Toksovo site dating by comparison frequencies of ornamental imprints on potsherds

Alexander Akulov
independent scholar; Saint Petersburg, Russia; e-mail: aynuinbox.ru

Abstract

The Neolithic site of Toksovo was discovered in 1926, but has never been properly dated, however, a collection of potsherds was picked on it (the site is located in the southern part of the Karelian Isthmus, on the southern bank of Kavgolovo lake). Not far from the site of Toksovo there is another Neolithic site (Hepojarvi) that was properly dated (5314 – 2342 cal BCE). The Comb-Pit Ware of Hepojarvi site is subdivided into three subtypes: the Comb-Pit Ware of the early stage, of the developed stage, and of the late stage. The collection of potsherds of Toksovo site is very close to the developed Comb-Pit Ware of Hepojarvi, and so Toksovo site existed in the 4th millennium – in the very beginning of the 3rd millennium BCE. Both sites belonged to the same group of people; initially people dwelled on the site of Hepojarvi and later appeared the site of Toksovo.

Keywords: Comb-Pit Ware; Neolithic pottery; ornaments of pottery; mathematical semiotics

1. Introduction

The site of Toksovo was discovered by L. A. Dintses and S. N. Zamyatnin in 1926 when they performed an archaeological survey of the vicinities of Saint Petersburg (then Leningrad); the site is located upon the southern bank of the Kavgolovo lake (fig. 1) (Lapshin 1995: 174 – 175). A proper excavation has never been performed on the site, but a relatively representative collection of potsherds of Comb-Pit Ware1 (fig. 3) and a collection of chert and granite flakes were picked (Gurina 1961: 438).

The site of Toksovo has never been properly dated. Radiocarbon dating didn’t exist yet when the site was explored and no appropriate organic materials were picked on the site.

And thus, if we are going to date the site, we have to use indirect methods of dating. It is possible to date the site by comparing its collection of potsherds with the collection of potsherds from the site of Hepojarvi.

The site of Hepojarvi is located not far from the site of Toksovo (fig. 1), and it’s logical to suppose that they could belong to closely related groups.

The site of Hepojarvi was excavated by I. V. Vereschagina in 1978 (Vereschagina 2003). The site of Hepojarvi is the first excavated Neolithic settlement in the south of the Karelian Isthmus in the immediate vicinity of Saint Petersburg. The site was properly dated: it existed in 5314 cal BCE – 2342 cal BCE (Vereschagina 2003: 149, Akulov 2019).

The collection of potsherds from the site of Hepojarvi can be subdivided into three types: the Comb-Pit Ware of the early stage2 (6th – 5th millennia BCE), the Comb-Pit Ware of the

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1 The Comb-Pit Ware is a local type of the Pit-Comb Ware, the term Comb-Pit means that in this ornamental tradition there are more imprints of combs than pits.
developed stage (4th millennium – in the very beginning of the 3rd millennium BCE), and the Comb-Pit Ware of the late stage (3rd millennium BCE).

Vereschagina suggested that each of these three types of pottery correlated with a certain new ethnic group and that the site of Hepojarvi was a settlement of repeated settling, and took place population shifts (Vereschagina 2003: 149). However, my analysis of potsherds from the site of Hepojarvi gives another result: despite it is possible to single out three types/subgroups, but there were no serious population shifts, and all three types/subgroups belong to the same group of people and changes in pottery reflect changes that happened to this group of people under the influence of different outer factors (Akulov 2020b).

Fig. 1. Map showing locations of Hepojarvi and Toksovo sites, and Sestroretskii Razliv lake (drawn by the author)

The Pit-Comb Ware of early stage is often named Sperrings pottery in Russian archaeology while in Western archaeology Sperrings pottery is considered as an early stage of the Pit-Comb Ware, and the term Sperrings itself is often considered as outdated; in Russian archaeology Sperrings is still traditionally considered as a separated type of pottery preceding the Pit-Comb Ware.
Anyway, it is possible to single out three types/subgroups within the collection of potsherds from the site of Hepojarvi. And it is possible to date the site of Toksovo by estimating the degree of resemblance of its collection of potsherds with each of the three types/subgroups of potsherds from the site of Hepojarvi: the time of existence of the site of Toksovo is the same as the time of existence of the most similar subgroup of potsherds of Hepojarvi. The method of comparison of collections/assemblages of potsherds is described in a detailed way is described in part 2.

2. The method of dating

2.1. General idea of the method

If there are two randomly selected collections of randomly broken potsherds with fragments of a certain ornament it is possible to conclude about the most frequent imprints. The most frequent imprints are supposed to be the most characteristic imprints of a certain local ceramic tradition. And thus, comparing the frequency of different imprints it is possible to conclude about the degree of resemblance of collections of potsherds and about the degree of relatedness of corresponding groups of people. To estimate the degree of resemblance of two collections of potsherds should be done the following procedures: 1) to estimate the degree of correlation of sets of represented imprints, 2) to estimate the degree of correlation of percentages of common imprints (imprints represented upon potsherds belonging to each of compared collections), 3) to take a superposition of two degrees of correlation. The closer are certain ornamental traditions the higher is the corresponding degree of proximity.

For the sake of shortness and convenience the method is named the Monte Carlo method since it is about comparing randomly selected collections of potsherds which in their turn were randomly broken. Actually there are three moments of random over here: pots herds were randomly broken, a random amount of potsherds was picked and a random amount of the picked was published.

The formula for the degree of correlation of two sets is the following:

\[
\frac{1}{2}\left(\frac{m}{N_{imp(A)}} + \frac{m}{N_{imp(B)}}\right) \times \frac{1}{m} \left(\sum_{i=1}^{m} \frac{\text{smaller percentage}_i}{\text{larger percentage}_i} + \ldots + \frac{\text{smaller percentage}_m}{\text{larger percentage}_m}\right)
\]

where:

- \(N_{imp(A)}\) – the number of imprints represented in A (first set),
- \(N_{imp(B)}\) – the number of imprints represented in B (second set),
- \(m\) – the number of common imprints.

For more details about the method see: Akulov, Nonno 2019.
2.2. An illustration of the method

Let’s imagine that we have three collections of potsherds: A, B, and C.

Collection A:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
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| /// | /// | /// | /// | /// | ///

Collection B:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>
| /// | /// | /// | /// | ///

Collection C:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
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It is important to note that one potsherd can bear more than one imprint.

In order to single out basic elements of a certain ornament the following recommendations can be offered: each potsherd has a certain set of imprints; if this set consists of homogenous/similar elements only then the whole set is a basic element of ornamentation. If this set consists of several groups of heterogeneous elements that have no intersections then each of these groups is a basic element (for more details see: Nonno 2020)

In collection A there are two imprints: /// and ♂
/// is represented on 6 potsherds of 6 and so its frequency/percentage is 1; and ♂ is represented on 3 potsherds of 6, so its percentage is 3/6 = 0.5

In collection B there are the same imprints: /// and ♂
/// is represented on 5 potsherds of 5, so its percentage is 1; and ♂ is represented on 2 potsherds of 5 so its percentage is 2/5 = 0.4.

In collection C there is only one imprint ///, its percentage is 1.

And thus, according to the formula shown in 2.1 the degree of resemblance of A and B is the following: \((2/2 + 2/2)/2 \times (1/1 + 0.4/0.5)/2 = 0.9\)

The degree of resemblance of A and C is the following: \((1/2 + 1)/2 \times 1/1 = 0.75\)

The degree of resemblance of B and C is the following: \((1/2 + 1)/2 \times 1/1 = 0.75\)
2.3. Potential error

The potential error that can occur depends on the ratio of numbers of potsherds in the compared collections: if the ratio is $1 - 0.7$ then the potential error is $1\%$ or even less; if the ratio is $0.65 - 0.6$ then the potential error is $4 - 5\%$; if the is $0.55 - 0.5$ then the potential error is $7 - 8\%$; if the ratio is $0.45$ then the potential error is $14\%$; if the ratio is $0.4$ and less then the potential error is about $19\%$ (for more details see: Nonno 2019).

In the case of the above considered A, B, and C the potential error is about $1\%$.

2.4. Threshold values

When two collections of potsherds are compared then appears the question of interpretation of the received values of degrees of resemblance and also the question of threshold values.

If the question is about thresholds then there can be the following two scenarios.

If there are collections X and Y which belong to undoubtedly related groups and a collection C the degree of resemblance of which with X and Y is unknown, then if the degree of resemblance of X and Z or Y and Z is close to that of X and Y or higher than that of X and Z then it means that collections X, Y, and Z belong to closely related groups. This is the case of a local threshold value.

If there are two collections X and Y that belong to the same tradition but are rather isolated and it is unclear whether they belong to related groups then a standard set of related collections can be used as a source of threshold values.

Also a standard set of related collections can be used when the aim is to compare different subgroups singled out within a certain collection of potsherds.

A standard set of related collections should contain several collections in order to be representative, and collections of the set should have originated from sites that have been proved to be related.

Let there is a collection of potsherds X from a certain site, and let’s suppose that within X can be singled out three subgroups: $X_1$, $X_2$, $X_3$. Also let there is a standard set of collections that contains the following collections: $S_1$, $S_2$, $S_3$ ... $S_n$. $V_S$ is the set of values of degree of resemblance of collections of $S$, its elements are: $v_{S1}$, $v_{S2}$, $v_{S3}$ ... $v_{Sk}$, and $v_{Sa}$ is the average value. $V_X$ is the set of values of degree of proximity for subgroups of X, elements of $V_X$ are: $v_{X1}$ – the degree of proximity of $X_1$ and $X_2$, $v_{X2}$ – the degree of proximity of $X_1$ and $X_3$, and $v_{X3}$ – the degree of proximity of $X_2$ and $X_3$. Let suppose that: $v_{X1} \leq v_{Sa}$, $v_{X2} \approx v_{Sa}$, and $v_{X3} \geq v_{Sa}$, it means that $X_2$ and $X_3$ undoubtedly belong to the same group, while $X_1$ and $X_2$ are more distantly related. If a certain value $v_{Xn}$ is lower than $v_{Sa}$ then also should be paid special attention to the frequency of same or close values in $V_S$.

In the case of collections which are considered in the current paper a standard set of collections can be collections of potsherds from Neolithic sites located on the lake Sestroretsii Razliv (or simply Razliv) (see fig.: 1, 2). Neolithic sites located upon the lake Razliv belong to the same stage (late Neolithic period), all are geographically close, and it is possible to say that they all belonged to closely related groups of people and so values of degree of resemblance
received for different pairs of collections from Razliv sites demonstrate the values of degree of resemblance which can be shown by a set of closely related collections of potsherds. The collections from the sites of Razliv can be used as a standard set of related collections for Pit-Comb Ware of the Northwest of Russia.

It is interesting to note that the higher values of the degree of proximity are shown by those collections of potsherds that originated from more neighbor sites (see fig. 2).

It should be noted, that considering values of the degree of resemblance of the collections of potsherds from Razliv we should keep in mind that the lake was artificially created in the 1720s and that all sites are connected with ancient streambeds of rivers which flew on the place where now is the lake (for more details see Akulov 2020a: 6 – 7).

![Fig. 2. Scheme showing proximity degrees of sites of Sestroretskii Razliv: in the current context different levels of resemblance are marked by lines of different colors: red lines mark the highest degrees of resemblance and blue lines mark the lowest degrees of resemblance. A triangle means sites with stone tools of late types, a circle means sites of the late Neolithic stage, and a square means Mesolithic site (original image source – Gurina 1961: 415)](image)

The average value of the degree of resemblance for the collections of potsherds from the sites of Razliv is 0.34. For more details about threshold values (Akulov 2020a: 6 – 7).
3. Comparing the collection of potsherds of the site of Toksovo with collections of potsherds of the site of Hepojarvi

3.1. Calculation of degrees of resemblance

Thus, in order to date the site of Toksovo, we have to estimate the degree of resemblance of the collection of potsherds from the site of Toksovo with three collections of potsherds from the site of Hepojarvi.

Fig. 3. Potsherds from the site of Toksovo (image source – Gurina 1961: 439)
The collection of the Comb-Pit Ware potsherds of the site of Toksovo

There are 18 potsherds (fig. 3), and can be singled out 3 imprints:

1) Comb (potsherds: 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 16, 17, 18, fig. 3), its percentage is 15/18 ≈ 0.83;
2) Pit (potsherds 1, 2, 3, 4, 6, 7, 10, 11, 12, 13, 14, 15, 16, 18, fig. 3) its percentage 14/18 ≈ 0.78;
3) Stroke (potsherds: 1, 8, 15, fig. 3), its percentage is 3/18 = 0.16.

The Comb-Pit Ware of the early stage of the site of Hepojarvi

There are 12 potsherds (fig. 4) in the collection of Early Comb-Pit Ware from the site of Hepojarvi, and can be singled out 4 imprints:

1) comb (potsherds 8, 9, 10, fig. 4) its percentage is 3/12 = 0.25;
2) pit (potsherds 1, 7, 11, fig. 4) its percentage is 3/12 = 0.25;
3) rope (potsherds 11, 12, fig. 4) its percentage 2/12 = 0.16;
4) stroke (potsherds 1, 2, 3, 4, 5, 6, 7, fig. 4) its percentage is 7/12 = 0.58.

The Comb-Pit Ware of the developed stage of the site Hepojarvi

There are 25 potsherds in the collection of the Comb-Pit Ware of the developed stage (fig. 5), and can be singled out 7 imprints:
1) circle (potsherd 20, fig. 5) its percentage is \(1/24 = 0.04\);
2) comb (potsherds 1, 2, 3, 6, 7, 9, 12, 17, 18, 19, 21, 22, 23, 24, 25, fig. 5), its percentage is \(15/25 = 0.6\);
3) pit (potsherds 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 17, 19, 21, fig. 5); its percentage \(14/24 = 0.56\);
4) rope (potsherd 15, fig. 5), its percentage \(1/25 = 0.04\);
5) imprint of a stick with teeth (potsherd 14, fig. 5) its percentage \(1/25 = 0.04\);
6) stroke (potsherds 4, 5, 8, 11, 21, fig. 5) its percentage \(5/25 = 0.2\);
7) triangle pit (potsherds 13, 16, fig. 5); its percentage is \(2/25 = 0.08\).

Fig. 5. The collection of fragments of the Pit-Comb Ware of the developed stage from the site of Hepojarvi (image source – Vereschagina 2003: 147, 148)
The Comb-Pit Ware of the late stage of the site of Hepojarvi

There are 6 fragments in the collection of late pottery (fig. 6).

And can be singled out 2 imprints:

1) comb (potsherds 1, 6, fig. 6) its percentage is $2/6 = 0.33$;
2) stroke (potsherds 2, 5 fig. 6), its percentage is $2/6 = 0.33$.

Fig. 6. The collection of late Comb-Pit Ware pottery from the site of Hepojarvi (image source – Vereschagina 2003: 148)

The Comb-Pit Ware of the site of Toksovo and the Comb-Pit Ware of the early stage of the site of Hepojarvi

Common imprints are: comb, pit, stroke.

$(3/4 + 3/3)/2 \times (0.25/0.83 + 0.25/0.78 + 0.16/0.58)/3 \approx 0.25$

The potential error in the current case is between 1% and 4% since the ratio of numbers of potsherds of the compared collection is $12/18 = 0.66$.

The Comb-Pit Ware of the site of Toksovo and the Comb-Pit Ware of the developed stage of the site of Hepojarvi

Common imprints are: comb, pit, stroke.

And thus, the degree of resemblance is the following:

$(3/7 + 3/3)/2 \times (0.6/0.83 + 0.56/0.78 + 0.16/0.2)/3 \approx 0.53$

The potential error in the current case is about 1% since the ratio of numbers of potsherds of the compared collection is $18/25 = 0.72$. 
The Comb-Pit Ware from the site of Toksovo and the Comb-Pit Ware of the late stage of the site of Hepojarvi

Common imprints are: comb and stroke.
\((2/2 + 2/3)/2 * (0.33/0.83 + 0.16/0.33)/2 \approx 0.36\).

The potential error in the current case is about 19% since the ratio of numbers of potsherds of the compared collection is \(6/18 \approx 0.33\).

3.2. Interpreting the received values of degree of resemblance

Thus, have been received three values of the degree of resemblance for the collection of potsherds from the site of Hepojarvi:

The degree of resemblance of Comb-Pit Ware from the site of Toksovo and early Comb-Pit Ware from the site of Hepojarvi is 0.25.

The degree of resemblance of Comb-Pit Ware from the site of Toksovo and developed Comb-Pit Ware from the site of Hepojarvi is 0.53.

The degree of resemblance Comb-Pit Ware from the site of Toksovo and late Comb-Pit Ware from the site of Hepojarvi is 0.36.

And the system of threshold values derived from the collections of potsherds from Razliv (see 2.4) can be applied to these values.

The values of the degree of resemblance derived from the standard set of collections from Razliv can range from 0.2 to 0.67, so all the values received for the collections of potsherds from Toksovo and Hepojarvi fall into the range of values which can be demonstrated by collections belonged to related groups: \(0.2 < 0.25 < 0.67; 0.2 < 0.53 < 0.67; 0.2 < 0.36 < 0.67\).

The degree of resemblance of the Comb-Pit Ware from the site of Toksovo and early Comb-Pit Ware from the site of Hepojarvi is lower than the average value of the degree of resemblance for standard collections that is 0.34; it means that these collections of potsherds are not very close.

The degree of resemblance of the Comb-Pit Ware from the site of Toksovo and the Comb-Pit Ware of the late stage from the site of Hepojarvi is very close to the average value.

The degree of resemblance of the Comb-Pit Ware from the site of Toksovo and Comb-Pit Ware of the developed stage is higher than the average value and is close to the values of the degree of resemblance demonstrated by closely related collections of the standard set.

Also it is noteworthy and interesting that the Comb-Pit Ware of the developed stage from the site of Hepojarvi being compared with early and late Comb-Pit Ware of the same site demonstrates values of degree of resemblance which are very close to those which are demonstrated in by the Comb-Pit Ware of the site of Toksovo when it is compared with
collections of early and late Comb-Pit Ware of Hepojarvi: the degree of resemblance of developed Comb Pit Ware from Hepojarvi and early Comb-Pit ware from Hepojarvi is 0.28; the degree of resemblance of developed Comb-Pit ware from Hepojarvi and late Comb-Pit Ware from Hepojarvi is 0.37 (Akulov 2020b: 14 – 15)

All this means that the collection of potsherds from the site of Toksovo is especially close to the Comb-Pit Ware of the developed stage from the site of Hepojarvi.

4. Conclusion

Thus, taking into account the fact that the collection of potsherds from the site of Toksovo is especially close to the developed Comb-Pit Ware of Hepojarvi, and the time of existence of the Comb-Pit Ware of the developed stage is the 4th millennium – the very beginning of the 3rd millennium BCE, it is possible to state that the site of Toksovo existed in the 4th millennium – in the very beginning of the 3rd millennium BCE (see fig. 7). As far as on the site of Toksovo is represented only the pottery that is closely connected with the developed Comb-Pit Ware of Hepojarvi site and there are no other types of pottery that existed in other periods, so it is possible to state that the site of Toksovo was secondary to the site of Hepojarvi, i.e.: both sites belonged to the same group of people, but initially those people started to dwell on the site of Hepojarvi and later founded the site of Toksovo.

Fig. 7. Scheme showing the timeline of existence of Hepojarvi site, different subtypes of the Comb-Pit Ware (CPW), and approximate time of existence of Toksovo site (drawn by the author)

The site of Toksovo as well as that of Hepojarvi seems to have been winter settlements. The whole life of the people who lived between the Littorina Sea\(^3\) and Ladoga Lake (see fig. 8) in

\(^3\) The Littorina Sea is the stage of the Baltic Sea that existed in 5th – 2nd millennia BCE.
the Neolithic period was seasonally determined since gathering, fishing, and hunting are seasonal activities, and therefore there were seasonal settlements: winter and summer. The summer ones were located on the seashore, at the river mouths, where fishing was carried out, and the winter ones – in the depths of the forest, in the upper reaches of the rivers, where the autumn-winter hunting for forest animals was carried out.

Fig. 8. General map of the region between the Littorina Sea and Ladoga Lake (drawn by the author)

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