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The Ratio of Indigenous to Immigrant Populations in the Western Steppe During the Bronze Age (Based on Cranial Data)

Measurements of ~730 male crania from cemeteries associated with Bronze Age cultures of the steppe and forest-steppe zone of Eastern Europe (Yamnaya, Catacomb, Poltavka, Babino, Lola, and Timber-Grave) were subjected to multivariate analyses. D^2 distances between sample centroids were calculated, and non-metric multidimensional scaling was carried out. The results are used to evaluate the proportion of indigenous and immigrant groups during four successive periods—Early Bronze Age, Middle Bronze Age, Middle to Late Bronze Age transition, and Late Bronze Age. The differences between Yamnaya populations are comparable to those between recent groups inhabiting vast territories of Eastern Europe, from Karelia to the Northern Caucasus. The role of the substrate component in the origin of Early and Middle Bronze Age groups was considerable. However, virtually no continuity was observed at the Middle to Late Bronze Age transition, when post-Catacomb cultures originated. Continuity with Middle Bronze Age groups is observed in Late Bronze Age samples representing the Timber-Grave people, who combined features of the Catacomb and post-Catacomb people. Factors accounting for such a process may include "pendulum migrations" and temporary reversal of funerary tradition from kurgans to "invisible" flat burials.

Keywords: *Physical anthropology, craniology, craniometry, Bronze Age, Eastern Europe, human populations.*

Introduction

Ascertainment of the complexity of the composition of populations of all historical periods is one of the most frequent conclusions found in Russian craniometric studies (Shirobokov, 2019: 144). The multicomponent nature of the population is often suggested even when studying cranial samples from a single archaeological culture (Shevchenko, 1986, 1993; Batieva, 2010; Balabanova, 2016; Khokhlov, 2017; Khokhlov, Kitov, 2019; and others). Such conclusions, though not always convincingly confirmed, are probably not completely unreasonable, as the admixed composition of most ancient and modern populations has also been confirmed by the paleogenetic studies of the last two decades (Reich, 2020).

The aim of the present study is to detect only the substrate components of the Bronze Age steppe populations of Eastern Europe. Thus, primary attention is paid, not to the influence of new migrant populations and their origin, but to the role of the local inhabitants in the formation of new archaeological cultures and cultural-historical communities.

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The area of research includes the steppe and, partially, forest-steppe zones of Eastern Europe, from the lower Dnieper River in the west to the middle Ural River in the east.

Material and methods

Individual measurements and sample means of ~730 male Bronze Age skulls were employed, including the following craniometric variables: cranial length, maximum cranial breadth, cranial height (basion-bregma), bizygomatic breadth, minimal frontal breadth, upper facial height, nasal height and breadth, orbital height and breadth, nasomalar and zygomaxillary angles, simotic index, and nasal protrusion angle (Martin, Saller, 1957; Alekseev, Debets, 1964). The measurements of more than 1300 male skulls representing modern populations were employed as well. As female cranial samples are not available for many periods of the Bronze Age, and, if present, are substantially smaller, these were not analyzed in the study. Most data were taken from previous publications, while the unpublished data from several skulls were obtained from the archive of the Department of Anthropology of the Peter the Great Museum of Anthropology and Ethnography RAS (hereinafter, DA MAE RAS).

Intergroup comparisons of the cranial samples were carried out using squared Mahalanobis distances (D^2), with an adjustment for the sample size in CANON (Kozintsev, 2007). The distances were further visualized in two-dimensional plots by multidimensional scaling (Guttman's algorithm). The statistical significance of the pair-wise interpopulation differences in single variables was assessed using Student's t-test. This test was also employed for comparing D^2 means, whereas normality of the distributions was tested via the Shapiro-Wilk test. Those three statistical procedures were carried out in Statistica 12.0.

Results and discussion

At the first stage of the study, the influence of the Chalcolithic groups (represented by cranial samples, not single skulls) on the formation of the Early Bronze Age population was assessed. This question is of interest in the context of the relevant archaeological debates (Telegin, 1973; Merpert, 1974; Vasiliev, 1981, 2003; Ivanova, 2006; Ivanova, Nikitin, Kiosak, 2018). An aggregate sample was employed, including skulls from the following sites from the middle Dnieper and Seversky Donets rivers: Igren, Kamennye Potoki, and Alexandriya (Gerasimov, 1955; Surnina, 1963; Zinevich, 1967; Potekhina, 1983). In craniological publications, these sites are typically assumed to represent the Sredni Stog culture. Two samples from the Khvalynsk I and Khvalynsk II sites were used as well. The sites are located in the north of the Saratov Region and belong to the homonymous archaeological culture (Mkrtchyan, 1988; Vasiliev, 2003; Khokhlov, 2010, 2017). The population of the Early Bronze Age is represented by more abundant cranial collections, which were grouped

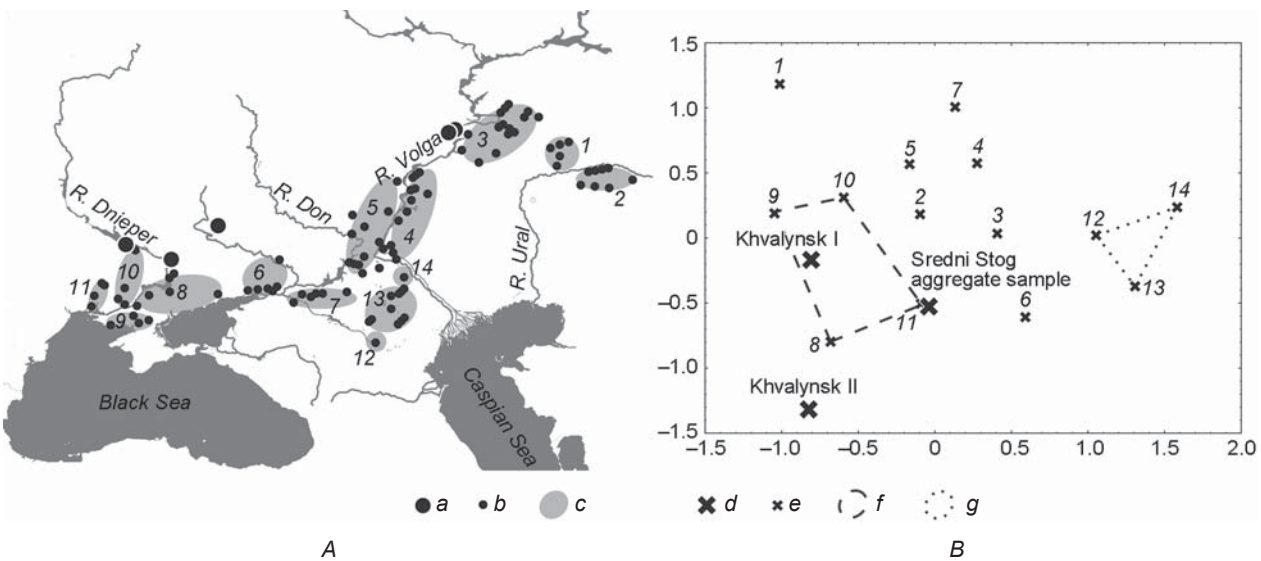

Fig. 1. Chalcolithic and Early Bronze Age sites (*A*), and the distribution of respective cranial samples in the morphospace of two axes of a non-metric multidimensional scaling of D^2 between them (*B*).

a – Chalcolithic sites; *b* – Yamnaya culture sites; *c* – local groups of the Yamnaya culture; *d* – Chalcolithic cranial samples; *e* – Yamnaya cranial samples; *f* – western (Lower Dnieper) Yamnaya samples; *g* – southeastern (Caspian) Yamnaya samples. See the main text for the names of the numbered samples.

into 14 samples according to their geographic location (Fig. 1, *A*): *1* – Ural (Tamar-Utkul), right bank of the Ural River (Khokhlov, 2017); *2* – Ural (Tamar-Utkul), left bank of the Ural River (Ibid.); *3* – Samara, left bank of the Volga River, around and to the south from the Samara Bend (Debets, 1936; Fierstein, 1967; Khokhlov, 2017); *4* – Lower Volga, left bank of the Volga River (Debets, 1936; Ginzburg, 1959; Glazkova, Chtetsov, 1960; Fierstein, 1967; Balabanova, 2016; Khokhlov, 2017); *5* – Volga-Don, interfluve of the Volga and Don rivers (Balabanova, 2016; Khokhlov, 2017) (Archive of the DA MAE RAS); *6* – Lower Don, right bank of the Don River (Batieva, 2010); *7* – Lower Don, left bank of the Don River (Ibid.); *8* – Lower Dnieper, eastern (Zinevich, 1967; Kruts, 1984); *9* – Lower Dnieper, southern (Kruts, 1984); *10* – Lower Dnieper, western (Ibid.); *11* – Ingul (Ibid.); *12* – cemeteries of the East Manych River (Shevchenko, 1986; Kazarnitsky, 2012); *13* – Kalmykia (cemeteries of northern and central Kalmykia) (Shevchenko, 1986; Kazarnitsky, 2012); *14* – Astrakhan (Shevchenko, 1986; Kazarnitsky, 2012).

The cranial type of the Khvalynsk and Sredni Stog samples finds direct analogs only among the westernmost Yamnaya culture groups from the lower Dnieper and Ingulets rivers (Fig. 1, *B*, *8–11*). The common cranial features are dolichocrany, and a relatively narrow nose and face. The range of variation of other Early Bronze Age populations is substantially wider. The Yamnaya culture sample from the right bank of the Ural (Fig. 1, *B*, *1*) exhibits the strongest dolichocrany, the most clinognathic face, and the widest and tallest piriform aperture. Notably, the sample from the opposite bank of the Ural (Fig. 1, *B*, *2*) displays morphology more typical of the Yamnaya groups from the Don and Volga, located in the central part of the plot (Fig. 1, *B*, *3–7*). The southeastern groups from the Northwestern Caspian region (East Manych, Kalmykia, and Astrakhan samples (Fig. 1, *B*, *12–14*)) are separated along the y-axis owing to the large transverse dimensions of their face and cranial vault.

Thus, the widely accepted conclusion regarding the population diversity of Yamnaya culture groups is confirmed (Shevchenko, 1986; Kruts, 1997; Ivanova, 2015; Khokhlov, 2017). How wide this diversity actually is can be assessed against a background of the craniometric variation of modern populations of various origins (Fig. 2). Two comparative analyses were carried out. The first included samples from a very vast area from the Baltic region to Transbaikalia (Alekseev, 1969, 1974; Ismagulov, 1970; Shirobokov et al., 2017), while the second only employed Eastern European data (Fig. 3). The mean and median sizes of the modern and Yamnaya samples were 30 and 15 individuals, respectively.

The mean D^2 among modern Eurasian groups is 8.115, among European 3.556. The same value inside the regional groups of closely related populations ranges from 1.5 to 2.3. The mean D^2 among the samples

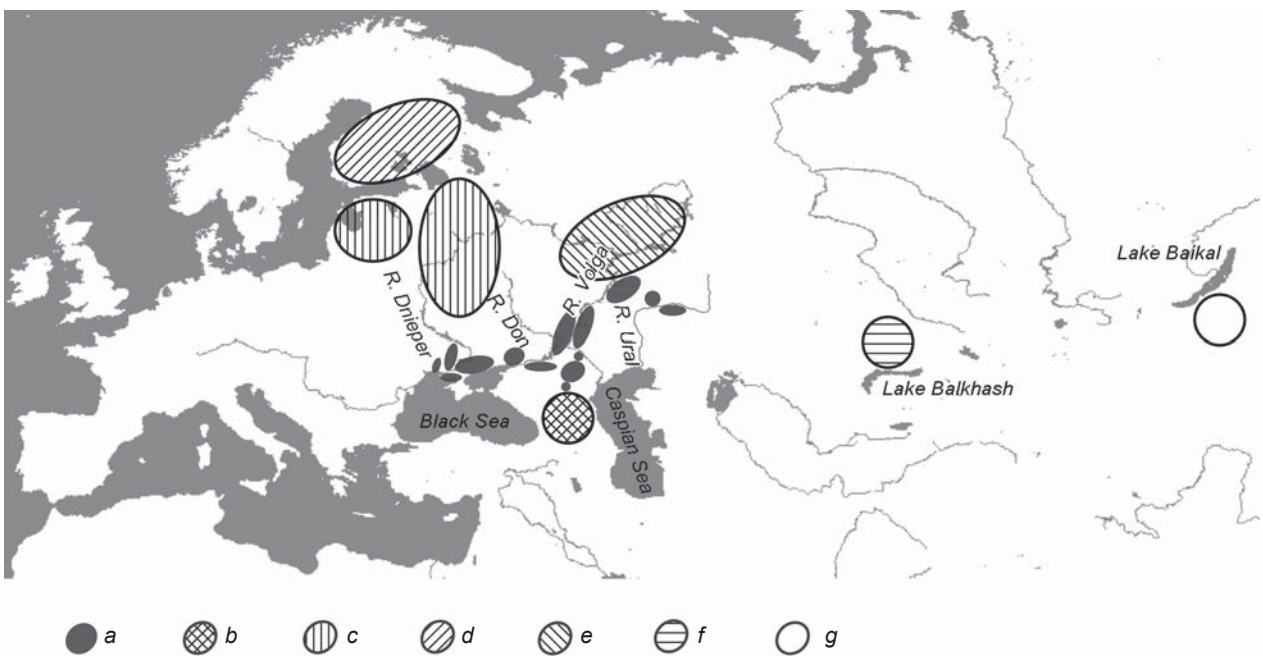

Fig. 2. Locations of the cranial samples of the Yamnaya culture and recent populations.
a – Yamnaya culture people; *b* – Ossetians and Ingush; *c* – Russians and Latvians; *d* – Karelians and Finns; *e* – Chuvash, Mari, Mordva, Udmurt; *f* – Kazakh; *g* – Buryat.

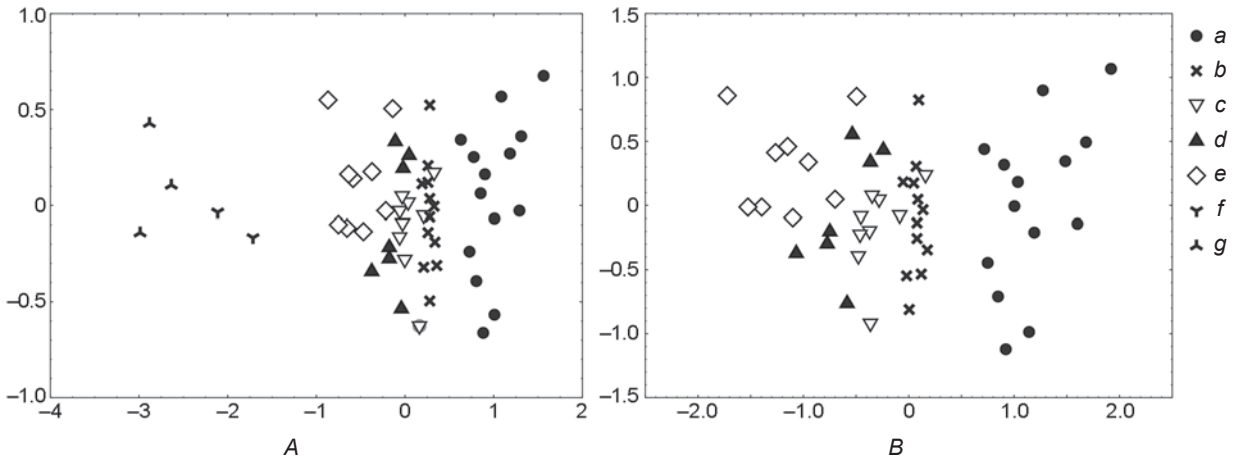

Fig. 3. Multidimensional scaling of D^2 among the Yamnaya samples as compared to the recent Eurasian (*A*) and European (*B*) samples.

a – Yamnaya culture people; *b* – Ossetians and Ingush; *c* – Russians and Latvians; *d* – Karelians and Finns; *e* – Chuvash, Mari, Mordva, Udmurt; *f* – Kazakh; *g* – Buryat.

of the Yamnaya culture is 4.059. Therefore, the plots of the scaled Mahalanobis distances show that the range of the coordinates of the Yamnaya samples is less than the differences between the Asian and European samples (Fig. 3, *A*). But it is about the scale of variation of the modern European groups, which speak languages of several families and populate a huge area from Karelia to the Caucasus and from the Baltic Sea to the Middle Volga and Urals. Clearly, cranial morphology varies widely among these modern European populations (Fig. 3, *B*).

Thus, the relatively higher morphological diversity of the Yamnaya groups than that of the Chalcolithic populations precludes ascertaining the people of the Khvalynsk-Sredni Stog burial traditions as a substrate for the whole Early Bronze Age steppe population (Vasiliev, 1981; Khokhlov, 2017). A substantial influence of the Khvalynsk-Sredni Stog groups is traceable mainly in the western part of the Yamanaya culture area. In the other Yamnaya populations, individuals of a different origin prevail. Among these, there are at least three regional clusters: Don-Volga (including the left bank of the Ural), Caspian, and Ural (right bank). Did all of them take part in the formation of the population of the next historical period?

In order to answer this question, the following analysis was carried out, excluding the Chalcolithic samples, but including those from the Middle Bronze Age*. These are samples from the Poltavka culture (Khokhlov, 2017) (Fig. 4, *A*, *1*), and from several territorial groups belonging to the Catacomb cultural circle (Fig. 4, *A*): *2* – Volga-Don; *3* – Lower Don, right bank; *4* – Lower Don, left bank (Kazarnitsky, 2012); *5* – Zaporozhye; *6* – Kherson; *7* – Ingul (Kruts, 1984); *8* – Samara-Orel (Melnik, 1982; Kruts, 2017); *9* – Crimea (Dyachenko, Pokas, 1986; Kruts, 2017); *10* – East Manych, southern; *11* – East Manych, central, and *12* – East Manych, northern (Kazarnitsky, 2012). The mean and median sample size was 18 individuals.

This analysis has shown the population continuity between the Poltavka and Catacomb cultures and between the Don-Volga (Fig. 4, *B*, *3–6*) and Lower Dnieper (*8–11*) groups of the Yamnaya culture. The scales of their variation are similar in general, but often differ at the local level. For instance, the Poltavka and Lower Don Catacomb groups (*1–4*) display a clear similarity with the geographically proximate Don-Volga samples of the Yamnaya culture, but the Yamnaya (*8–11*) and Catacomb (*5–9*) groups from the Lower Dnieper are much less similar. This observation suggests the appearance of large new groups of migrants of different origins in the Northern Black Sea region during the Middle Bronze Age.

The Caspian groups of the Catacomb culture (Fig. 4, *B*, *10–12*), though inhabiting a relatively small area, exhibit a high level of morphological variation displaying features similar to both the Don-Volga and Lower Dnieper, but not Caspian, Yamnaya samples (Fig. 4, *B*, *12–14*). Thus, the Northwestern Caspian region (vicinity of the Ergeni Upland) experienced the most intense population turnover during the Middle Bronze Age. The Caspian and Ural (right bank) Yamnaya groups likely did not leave a noticeable trace in the composition

*Such a grouping of the skulls from Middle and Late Bronze Age burials was employed earlier; for more details on the sample composition, names of the cemeteries, and field abbreviations, see (Kazarnitsky, 2020)).

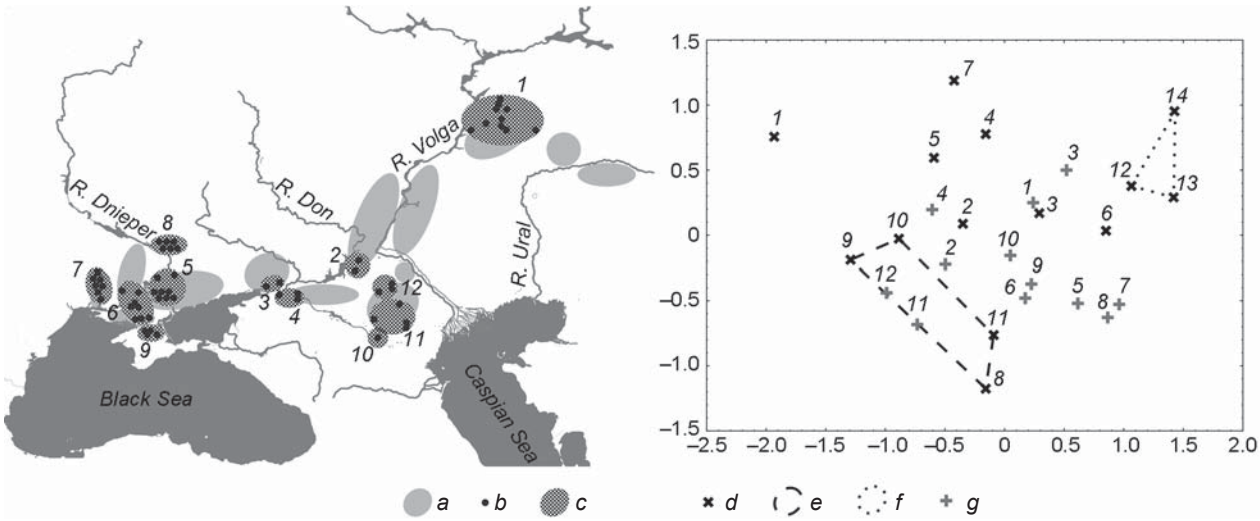

Fig. 4. Early and Middle Bronze Age sites (*A*), and the distribution of respective cranial samples in the morphospace of two axes of non-metric multidimensional scaling of D^2 between them (*B*).
a – local groups of sites of the Yamnaya culture; *b* – Middle Bronze Age sites; *c* – local groups of sites of the Middle Bronze Age; *d* – Yamnaya samples; *e* – western (Lower Dnieper) Yamnaya samples; *f* – southeastern (Caspian) Yamnaya samples; *g* – Catacomb and Poltavka samples. See the main text for the names of the numbered samples.

of the later population of the respective regions. This also probably led to the lower level of craniometric variation among the Catacomb and Poltavka samples: the mean D^2 between them is only 1.964, which is comparable to the degree of similarity of modern closely related populations.

The post-Catacomb (Babino and Lola) archaeological cultures, which emerged in the area of the Catacomb cultural-historical community later, belong to the next chronological period. Though this period is described as a junction between the two historical eras, it was only slightly shorter than each of those eras (Litvinenko, 2011; Mimokhod, 2013, 2018). The post-Catacomb population is represented by relatively small cranial samples (mean and median size is 9 individuals), which were combined into seven groups (Fig. 5): *1* – Babino Dnieper-Prut and/or Dnieper-Don (local groups disregarded), *2* – Babino Dnieper-Prut, *3* – Babino Dnieper-Don, *4* – Babino Dnestr-Prut, *5* – Babino Volga-Don, *6* – Lola, eastern (Kalmykia), *7* – Lola, western (Stavropol-Rostov) (Kruts, 1984; Batieva, 2011; Velikanova, 1975; Gerasimova, Kalmykov, 2007; Khokhlov, Mimokhod, 2008; Kazarnitsky, 2010, 2020).

The post-Catacomb samples display a high level of diversity, which can be related not only to their true population differences but to the low sample size as well. All these samples differ from the steppe population of the preceding periods by longer and narrower skull vaults, a narrower and more clinognathic face, and taller nose and orbits (Fig. 5, *B*). The differences in the variables listed above between aggregate samples of the Catacomb and post-Catacomb cultures reach a high level of statistical significance ($p < 0.01$). Apparently, in this period, the role of substrate groups in the formation of the population of the new historical era was minimal for the entire Bronze Age (Kazarnitsky, 2020). However, the cranial features of the steppe populations of the Middle Bronze Age did not disappear without a trace in Eastern Europe.

The skulls from the burials belonging the Timber-Grave culture, the final stage of the Bronze Age, were combined into 13 local samples (including two special chronological samples from Early Timber-Grave sites) (Fig. 6, *A*): *1* – Bashkiria, *2* – Samara, northern and central, *3* – Samara, northwestern and southwestern, *4* – Samara, early, *5* – Ulyanovsk and Tatarstan, *6* – Saratov, *7* – Volgograd, northern, *8* – Volgograd, western and southern, *9* – Rostov, *10* – Rostov, early, *11* – Astrakhan, *12* – Kalmykia, *13* – Lower Dnieper (Batieva, 2011; Debets, 1954; Gerasimova, 1958; Zinevich, Kruts, 1968; Kazarnitsky, 2012; Kruts, 1984; Shevchenko, Yusupov, 1991; Fierstein, 1967; Khokhlov, 1998, 2017; Khokhlov, Mimokhod, 2008) (Archive of the DA MAE RAS). The mean and median sample size is 16/17 individuals.

All the Late Bronze Age samples, excluding the two Early Timber-Grave groups, differ from the populations of the Catacomb culture in the same variables as are typical of the post-Catacomb groups but to a lesser degree (Fig. 6, *B*). Paradoxically, the differences from the preceding populations of the Middle Bronze Age have decreased over time rather than increased. The

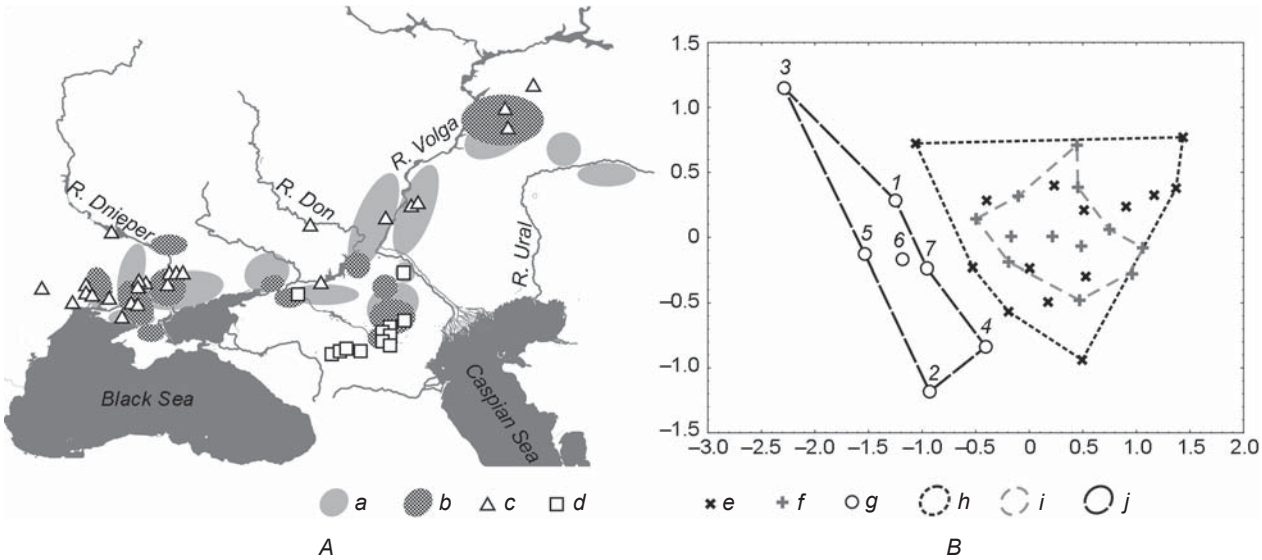

Fig. 5. Sites of the Early and Middle Bronze Ages and of the Middle to Late Bronze Age transition (*A*), and the distribution of respective cranial samples in the morphospace of two axes of a non-metric multidimensional scaling of D^2 between them (*B*). *a* – local groups of sites of the Yamnaya culture; *b* – local groups of sites of the Catacomb and Poltavka cultures; *c* – sites of the Babino culture; *d* – sites of the Lola culture; *e* – Yamnaya samples; *f* – Catacomb and Poltavka samples; *g* – post-Catacomb samples; *h* – range of variation of the Yamnaya samples; *i* – range of variation of the Catacomb and Poltavka samples; *j* – range of variation of the post-Catacomb samples. See the main text for the names of the numbered samples.

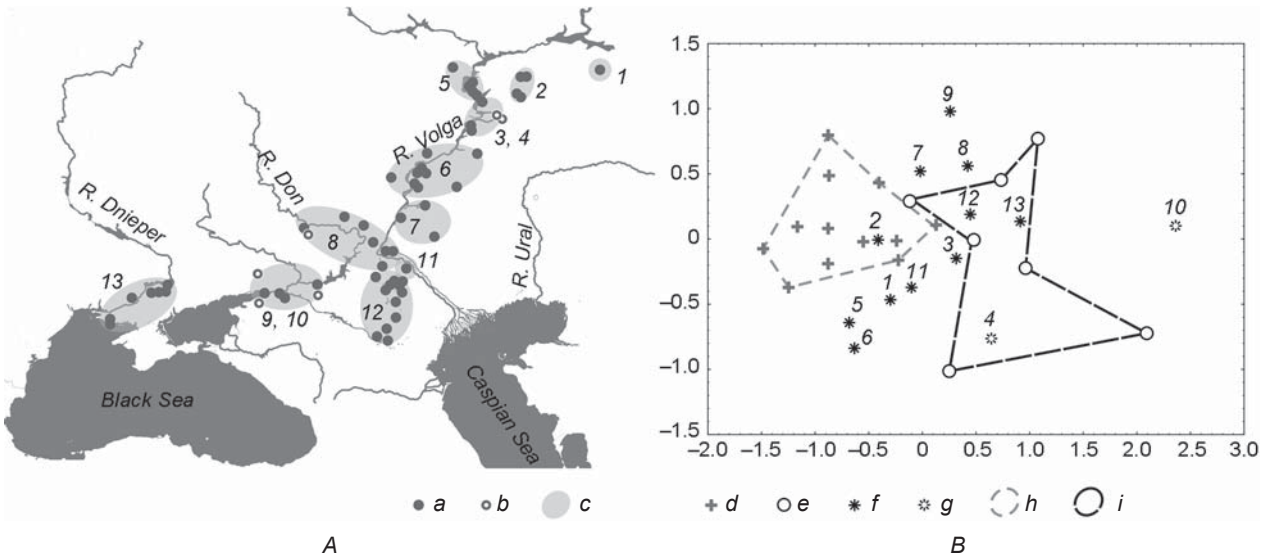

Fig. 6. Late Bronze Age sites (*A*), and the distribution of respective cranial samples in the morphospace of two axes of a non-metric multidimensional scaling of D^2 between them against a background of the Catacomb and post-Catacomb samples (*B*). *a* – sites of the Timber-Grave culture; *b* – early sites of the Timber-Grave culture; *c* – local groups of the sites of the Timber-Grave culture; *d* – Catacomb and Poltavka samples; *e* – post-Catacomb samples; *f* – Timber-Grave samples; *g* – Early Timber-Grave samples; *h* – range of variation of the Catacomb and Poltavka samples; *i* – range of variation of the post-Catacomb samples. See the main text for the names of the numbered samples.

morphological diversity of the Timber-Grave samples, according to the mean D^2, is significantly higher ($p = 0.03$) than that of the Catacomb and Poltavka populations. Notably, the number and size of the samples are similar between the two periods.

The hypothesis of "pendulum migrations", according to which the vectors of population movements change systematically down to the opposite (Ivanova, Nikitin, Kiosak, 2018), can potentially explain this apparent paradox. As an alternative, it may be hypothesized that

the substrate populations abandoned the tradition of kurgan burials not only in Timber-Grave times (Kolev, 2003; Lunkova, Lunkov, 2014) but also during the post-Catacomb period, which could make them "invisible" among the representatives of the kurgan cultures.

The era of the Scytho-Sarmatian cultures of the Early Iron Age became the beginning of an entirely new stage of the population history of the region, when the representatives of the steppe cultures of the Bronze Age finally dissolved among migrants of Western and Southern Siberian origin (Kazarnitsky, 2017).

Conclusion

The influence of the populations of the Sredni Stog and Khvalynsk Chalcolithic cultures (at least those represented by cranial samples) is traceable mostly in the western part of the area of the Yamnaya cultural-historical community. The groups practicing the Yamnaya burial tradition are very diverse morphologically. The range of their variation is about the scale of that among the cranial samples of modern peoples of various origins populating the vast area from Karelia to the Caucasus and from the Baltic Sea to the Urals. Only some of the Yamnaya groups—mainly Don-Volga and Lower Dnieper—became part of the population of the subsequent Middle Bronze Age. Some of the Uralian and all of the Caspian Yamnaya groups were almost not involved in the formation of the Catacomb and Poltavka cultures, which led to a decrease in the mean interpopulation distances. But the most radical change in the population of post-Catacomb cultures occurred at the turn of the Middle and Late Bronze Age, when the influence of substrate population on the groups of the later period is barely traceable. But during the Late Bronze Age, the cranial features typical of the Catacomb population appeared again in the groups of the Timber-Grave cultural-historical community.

A similar model of the formation of ancient populations we suggested previously for an earlier historical period (Kazarnitsky, 2014): in Eastern Europe, the cranial morphology typical of the Mesolithic population is not found during the Neolithic, but the features of both periods are observed in various local groups of the Early Bronze Age. This observation can explain the high level of craniometric variation among Yamnaya cultures populations.

Acknowledgements

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