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Panicoids in Xiongnu burial ground (Mongolia, First Century AD): problems of identification

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Keywords: nomads, Northern Mongolia, *Panicum*, plant remains, the Xiongnu.

Summary. The paper summarizes the data on plant remains from burial mounds of the Noin-Ula burial ground in Northern Mongolia (dated from the end of the 1st century BC to the beginning of the 1st century AD). Plant remains that were found in several mounds (20, 22, and 31) belonged to different plant species. Some of them, the remains of *Pinus sylvestris* L. and *Betula* sp., got into a mound (31) accidentally during burial ceremony. They are typical for that area. Another part of plants, found in all three mounds, was placed there intentionally, most likely, for ritual purposes. They are loose grains inside the casket (mound 31) and on the floor of a burial chamber (mounds 20, 22) at 17-meter depth. The problems of identification of panicoid remains from burial grounds are discussed in detail. For diagnostics of panicoid graminoids in this case study only caryopsis macroparameters were possible to use. The knowledge on morphology of ultrasculpture of caryopses surface is fragmentary and weakly studied even for the modern material which could be used as a standard for identification of archaeological material. The written sources of the time close to the burial age, if existed, should be used very carefully. Plant remains from all three mounds were identified up to a species level. They all belong to *Panicum miliaceum* L. The Xiongnu culture featured a special attitude to millet as reflected in burial rituals of the Xiongnu nobles among other numerous traditions of Han civilization.

Паникоидные злаки в захоронениях хунну (Монголия, I век н. э.): проблемы идентификации

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Ключевые слова: кочевники, растительные остатки, Северная Монголия, хунну, *Panicum*.

Аннотация. Обобщены данные о растительных находках в погребальном комплексе кочевников могильника «Ноин-Ула» на территории Северной Монголии (датируемый концом I века до н. э. – началом I века н. э.). Растительные остатки, обнаруженные в нескольких курганах ноин-уланском захоронении (курганы 20, 22, 31), принадлежали разным видам растений. Некоторые попали в погребения случайно – это фрагменты *Pinus sylvestris* L., *Betula* sp. Эти растения являются обычными для данной местности. Другая же часть растений, найденная во всех трех курганах, вероятно, была использована преднамеренно в погребальном обряде – это россыпи зерна внутри гроба (курган 31) и на полу погребальной камеры (курганы 20, 22) на глубине около 17 метров. В статье подробно обсуждаются проблемы идентификации остатков паникоидных злаков в за-

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хоронениях. Для диагностики паникоидных злаков в захоронениях в данном конкретном случае, возможно было использовать только макропризнаки зерновок. Знания об особенностях морфологии ультраскульптуры поверхности зерновок слишком фрагментарны и недостаточно исследованы даже для современного материала, который мог бы быть использован в качестве стандартов для определения археологического материала. Письменные источники близкого времени датировки погребений, если они существуют, должны быть использованы с большой осторожностью. Видовая принадлежность остатков зерна во всех трех курганах установлена – они относятся к виду *Panicum miliaceum* L. Особое отношение к просу было принято в китайской цивилизации. Это же проявлялось и у хунну, что отражено в погребальных ритуалах элиты хунну, как и многие другие традиции ханьской цивилизации.

Introduction

In 2006–2012, the Russian–Mongolian archaeological expedition performed excavations of several large Xiongnu mounds at the Noin-Ula burial ground in Northern Mongolia; the mounds are dated from the end of the 1st century BC to the beginning of the 1st century AD. In addition to material culture items (Bogdanov, Polosmak, 2015; Polosmak, Karpova, 2016), the burial chambers contained plant remains that allowed the genus identification of some of the specimens. Some data on mounds 20 and 31 have been published earlier (Korolyuk, Polosmak, 2010). Presently, we are able to identify the plant remains more accurately and to summarize the data obtained during a 10-year period of the study.

The Xiongnu were a nation of nomads and cattle-breeders who lived in Central Asian steppes from 1000 BC to 1000 AD. At the turn of the 3rd and 2nd century BC, the Xiongnu created the first nomadic empire, which united many ethnic communities of Central Asia, South Siberia, and the Far East. For 250 years, the Xiongnu were in military opposition to their southern neighbor – the Han Empire of China. The nomads managed to contrive a successful strategy in their relations with China: during the entire period of their confrontation, the Han emperors had to pay substantial tributes with chariots, silk fabrics and clothes, works of art and household items, foods and wine..., which were disguised as gifts to the *chanyu*.

The finds of plants that remained in nomadic burial mounds are quite rare and rather sporadic. Thus, identification and interpretation of such finds are always of great interest to specialists. Knowing what plants were used in burial rituals, we can learn more about the cultural ties between peoples of Central Asia and about their worldviews.

Materials and methods

We studied the remains from three burial mounds. The burial site is situated in Tov Province (Central Aimak), Bornuur Sum (N48°33´, E106°30´), on Noin-Uul Mountain located within the western spurs of the Khentei Range, in close vicinity to temporary tributaries of the Khara-gol River (the Bara-gol River basin), at an elevation of 1345 m above sea level (Fig. 1).

Vegetation type at the burial site was described based on the results of botanical expedition conducted by the authors in 2006. Twenty geobotanical relevés and herbarium material (NS) were collected at the excavation site.

Plant remains found at the Noin-Ula burial site were of different type and belonged to different plant species. Among the contents of a burial chamber (burial mound 31) plant macrofossils were recorded represented by cones and several twigs. Numerous and homogenous plant remains were found in all the burial mounds as a pressed layer as thick as 1–0.5 cm and represented by "seed remains" (burial mounds 20, 22, 31; the burial chambers located at a depth of 16–18 m) (Fig. 2, 3). The whole plant material was thoroughly prepared (cleaned and rinsed using soil sieves with various mesh size, and dried) for the following study using high resolution microscopes.

The principal method of the study was comparative-morphological applied both for archaeological and modern samples. The grains were studied using carpological method involving the analysis of lemma and palea surface ultrasculpture.

To study ancient grains, those of 9 modern panicoid species (18 herbarium samples, Table 1) were used as a standard. These plants have long been used by a man as cereals: broomcorn millet, sorgo, barnyard grass, and foxtail millet from different regions of Asia. For comparative analysis, materials from herbarium collections of N. I. Vavilov Institute of Plant Genetic Resources RAS (WIR) and Herbarium of the Central Siberian Botanical Garden SB RAS (NS) were used as well. The microphotographs of modern and archaeological samples were made by means of "Discovery.V12" stereo microscope and digital image processing software "Axio vision 4.8", as well as Hitachi-TM-1000 scanning electron microscope. To analyze grains (or lemma and palea) the measurements of 10 upper lemmas and palea (archaeological samples) and of 3 to 10 caryopses (modern samples) were conducted. Scientific names of plants are given according to the Code of Botanical Nomenclature and cross-checked with the International Plant Names Index (www.ipni.org).

Results

1. Characteristics of modern vegetation at the burial site

The Khentei Mountains occupy the vast north-eastern part of the Mongolian People's Republic

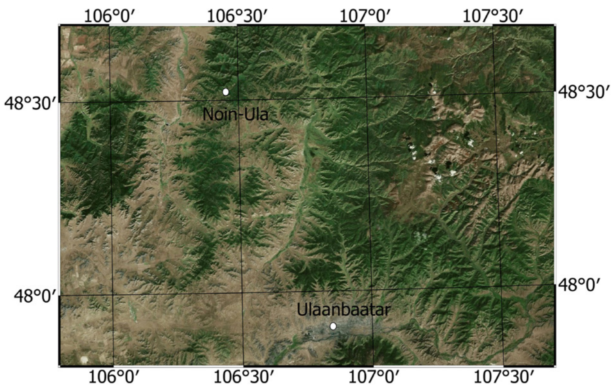

Fig. 1. Satellite image of the excavation site (Mongolia) (source: http://maps.google.com).

Fig. 2. Excavated Noin-Ula mound 22 (Russian-Mongolian expedition, 2012).

Fig. 3. Seeds on the floor of the burial chamber's corridor in the mound 22, next to the wooden fragments of a saddle (at a depth of 18 m) *in situ.*

Fig. 4. Scotch pine cone (*Pinus sylvestris*), birch twigs and stem fragments.

Fig. 5. Intact pressed plant remains: a) burial mound 20; b) burial mound 22.

Table 1
The list of the studied samples of modern taxa (* samples used for comparison of microcharacters)

Taxa, specimen	Sample number	Locality, Herbarium (acronym), herbarium number.
Tribe Paniceae R. Br.		
Panicum miliaceum ssp. *effusum* All	1 2	Iran (WIR), № K–1647. Afganistan (WIR), № 2209.
Panicum miliaceum L.	3 4 5* 6* 7* 8	Minor Asia (WIR), № 2042. Mongolia (WIR), № 500476. Russia, The Irkutsk Oblast, Kachugskii tract, 60 km N from Irkutsk, 07.09.2015, Lomonosova M, Korolyuk E(NS), №1167. Russia, the Chita Oblast', the Inogda River, Uleti village. 29.07.1970 (NS). Russia, Republic of Altai, Schebalinsky District, Seminskii ridge, the Sarlik River, N 49°90' E 86°60' Alt=1220 м. 28.06.1984. Pschenichnaya, (NS). Russia, the Novosibirsk oblast', SuzunskyDistrict, Meret' village, 30.08.1998. Schaulo. (NS), № 47.
Setaria italica (L.) P. Beauv. (syn. *Panicum glaucum* L.)	9 10 11 12*	Ussuriland (WIR), № 5255. Samarkand Oblast' (WIR), № 4946. Aral (WIR), № 5346. Pamir, Pyandj (WIR), № 20083.
Setaria palmifolia (Koenig) Stapf	13	China, Moc-chan (WIR), № 674.
Setaria glauca (L.) P. Beauv. (syn. *Panicum glaucum* (L.)	14	China (WIR); № 5252.
Echinochloa crus-galli (L.) P. Beauv. s. l.	15	Japan (WIR), № 0084296/5106
Echinochloa frumentacea Link.	16	Far East (WIR), 1971.
Tribe Andropogoneae Dumort.		
Sorghum durra (Forsk.) Stapf	17	Turkmenistan (WIR), № 521
Sorghum saccharatum (L.) Moench	18	Japan (WIR), № I-299080/743

(MPR). The Orkhon River demarcates them from the Khangai Mountains in the west while Torei Lakes depression in the east (Obruchev, 1946; Isaev, 1988). They represent a low-level, strongly eroded and subdued tableland with characteristic fell-field relief at the top of the arch. Khentei is composed of several ranges Baga Khentei being the highest one with fell-fields at 2200–2600 m above sea level. The characteristic feature of Khentei highlands is the presence of inter-mountian tectonic depressions. Stretching in north-eastern direction, this tableland represents a part of the watershed between the basins of the Arctic and Pacific Oceans. All Khentei rivers belong to the category of mountain rivers with rain precipitations as a major source of nourishment. River valleys are usually swamped and covered with yernik. The climate is sharply continental.

According to the MPR forest site regionalization, this region belongs to Khentei-Chikoy forest site province (Zhukov, 1978). At the excavation site forest vegetation predominates representing now the herbaceous birch forests. These forests are presumably of secondary origin appeared in place of eliminated pine forests which are characteristic for the altitudinal-belt complex of subtaiga forests in the studied area. The valleys of small rivers and creeks are occupied with shrub communities alternating with meadows. The steppes cover insignificant areas confined to prominent south facing stony slopes. The areas with steppe vegetation increase with the decrease of absolute elevations reflecting transition of a forest altitudinal belt into a forest-steppe one.

2. Plant macroremains in burial mound 31

Several well-preserved seedless cones and some twigs were found in a burial chamber of the burial mound 31. Those large remains were easily identified based on specific morphological characters.

The cones were identified as the cones of Scotch pine (*Pinus sylvestris* L., Fig. 4). The twigs without leaves and buds, as well as rather thin fragment of a 20 cm long stem belonged to a non-specified birch genus (*Betula sp*.) (Fig. 4). Probably, those plant fragments fell into the chamber during a burial ceremony since they represented tree plants common for the flora of Northern Mongolia's forest zone and predominate in modern vegetation types in mid-mountain belt of the Khentei Mountains.

3. Plant remains in burial mounds 20, 22, 31. Grain of nomads

Based on comparison of grain morphology and size, we attributed those fragments to panicoid cereals, specifically to the representatives of modern tribes of *Paniceae* R. Br. and *Andropogoneae* Dumort.

The origin of cereals, found in the Xiongnu burials, may be related both to the territories of Northern Mongolia and Tuva that are suitable for arable farming, and to agrarian China. Besides, in the studied period of time the Xiongnu had indirect contacts with the regions of East Turkestan, Central and Western Asia, and North-West India. Thus, the studied burial sites may contain absolutely different sorgho or millet cereals (if they were cultivated at that time): common millet, cockspur grass, *chumiza*, *mogharicum*, *kunak*, sorgho, *dzhugara, gaolyan*, etc.

When studying plant remains from archaeological sites and their further interpreting, it is very important to review all available written sources from the region of excavations, both historical and modern, that may contain any data on finds and identification of plant remains.

A big problem may rise during the study of historical manuscripts. How to compare plant names found in those sources and in the modern literature? Trivial names used by different nations might imply absolutely different plants. A sizeable list of trivial names for panicoid grasses was compiled by V. N. Lysov (1975). D. Austin (2006) provided the names for 24 millet and sorgho species cultivated from ancient times in both hemispheres. The list included both scientific and trivial names, characteristic for different regions, with etymological explanations (excluding the territory of the former USSR). Such names could undergo modifications after translation into other languages. Besides, if an important food or technical plant had been cultivated for a long historical time, not just a name, but also its morphological characteristics changed in the course of selection.

Written sources of the time close to the burial age should be used very carefully. We cite some publications describing the use of panicoid grasses for adjacent territories in this paper.

Grain is known to have been an important element of the gifts with which Han China bought peace on the borders with the Xiongnu. In Han time, different types of grain were cultivated on the territory of China – chumise, millet, wheat, barley, rice, beans, hemp. Grain, especially millet, played an important role in the system of ancient Chinese sacrificial offerings.

According to written sources, in Han China there was grain of varying degrees of cleaning: poorly threshed, regularly threshed, well-threshed, and highest-quality grain (Kryukov et al., 1983). At that time, grain threshing was made easier through the use of a specialized mechanism – the hulling machine, which was essentially a stone pestle with a foot-driven lever (Ibid.). The imperial court made gifts with well-threshed grain of high quality, as was specifically stipulated.

However, the grain that is found in Xiongnu burials and settlements hardly had anything to do with imperial deliveries. Studies showed that the millet grains found in the elite Noin-Ula mounds 20, 22, and 31 were poorly threshed (inflorescences were found among caryopses). This suggests that it was either produced locally (in Mongolia), or gained as part of the spoils of war, or exchanged by Xiongnu at border markets (Fig. 5a, b).

There were periods in the history of the relations between the Han Empire and Xiongnu when there were open markets, profitable for the Xiongnu, at frontier posts, and large sections of the nomadic population could satisfy their needs, particularly, in grain. Another option was raids upon near-border Chinese settlements, during which Xiongnu grabbed much more goods than they received as gifts.

The *Panicum* L. genus counts over 500 species widespread in tropical, subtropical and partly in moderately warm countries in both hemispheres, though the majority of those species grow in America. Over 10 millet species are the most important cereals. This genus includes *Panicum miliaceum* L., one of the most ancient and still widely cultivated plants nowadays (Tzvelev, 1976). It is used for production of millet groats, flour, ale and alcohol. This species is considered to be the most ancient cereal in China (Lu et al., 2009a). It is certainly known that millet has been grown in Tuva during the last two hundred years (or even earlier) and now it represents the "paradoxical genetic material combining the features of both cultivated and aboriginal breeds, the populations of local traditional selection. And '*taraa*' is an ethnic food product of Tuva people. '*Taraa*' is traditional meal for regaling, especially in Western Tuva. When guests come, they are first regaled with tea served with fried millet (*chinge-taraa*) and dry barley flour (*talkan*)" *(Mongush, Namzalov,* 2013).

Common millet is a spring heat-loving plant. As compared to other cereals, it is a very drought-resistant crop consuming water two times less than wheat. Its growing period is 60–120 days, though it demands heat enough, especially for sprouting (Vekhov et al., 1978). Young crops of millet are very sensitive to low air temperature (–2… –3 °C), and its generative organs can be damaged by frost at +1… +2 °C. During different developmental stages millet requires rather high daily air temperature: 18 °C for sprouting-tillering, 20 °C for tillering-paniculation, 23 °C for paniculation-flowering, 21 °C for flowering-ripening. This species also includes subspecies *P. miliaceum* ssp. *ruderale* (Kitagav.) Tzvelev. Some authors consider it to be an ancestral form for millet "domestication" in China (Hunt et al., 2008).

The *Setaria* P. Beauv. genus includes the basic cultivated species *S. italica* (L.) P. Beauv. Some authors attribute it to *Panicum* genus (syn. *Panicum italicum* L.). It has several morphoforms each having personal trivial names: '*mogar*', '*kunak*', '*chumiza*', '*gomi*', etc. Some of them are cultivated mainly for cereals, while some of them for forage. The culture is also heat-loving and drought-resistant (Lysov, 1975; Vekhov et al., 1978).

4. Characteristics of flowers and caryopses in panicoids and selection of diagnostic features

A main criterion of identification of plant remains should be morphological characteristics of remained fragments and their comparison with modern material.

Grass fruit is called caryopsis. This is one-seeded indehiscent fruit featuring pericarpium adhered to the reduced seed coat so firmly that they are divided only by cuticular layer formed as a result of adhesion of surface cuticules of endocarpium and exotestum. Caryopsis shape, ventral side especially, as well as hilum shape are of great taxonomical importance. However, only in complex with other features they allow to identify samples to species level.

Caryopsis is covered with vegetative structures that are glumes, lemmas and palea. Lemmas and palea fit to caryopsis with variable firmness. In respect to technological process (threshing) two large groups of fruits are discerned: hull-less and paleaceous. Wheat, rye, and corn have hull-less grains since lemmas and palea are easily removed. The other group of cereals feature lemmas and palea firmly fused with caryopsis, so it is not removed when threshing (barley, oat, rice, millet (Fig. 6, 7), sorgho). The technological courses in seed studies offer caryopsis classification based on their appearance (morphological characters) discerning true (wheat, rye, barley, oat) and panicoid (the rest of) cultures. The fruit ultrasculpture and epidermis of lemma in various grasses are properly studied in modern literature for taxa definition and distinction between wild and cultivated species. These features

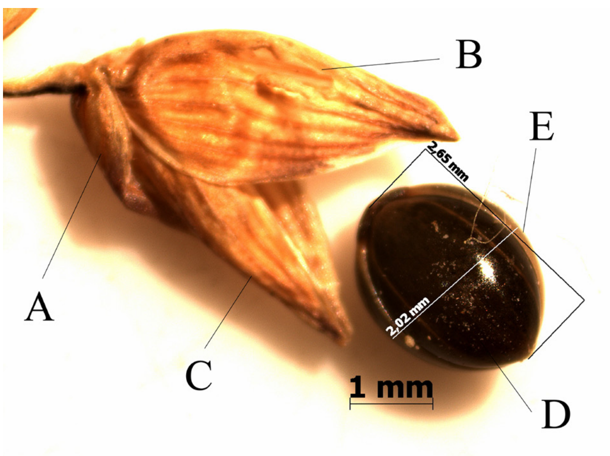

Fig.6. Illustration of spikelet and grain of *Panicum miliaceum*: (A, B) scarious glumes; (C) lower lemma of sterile floret; (D, E) upper lemma and palea of the second floret (sample no. 5*).

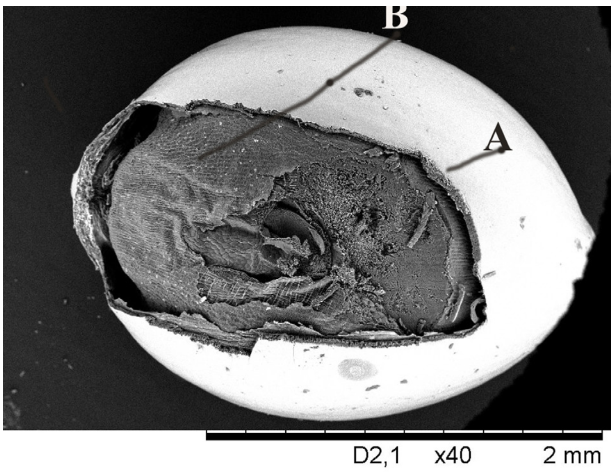

Fig. 7. (A) upper lemma with thick cuticular layer and outer epidermis underneath, cell walls of which form a distinct pattern; (B) caryopsis, also with cuticularised layer over the cells of fused pericarpium and seed coat, cells of which form a similar pattern (sample no. 8*).

are considered to be rather conservative and are used additionally as diagnostic features in taxonomy (Nikolaevskaya, Petrova, 1989).

We do not discuss the problems of domestication of panicoid grasses in this paper. However, the questions concerning identification of panicoid grasses found in archaeological monuments (settlements, burial sites) are worth of discussing. This issue is raised rarely. Previously, the botanical component in archaeological investigations was minimized; in addition, the methods of cereal macroremains identification were imperfect. According to H. Hunt et al. (2008) from 60 records of panicoid grasses finds in the Northern Hemisphere, practically all plant remains require special methods of identification and, probably, re-

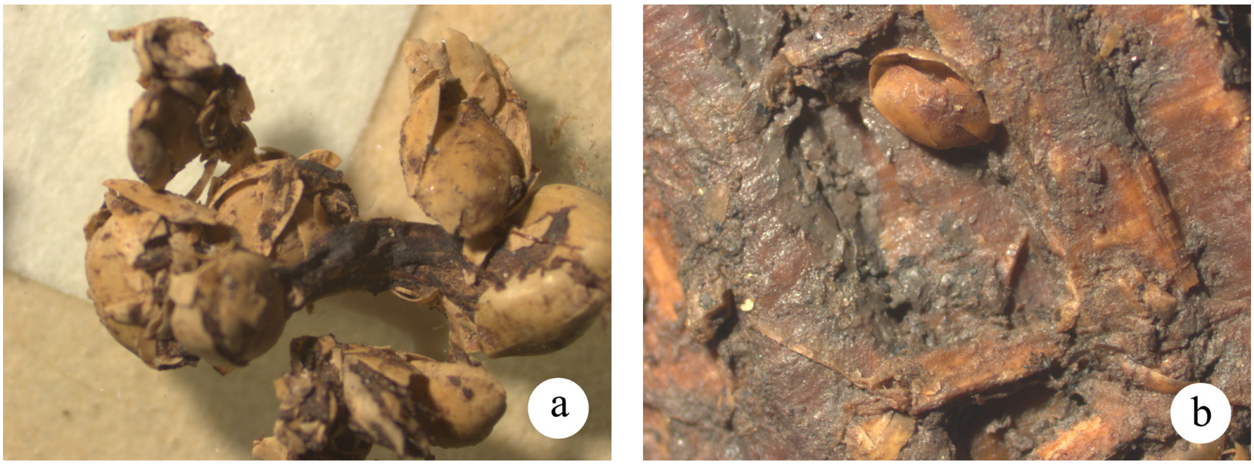

Fig. 8. Archeological material from burial mound 20: (a) the only remained inflorescence (washed fragment); (b) grain remains and destroyed vegetative parts (non-washed fragments).

Fig. 9. Archaeological material after washing (lemmas and palea): (a) burial mound 20; (b) burial mound 31; (c, d) burial mound 22.

identification. The attributing of plant remains to one or another botanical taxon is still disputable, while comparison of published data is complicated due to re-identifications of cereal fragments in earlier publications. The leading specialists consider now that the comparative analysis of these data may be doubtful. F. Gyulai (2014) emphasized this problem in one of his recent works on millet domestication into Eastern Europe. Another substantial problem that specialists face is the selection of proper diagnostic features. For this, an adherence to identification protocols and collaboration of different specialists applying various methods are required.

A spurt of publications number regarding the methods of identification of cereals found in historical monuments is associated with the progress in up-to-date technology. Numerous works on identification methods of panicoid grasses were made in Japan and India. Just now it became possible to study properly the remains of panicoid grasses found in 1970s in China (most massive than elsewhere) both in settlements and burial sites (Lu et al., 2009a, b; Yang et al., 2012; Song et al., 2013; Yang, Perry, 2013; Weisskopf, Lee, 2014). A large project on the study of panicoid grasses was fulfilled by a scientific team based on the data of archaeological excavations of settlements in Ukraine (The East-West Millet Project) (Hunt et al., 2011; Motuzaite-Matuzeviciute et al., 2012, 2013). Interesting findings of plant remains, including grasses, were recently made at the Begash burial site, Kazakhstan (Frachetti et al., 2010; Sprengler et al., 2014; Doumani et al., 2015).

Thus, studying numerous archaeological data has led us to understanding that proper development of up-to-date methods for graminoids investigations for the purposes of archaeology are required. This, first, refers to selection of modern materials to be used as standards (de Wet, 1979) and diagnostic methods (using only generative remains of graminoids), such as follows:

1. Macrocarpological method involving comparative studies of morphological features of caryopses. This method had been basic and widely applied before additional high-technology methods appeared (Sprengler et al., 2014). For the purposes of paleobotany and archaeology, D. Fuller (2006) developed the key for identification of panicoid grasses based on caryopses, K. Fukunaga et al. (1997) studied differences in caryopses shapes in various *Setaria* species from different habitats. Presently, new methods of morphological diagnostics of both various kin species and genera, and specific features of caryopses within species at different ontogenetic stages are developed (Motuzaite-Matuzeviciute et al., 2012; Song et al., 2013). All these works are useful though fragmentary.

2. Artificial carbonization of modern material and following comparison with archaeological material (Liu, Kong, 2004; Yang et al., 2012). Having tried various methods, Liu and Kong (2004) have come to conclusion that most reliable way of identification is the comparison of diagnostic features of caryopses' shapes and sizes (i. e. standard carpological).

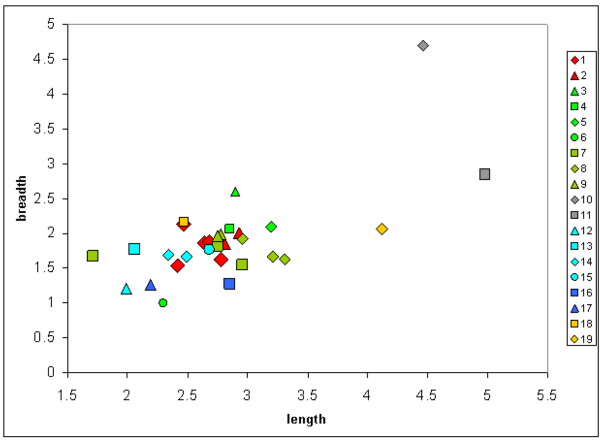

Fig. 10. Ratio of caryopses length/width in *Sorghum* species, *Andropogoneae* tribe, from burial mounds, and several panicoid species: red (1, 2) – archaeological material; green (3–9) – *Panicum miliaceum*; grey – Sorgum durra (10), S. saccaratum (11); light blue (12–15) – *Setaria italica*; blue – *Setaria palmifolia* (16), *S. glauca* (17); yellow – *Echinochloa crus-gali* (18), *E. frumentaceae* (19).

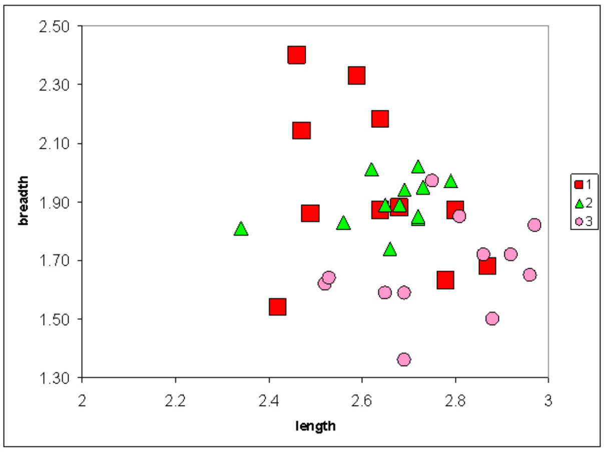

Fig. 11. Ratio of caryopses length/width from burial mounds and in *Panicum miliaceum*: red squares (1) – mound 22; green triangles (2) – *Panicum miliaceum* (sample 5); pink circles (3) – mound 31.

3. Starch grain structure is used as a diagnostic feature only in case caryopses remained whole (Yang et al., 2012; Yang, Perry, 2013). Based on the comparison of starch grains, all graminoids are divided into several types. This feature is reliable at tribe level (Tzvelev, 1976).

4. Caryopsis surface ultrastructure is used in case of preserved palea, lemmas and glumes (Nikolaevskaya, Petrova, 1989; Nasu et al., 2007).

5. In case only phytoliths are remained (Lu et al., 2009a, b; Weisskopf, Lee, 2014), examination and comparison of phytoliths for paleobotanic purposes are reasonable though not always reliable for distinguishing between species or genera.

6. Molecular methods (Fukunaga et al., 2006; Hunt et al., 2011; Li et al., 2016).

7. Ethnobotanical reconstructions of growing and usage together with the study of morphological variations of caryopses (Song et al., 2013; Moreno-Larrazabal et al., 2015).

Practically all specialists, who apply the above-mentioned methods of diagnostics and identification of graminoid remains, point to their utility, though recognize inaccuracy.

5. Lemmas and palea remains from burial mounds and analysis of their macrocharacters

Archaeological remains from the burial mounds were homogenous and numerous. The pressed layer contained remains of "grains" alternating with the layer of destroyed vegetative parts (leaves and stems). This was especially expressed in the mound 20, where even the only partly preserved inflorescence was found and washed (Fig. 8a, b). This brought us up to the conclusion that the burial chambers contained either roughly threshed grain, or the upper part of unripe panicles, but not cereal food (like groats or strained remains after brewing).

After washing, we had only numerous remains of "fruits" at our disposal represented by lemmas and palea in rather good state. Other vegetative and generative structures did not preserve (Fig. 9a-d).

To identify up to a taxonomical group (tribe, genus), a comparison of lemmas, palea or caryopses sizes of various "food" representatives of *Paniceae* and *Andropogoneae* tribes could be possible. Table 2 and the scatter plot in Figure 10 clearly show a distinct size of caryopses belonging to *Sorghum*

Table 2

Ratio of length/width mean values in caryopses from both archaeological material and studied modern taxa

Species	Sample	Length/width mean value
Archaeological material		
mound 22		2.62 × 2.06
mound 20		2.83 × 1.61
mound 31		2.87 × 1.93
Tribe *Paniceae*		
Panicum miliaceum ssp. *effusum*	1 Iran	2.9 × 2.6
P. miliaceum	2 Afghanistan	2.85 × 2.07
	3 Minor Asia	3.2 × 2.1
	4 Mongolia	2.3 × 1.0
	5 the Irkutsk Oblast	2.47 × 1.68
	6 the Chita Oblast	3.16 × 1.74
	7 Altai	2.77 × 1.98
	8 the Novosibirsk Oblast	2.5 × 1.8
Setaria italica	9 Ussuriland;	1.99 × 1.21
	10 the Samarkand Oblast;	2.06 × 1.78
	11 Aral region	2.45 × 1.68
	12 Pyandj	2.68 × 1.77
S. palmifolia	13 China	2.85 × 1.28
S. glauca	14 China	2 × 1.5
Echinochloa crus-galli	15 Japan	2.47 × 2.17
E. frumentacea	16 Russian Far east	4.12 × 2.07
Tribe *Andropogoneae*		
Sorghum durra	17 Turkmenistan	4.46 × 4.7
S. saccharatum	18 Japan	4.98 × 2.85

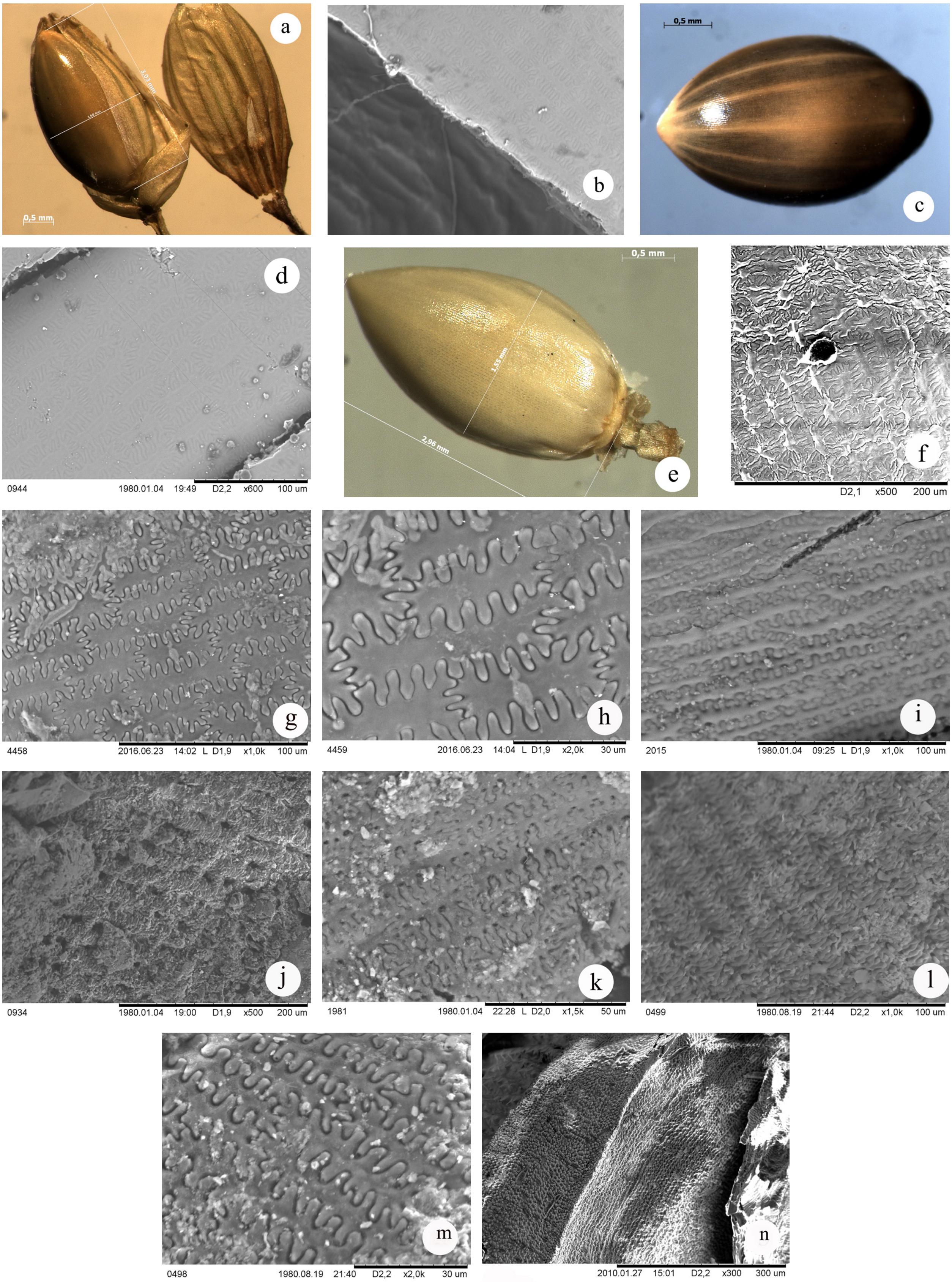

Fig. 12. Differences in upper lemma and palea surfaces in *Panicum miliaceum* (modern material) and archaeological material before and after processing. Non-treated: (a, b) 6* the Chita Oblast; (e, f) 5* the Irkutsk Oblast; (j) mound 22; (l, m) mound 31. Treated with chloroform and methanol mixture: (c, d) 6* the Chita Oblast; (i) Altai; (k) mound 22. Kept in water for six months: *(g, h) 5* the Irkutsk Oblast. (n) non-treated fruits of *Setaria italica* (12*, Pamir, Pyandj); caryopsis in the basic field of vision.

species (*Sorghum* Moench) (displayed in grey colour, Fig. 10). Thus, we assume that the archaeological material (displayed in red colour, Fig. 10) is to belong to *Paniceae* tribe, not to *Andropogoneae*. The caryopsis length/width ratio is not absolutely reliable for species identification due to deformation of archaeological material and the existence of a great amount of morphotypes of modern taxa which are impossible to cover in this study. The scatter plot in Figure 11 depicts the spread of mean values of the length/width ratio of different millet morphotypes as compared to the same variables from two burial mounds. We assume that Noin-Ula burial mounds contain plant remains of seeds most likely belonging to either *Panicum miliaceum* or to some species of kin genus *Setaria* (possibly *Setaria italica*).

6. Microcharacters of lemmas/palea in *Panicum, Setaria* and archaeological remains

Besides the comparison of the length/width ratio, the state of archaeological remains allowed us to study the peculiarities of upper lemma/palea microcharacters. We tried to figure out how reliable these features can be for identifying samples up to genus or even species level.

The upper lemma and palea differ by the presence/absence and number of nerves, keel development, and hair abundance. Upper lemma/palea structure is considered in close relation to pericarp structure (Nikolaevskaya, Petrova, 1989). Graminoid lemma/palea consists of epidermis (inner and outer), mesophyll, vascular bundles and mechanical tissues. Anatomical and morphological features of lemma/palea surfaces are determined basically by the shape and size of basic epidermal cells, thickness of their anticlinal and periclinal walls, as well as cuticle and wax layers forming together distinct surface ultrasculpture. The specialized cells of epidermis are silicified papules. These are isodiametric cells with strongly thickened outer walls. The thickening occupies nearly the whole cell cavity forming papula-like projections. Besides, some graminoid species possess specialized paired cells formed only in outer epidermis. One of these cells has a corked membrane and a large nucleus, while the other one features a silicified membrane with numerous penetrating pores. This differentiated silicified cell is dead.

We studied the peculiarities of lemmas/palea of two modern species, *Panicum miliaceum* (from several regions) and *Setaria italica*. The surface layer of lemma/palea epidermis in those species is covered with a thick layer of wax. Thus, to visualize the boundaries of anticlinal cells and, hence, the pattern they form, we had to remove that cuticular or wax layer. Several ways were used for wax removal both for modern and archaeological materials. The method offered by Vural et al. (2008) was used as a basis with our modifications. After additional treatment with the mixture of chloroform and methanol (1:1), and in some cases additionally with hydrochloric or sulphuric acid, the boundaries of anticlinal cells became more visible. Photos a–d in Figure 12 show the images of non-treated material with hardly seen boundaries of anticlinal walls. On photos e–k of Figure 12 the boundaries of treated cells are easily seen and suitable for analysis.

The photos of modern caryopses clearly show several layers of cells: the surfaces of the upper lemma and underlying epidermal layers (Fig. 7, 12n). The relief (or pattern) is determined by: cell arrangement and configuration, shape and relief of outer walls of cells, epicuticular layers, presence/absence of specialized cells. It is very important that the pattern may differ significantly at different developmental stages and on different parts of caryopses and lemmas/palea. Besides, the amount and distribution of epicuticular layer may also vary, etc. The surface patterns of caryopses and lemmas/palea proper have intergeneric and interspecific differences between *Panicum miliaceum* and *Setaria italica* (Fig. 12). According to our data and the data by Lu et al. (2009b), the presence of papillae over the whole surface of the upper lemma/palea (top, centre, and/or base) is the main characteristic feature distinguishing between *S. italica* and *P. miliaceum.* The pattern on the surface of caryopsis of *S. italica* is composed of large "comb-like" cell boundaries which do not affect the pattern of the upper lemma/palea surface. The upper lemma/palea has a thick cuticular layer impeding to visualize the boundaries of anticlinal cells.

Especially for archaeological purposes, Lu et al. (2009b) conducted the statistical analysis to estimate the criteria of ultrasculpture patterns in upper lemmas, palea and glumes of 6 species for 27 samples of modern wild and domesticated representatives of *Paniceae* grasses. For *P. miliaceum* and *S. italica,* the scale of comparison of the upper lemma and palea characters was offered with seven basic diagnostic features for both species. Lu et al. (2009b) believe that the following set of features is reliable to distinguish between fox millet and common millet: the presence of silica bodies of various shapes on glumes, the presence/absence of papillae on lemmas

Table 3

Comparison of the characteristics of glumes, lemmas and palea for *Setaria italica, Panicum miliaceum* and samples from Noin-Ula burial mounds

	Parts of spikelet	Criteria	*S. italica* (according to Lu et al., 2009b)	*P. miliaceum* (according to Lu et al., 2009b)	*P. miliaceum* (sample 5, 7)	Mound 22	Mound 31
1	Lower lemma and glumes	shape of silica bodies	cross-shaped type	bilobe-shaped type	bilobe-shaped type	–	–
2	Upper Lemma and palea	the presence or absence of papillae	regularly arranged papillae	smooth surface without any papillae	absence	absence	absence
3	–	the undulated patterns of epidermal long cells	Ω-undulated (V-I, II, III)	ŋ-undulated (g-I, II, III)	ŋ-undulated + Ω-undulated	Ω-undulated	Ω-undulated
4	–	the endings structures of epidermal long cells	cross wave type	cross finger type	both types	Ω-undulated	Ω-undulated
5	–	W	4.37 ± 0.89 µm	8.95 ± 2.02 µm	8.9 / 8.41 µm	12.29 µm	6.1 µm
6	–	R	0.33 ± 0.11 µm	0.79 ± 0.12 µm	0.74 / 0.84 µm	0.26 µm	0.24 µm

and palea, distinct types of patterns formed by the walls of anticlinal cells, different types of endings of dendriform epidermal cells and their width W (= width of endings interdigitation of dendriform epidermal long cells) and relative width R (= ratio of the width of endings interdigitation to the amplitude of undulations).

Table 3 shows the results of comparison of diagnostic features of *P. miliaceum* and *S. italica* according to Lu et al. (2009b) with our data. Unfortunately, too bad preservation state of the samples from mound 20 did not allow us to use them in our study. Besides, we were not able to use all the diagnostic features to analyze the archaeological material. Since glumes were absent, the most reliable feature to distinguish between these two species, the "presence/absence of four-lobed silica bodies", did not work in our case. The upper lemmas and palea of *S. italica* features rounded papillae on pedicles, but the archaeological material was so "dirty" and deformed that this character was not visible. We did not observe papillae on rather "clean" fragments as well, thus, this material could be attributed to *P. miliaceum.*

Comparison of modern material to the data published by Lu et al. (2009b) revealed that the "cell pattern" criteria for plants from Altai and Irkutsk populations match both species. Thus, *P. miliaceum* samples from Altai (7) featured Ω-undulated patterns of epidermal long cells similar to those of *S. italica* (Fig. 12j, 12n). We consider this criterion as an interspecific distinctive feature, however, it is subject to vary among populations or age groups. So, use of this criterion for comparative analysis of archaeological material is not reliable, though the patterns are possible to distinguish. If we still take into consideration "the undulated patterns of epidermal long cells" and "the endings structures of epidermal long cells", then the Noin-Ula samples are rather close to *S. italica*. The average W value of mound samples was intermediate between *P. miliaceum* and *S. italica,* while R values are close to those of *S. italica*. Thus, the identification key for archaeological purposes offered by Lu et al. (2009b) did not work in our study.

Discussion

Plant remains were found during archaeological excavations of several big mounds at the burial ground Noin-Ula, Mongolia (20, 22, 31) dated from the end of the 1st century BC to the beginning of the 1st century AD. Preservation state of plant remains allowed to identify them up to genus level, which helped to interpret their purpose in burial chambers. We consider the presence of several fragments of *Pinus sylvestris* and *Betula* sp. to be accidental. Most likely, they got into chambers during burial ceremony. These plants are among common species composing the vegetation of the studied region. The other part of plant remains was found in all three mounds and was used in a ritual ceremony. They are panicoid grasses.

We think that the key criteria for identification of ancient plant finds should be morphological and other characteristics of plant fragments and their comparison with modern material. Specification of standards of modern material requires thorough and accurate taxonomical identification.

Written sources of the time close to burial age should be used very carefully.

Data on ultrasculpture morphology of caryopses surfaces are too fragmentary and understudied even for modern material which could be a good standard for identification of archaeological material. This fact, as well as poor preservation state of plant remains, does not allow us to attribute the caryopses found in the mounds to one of these two species with 100 % of certainty based on the surface ultrasculpture of lemma and palea.

In our study, the complex of macrocharacters appeared to be more reliable way to identify plant remains. To analyze panicoid grasses from burial mounds, we used the macrocharacteristics of grains including the size of lemmas and palea. Plant remains from Noin-Ula burial mounds 20, 22 and 31 were attributed to *Panicum miliaceum* with great probability. However, we also assume that during Han times they cultivated species and morphoforms that are missing in our collections or already extinct.

The context of the millet grain finds in the elite Xiongnu burials is also interesting: they were found scattered over the felt carpet covering the floor of the inner burial chamber (in mounds 20 and 22) and on the poorly preserved cloth inside the coffin in mound 31. The Xiongnu, like the Han, used poorly threshed grain in burial rituals: they scattered it on the floor of the burial chamber directly under the coffin or on the bottom of the coffin. Millet played a special role because it was one of the earliest domesticated crops in China. The early domestication of millet in this region is due to millet being the most drought-resistant culture among the grains. It yields a harvest during a short growing season and can be cultivated on poor soils. Grain was placed in burials to revive the deceased. The special attitude to millet in the Chinese culture was adopted by the Xiongnu, like many other traditions of the Han civilization, which are reflected in the burial rituals of the Xiongnu elite.

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