolniceni 1 (Schlütz et al. 2023), the Chobareti site from the Eneolithic—Early Bronze Age in the southern Caucasus (Messager et al. 2015), and the Alekseyevskoye site located in the arid steppe in northern Kazakhstan (Fig. 6).

The comparative analysis relies on the natural $\delta^{15}N$ baseline for cereals grains at 6.1‰ (Schlutz et al. 2023). Figure 6 shows that the nitrogen and carbon isotopic data of the wheat grains from the State Historical Museum collection are plotted in the middle and above. Their isotopic composition is similar to that of several wheat specimens from the Trypillia Kosenivka, Chechelnyk and Maidanetske sites, with $\delta^{15}N$=9.31‰ (Chernovtsy). These data are consistent with most wheat samples from the Trypillia sites of the mega-site period which are characterized by very high $\delta^{15}N$ values ($\delta^{15}N$ above 9‰; the maximum value of $\delta^{15}N$=11.37‰ has been determined for one wheat grain from Maidanetske). According to these data, the residents of the Trypillia mega-sites applied a special agriculture strategy which included manure management. Animals grazed near the fields that could be surrounded by fences, dung was collected to be used as organic fertilizer and a new system of animal management was put in place. Such agricultural strategies aimed to increase crop yield, including wheat yield, resulted in elevated $\delta^{15}N$ values (Schlütz et al. 2023; Kirleis et al. 2024). The maximum threshold $\delta^{15}N$ value for several Khalepye ($\delta^{15}N$ from 6.58 to 7.44‰) and two Chernovtsy grains ($\delta^{15}N$=7.48 and 9.31‰) suggests occasional manuring in the fields where this wheat was grown. All values below the set baseline for cereals grains at 6.1‰ (Schlutz et al. 2023) for Khalepye ($\delta^{15}N$ from 4.38 to 6.2‰) and Chernovtsy ($\delta^{15}N$ from 5.39 to 6.09‰) clearly show that this agriculture strategy was not used.

Hence, the crop growth conditions in the fields improved by fertilizer application from which some wheat from Khalepye was collected were, probably, similar to those in the fields of other Trypillia settlements where agriculturalists improved crop yields using manuring strategy. More elevated nitrogen isotopic values in the fields of the Tripyllia mega-sites is an indication of long-term manuring practices, which, probably, were not applied systematically during the final stage of the Tripyllia culture when settlements became smaller and their residents engaged in agriculture on a smaller scale.

The Khalepye and Chernovtsy wheat isotopic data differ from the isotopic data on the wheat from the Eneolithic Chobareti site in the southern Caucasus (Messager et al. 2015) and the wheat from the Alekseyevskoye site in northern Kazakhstan dating to the early Iron Age and to the 18^{th} —19^{th} centuries CE, where other agricultural strategies were, most likely, used. A low threshold value of $\delta^{15}N$ in the Chobareti and Alekseyevskoye wheat grains means that the local population did not use manure to fertilize crop areas and that the natural and ecological conditions of the piedmont fields in the southern Caucasus and arable lands in northern Kazakhstan differed from those in the Trypillia area. Hence, the comparison with the Trypillia agriculturalists reveals that the Eneolithic population of the southern Caucasus and the population which inhabited northern Kazakhstan in the Early Iron Age and in the subsequent periods practiced agricultural strategies different from those used by the Trypillia population.

Therefore, the comparative analysis of the nitrogen and carbon isotopic composition of wheat, presumably, from Khalepye and Chernovtsy, confirms that this assemblage is best linked to the tradition of Trypillia crop management when a system using organic fertilizers (animal manure) aimed to intensify farming was put in place (Schlutz et al. 2023).

Conclusion

The archaeobotanical analysis of the selected grains from the old cereal grain assemblages kept in the State Historical Museum defined the morphological character of the grains and assigned them to wheat species: *Tr. aestivum* subsp. *Aestivum* and *Tr. turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell (Fig. 3: 1, 1.1, 2.2, 2.3, 2.4). The analysis found that other grains belonged to the group of tetraploid (4x), domesticated, free-threshing *Tr. turgidum* L. (Fig. 4: 3.3, 3.5, 3.7).

These data are consistent with the results of the earlier investigation of the cereal grain collection from Khalepye (excavated by Khvoyka in 1895), a site located not far from the Trypillia village which was ascribed to the culture identified in the Russian publications as the Trypillia culture. This investigation was conducted by K.A. Flyaksberg in the 1930s (Yanushevich 1976). While the Khalepye cereal grain assemblage was lost during World War II, we think that a part of this assemblage was acquired by the State Historical Museum in Moscow before the war; it was registered not later than 1939, and then included in the museum axillary scientific collections of the Archaeological Department, and subsequently put on permanent display. The catalog cards that mention the Trypillia assemblage from the excavations conducted by V.V. Khvoyka and the cereal grain assemblage from the Chernovtsy Museum are still kept in the museum. The data on the direct radiocarbon dating of five specimens from, presumably, Chernovtsy and Khalepye, are consistent with the chronology of Trypillia sites C1—C2, i.e. 4600—3600 calBC (Hofmann et al. 2019: 43; Palaguta, Starkova 2018: 97; Kirleis et al. 2024) and, therefore, both the Chernovtsy cereal assemblage and the Khalepye assemblage can be attributed to the Trypillia culture.

The analysis of the nitrogen and carbon isotopic composition of fifteen wheat grains from Khalepye and Chernovtsy and wheat grains from other Trypillia sites as well as the southern Caucasus and northern Kazakhstan confirms this conclusion. Agricultural strategies that probably included use of organic fertilizers (animal manure) were known to the population that cultivated wheat found at Khalepye and Chernovtsy.

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Table 1. **Results of AMS-dating of the wheat samples from *Contexts 1&2* (unmodeled data).**

Lab No.	Sample	Date (BP)	From	To	%	From	To	%
Calibrated range (unmodeled) BCE								
Chernovtsy Museum (*Context 2*)								
DeA-38151	Wheat grain	5316±26	4133	4047	68.3	4233	3998	95.4
Poz-136462	Wheat grain	5215±35	4048	3987	68.3	4215	3960	95.4
IGANams-10094	Wheat grain	5210±25	4046	3985	68.3	4156	3967	95.4
Calibrated range (unmodeled) BCE								
Khalepye (*Context 1*)								
Lab No.	**Sample**	**Date BP**	**From**	**To**	**%**	**From**	**To**	**%**
DeA-38150	Wheat grain	4999±27	3789	3663	68.3	3913	3653	95.4
IGANams-10095	Wheat grain	4910±25	3708	3646	68.3	3766	3641	95.4

Table 2. **Calibrated *Date* intervals for the wheat samples from *Contexts 1&2* (modeled data).**

Lab No.	Sample	Date BP	From	To	%	From	To	%
Calibrated range (modeled) BCE								
Chernovtsy Museum (*Context 2*)								
Start boundary			4249	4050	68.3	4923	3998	95.4
DeA-38151	Wheat grain	5316±26	4133	4047	68.3	4233	3998	95.4
Poz-136462	Wheat grain	5215±35	4048	3987	68.3	4215	3960	95.4
IGANams-10094	Wheat grain	5210±25	4046	3985	68.3	4156	3967	95.4
End boundary			4038	3889	68.3	4152	3205	95.4
Calibrated range (modelled) BCE								
Khalepye (*Context 1*)								
Lab No.	**Sample**	**Date BP**	**From**	**To**	**%**	**From**	**To**	**%**
Start boundary			3969	3676	68.3	3913	3653	95.4
DeA-38150	Wheat grain	4999±27	3789	3663	68.3	3913	3653	95.4
IGANams-10095	Wheat grain	4910±25	3708	3646	68.3	3766	3641	95.4
End boundary			3708	3646	68.3	3766	3641	95.4

Table 3. **Stable isotope data ($\delta^{13}C$ and $\delta^{15}N$) of wheat grains from *Context 1* (Khalepye) and *Context 2* (Chernovtsy).**

№	Sample	$\delta^{13}C$, ‰ VPDB	$\delta^{15}N$, ‰ AIR	C/N
Context 1 (Khalepye)				
1	Wheat grain	-22.58±0.21	6.58±0.24	43.57±0.51
2	Wheat grain	-22.43±0.18	5.86±0.31	49.62±0.66
3	Wheat grain	-22.64±0.22	7.16±0.28	53.39±0.37
4	Wheat grain	-22.71±0.20	7.44±0.24	55.16±0.28
5	Wheat grain	-22.66±0.08	6.1±0.22	48.37±0.3
6	Wheat grain	-24.08±0.11	7.37±0.21	54.89±0.36
7	Wheat grain	-22.96±0.06	6.20±0.31	55.27±0.29
8	Wheat grain	-22.37±0.21	4.38±0.27	48.36±0.25
9	Wheat grain	-23.49±0.24	7.05±0.21	50.08±0.21
10	Wheat grain	-22.84±0.17	7.54±0.22	46.31±0.3
Context 2 (Chernovtsy Museum)				
11	Wheat grain	-24.24±0.21	5.52±0.22	19.55±0.32
12	Wheat grain	-24.12±0.13	6.09±0.17	22.39±0.24
13	Wheat grain	-24.28±0.2	7.48±0.24	47.32±0.2
14	Wheat grain	-23.38±0.22	9.31±0.26	54.47±0.37
15	Wheat grain	-23.75±0.18	5.39±0.18	44.03±0.34

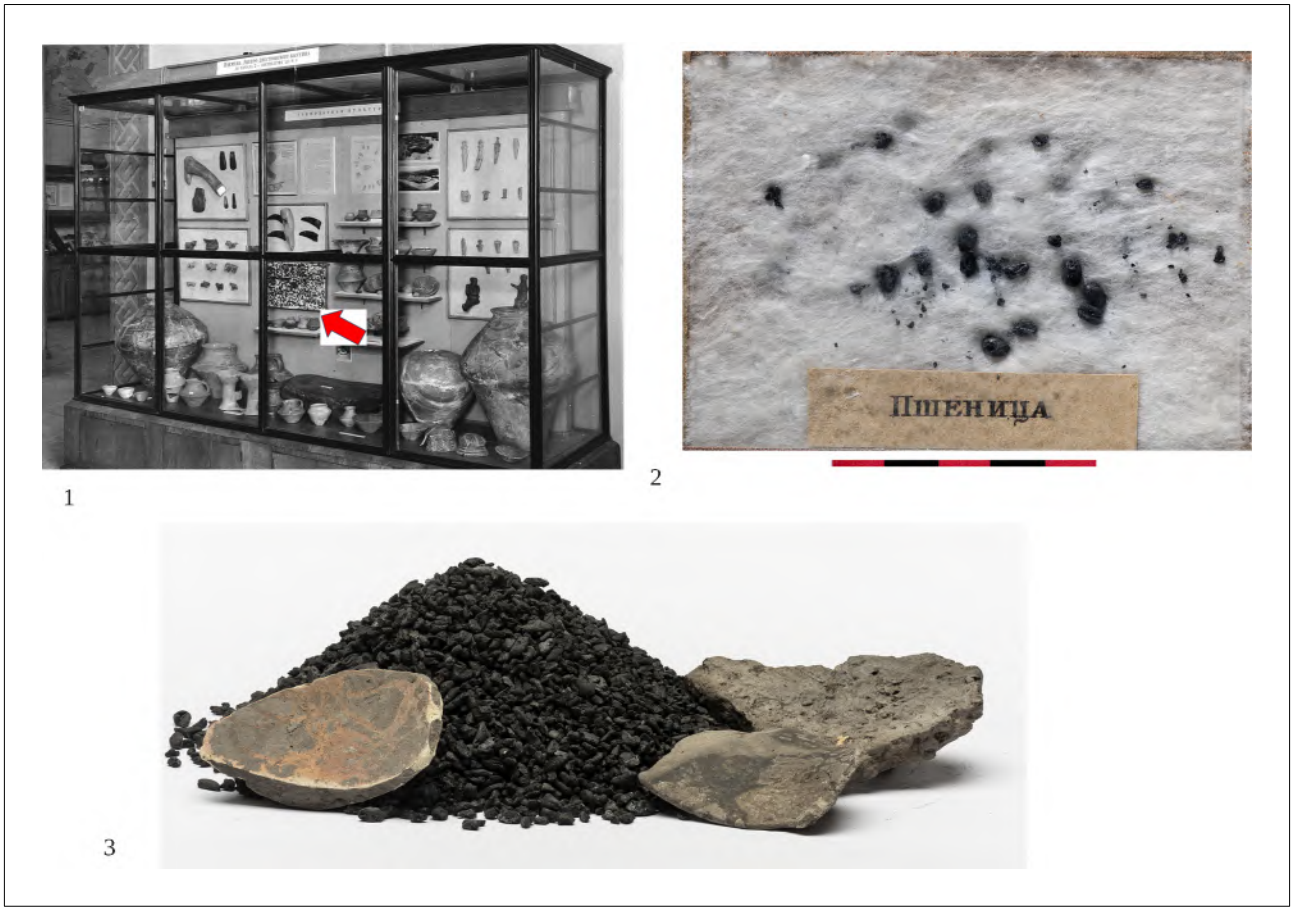

Fig. 1. *1* — Permanent display of the State Historical Museum. Bronze Age Period Room, the cabinet with the Trypillia artifacts; a – the wheat grains on display in the frame under glass; *2* — fragment of the exposition frame with the charred wheat grains, presumably, from the Chernovtsy Museum, with the 'wheat'[*pshenitsa*] (in Russian); *3* — charred grains and fragments of clay pots, presumably, from the Khalepye village located not far from the Trypillia village, excavations by V.V. Khvoyka in 1895.

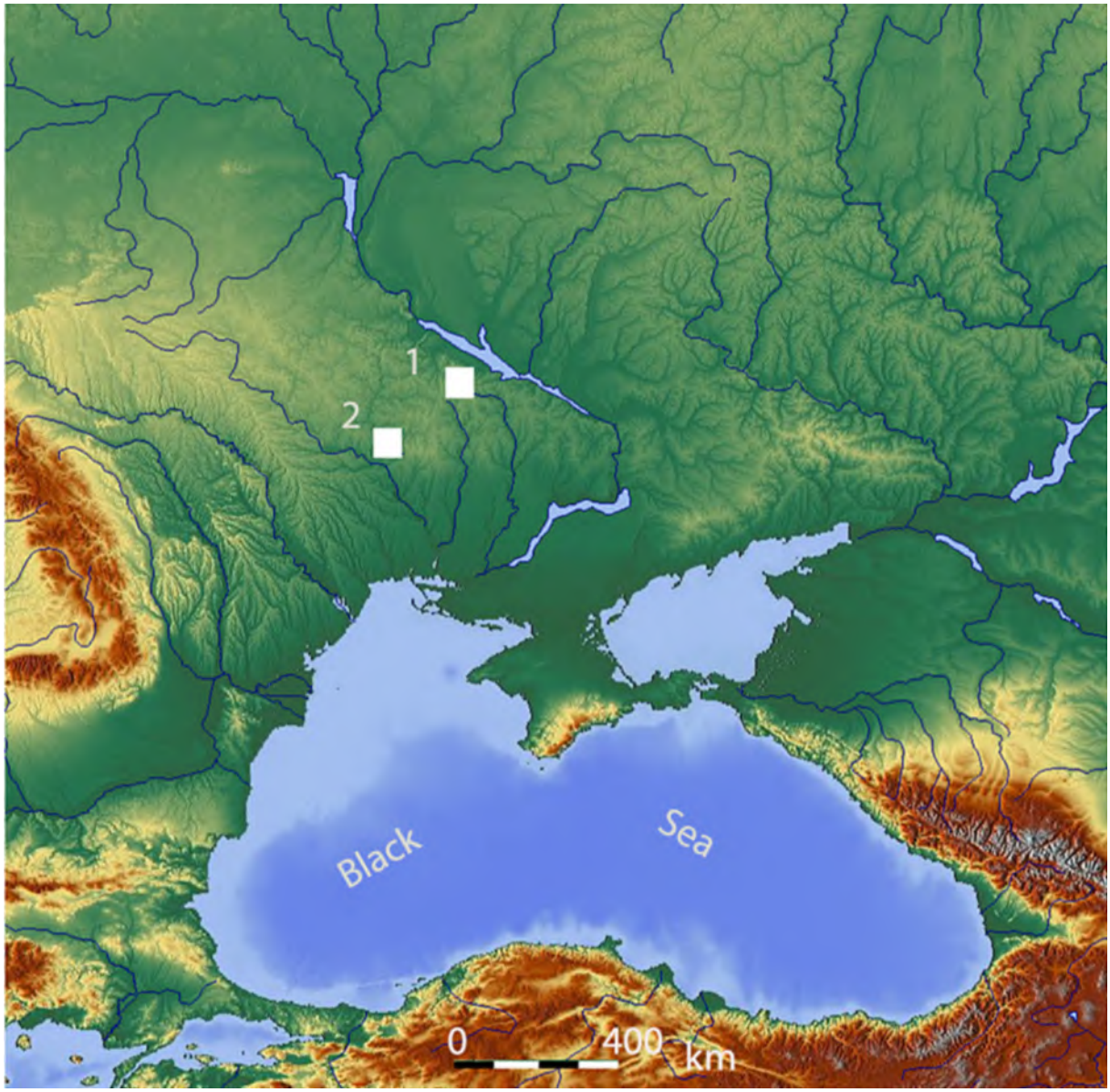

Fig. 2. Location of cereal assemblages from State Historical museum: *1* — Khalepye; *2* — Chernovtsy

Fig. 3. ***Context 1*** **Group: wheat grains.**

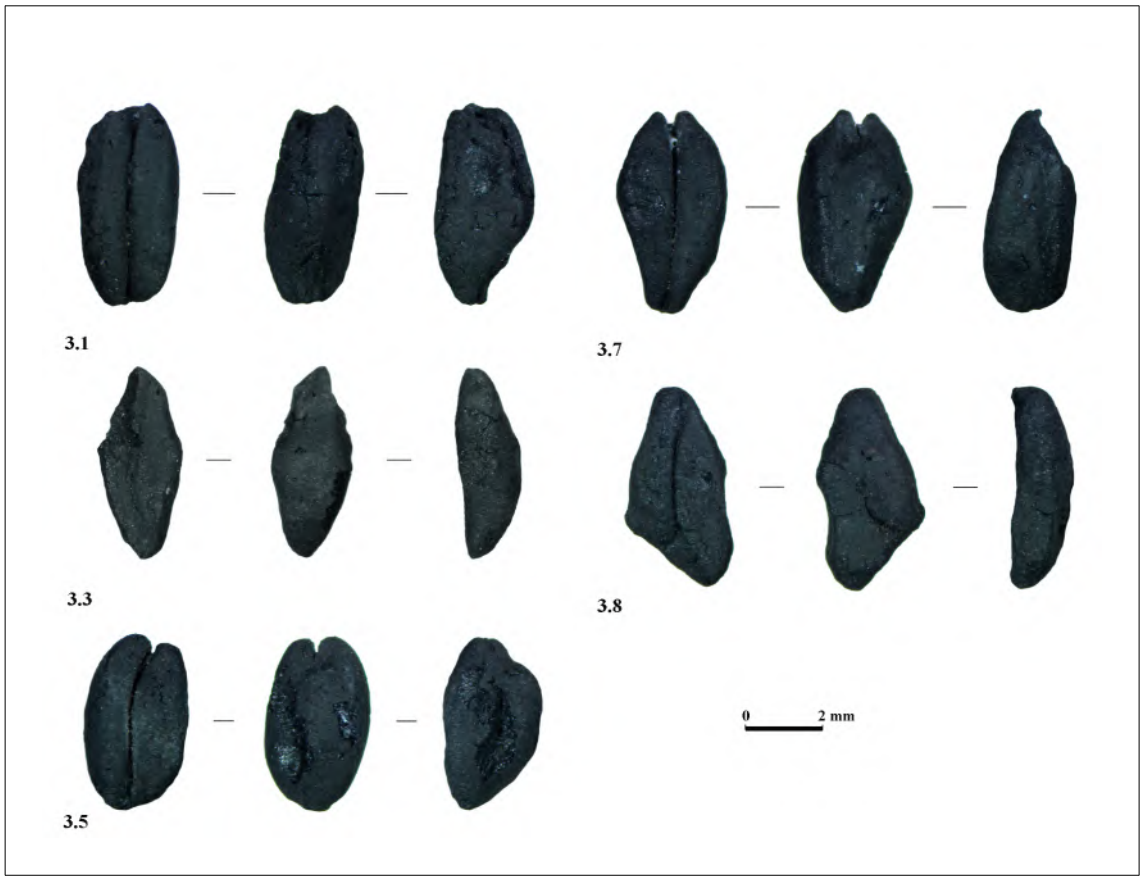

Fig. 4. ***Context 2*** **Group: wheat grains.**

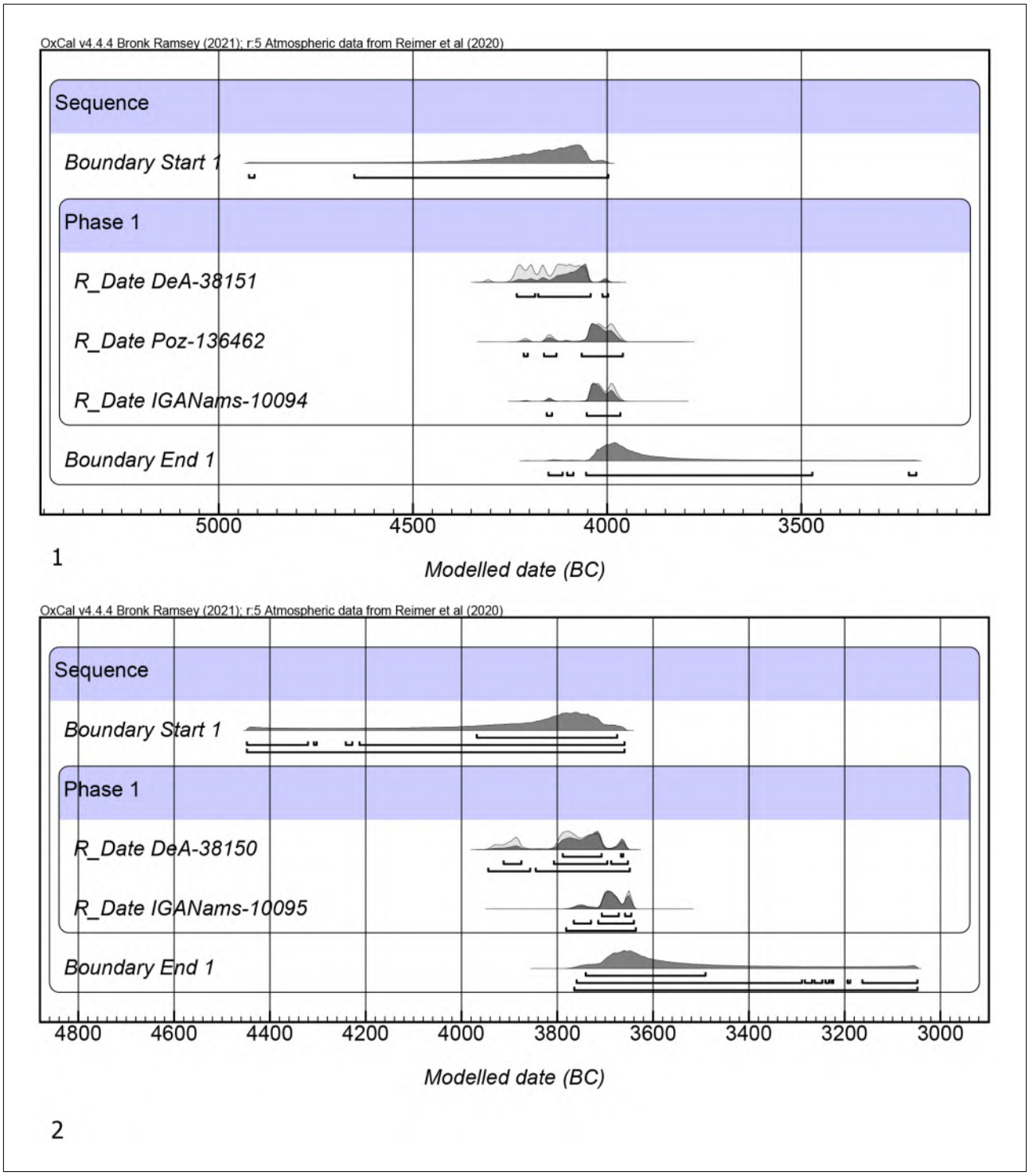

Fig. 5. Summary of the modeled radiocarbon dates of the wheat grains: 1 — *Context 2*; *2* — *Context 1*.

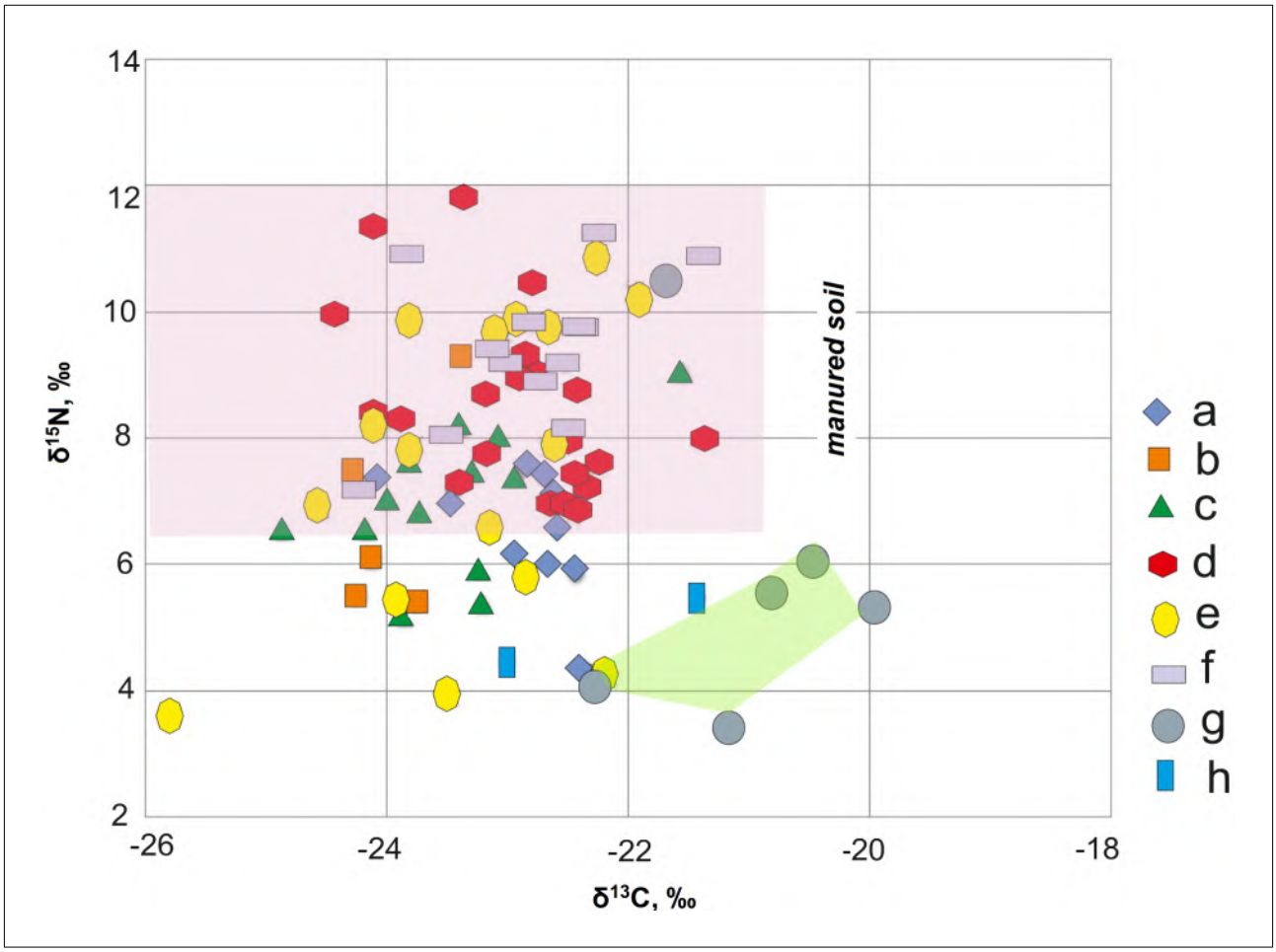

Fig. 6. $\delta^{15}N$ and $\delta^{13}C$ values for wheat grains: *a* — Khalepye; *b* — Chernovtsy; *c* — Kosenivka; *d* — Maidanetske; *e* — Stolniceni 1; *f* — Chechelnyk (*c*—*f*: after Schlütz et al. 2023); *g* — Chobareti (after Messager et al. 2015); *h* — Alekseyevskoye.