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PREHISTORIC FLINT PROVENANCE IN FINLAND: REANALYSIS OF SOUTHERN DATA AND INITIAL RESULTS FOR THE NORTH

Abstract

I attempt to determine whether archaeological flint samples from southern and northern Finland can statistically be divided into eastern and western groups, based on their chemical composition. Pre-existing chemical composition data for southern Finnish flint are re-analysed and new data for northern Finnish samples are incorporated. They are compared to geological samples from Russia, Sweden, and Denmark. I conclude that despite differences in the analytical methods used to derive southern and northern data, the samples can reliably be grouped into eastern and western groups. Finally, I suggest that we must now test the hypothesis that there is a continuum of flint composition variation in northern Europe, and I outline a project which will accomplish that goal.

Keywords: flint, geological sources, geochemistry, statistical methods, Principal Component Analysis, discriminant analysis, Finland.

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INTRODUCTION

Background

Finnish archaeology has always had a strong interest in disentangling influences upon the early cultural and technological development of Fennoscandia (Edgren 1988; Schulz 1990). More specifically, it has been thought that with the introduction of metal, the primary exchange networks of the Finnish population shifted from an eastward to a westward orientation (Huurre 1982; 1983; Kehusmaa 1985). According to this view, metal was introduced by trade from the west, or a new metal using population migrated to Finland from the west.

In the 1980's Matiskainen, Vuorinen and Burman (1989) turned to the geochemical study of flint provenance in order to investigate the eastward and westward trade contacts existing in southern Finland at the close of the Neolithic. This followed the pioneering flint study conducted by Kinnunen *et al.* (1985) which dealt mainly with petrographic and microfossil classification of siliceous lithic materials. Kinnunen *et al.* however, did not specifically address the question of provenance of archaeological flint.

Flint is not thought to occur naturally in Finland. Two main areas are usually identified as the source of archaeological flint found in Finland: to the west, northern Denmark and the flint bearing areas of Scania in southern Sweden, and to the east the Valdai region of the Russian plain. Before the development of geochemical sourcing methods, flint colour and texture were used to differentiate between "eastern" and "western" flints found in Finnish archaeological sites. By the late 1970s, significant technical and analytical developments allowed the increasingly reliable discrimination of lithic materials from various geological sources on the basis of elemental composition (Harbottle 1982; Shackley 1998). In the case of Matiskainen *et al.* (1989), limitations inherent to their tools, and the medium for publication of their results (symposium proceedings) conspired to limit the amount of detail included in their report as well as the breadth of their discussion.

Using the statistical methods, technical tools, and archaeological material available in the late 1980's, Matiskainen, Vuorinen and Burman studied the composition of 70 samples of flint, including 59 from archaeological contexts and 11 from known geological sources. Their work strongly suggested that it was possible to reliably discriminate between flint from the known eastern and western geological sources which surround Finland. It further suggested that available flint samples from southern Finnish Metal Age contexts were likely to fall into the western category, while samples from late Neolithic contexts were likely to be classified as eastern.

Since then, technical and analytical developments, as well as an intensification of archaeological activity in northern Finland, have made possible a reanalysis of their material and a reappraisal of their conclusions. The results of the present work agree in large measure with theirs, while adding detail to certain findings, and contributing new information which raises fresh questions about exchange networks in Fennoscandia during the Early Metal Age.

A factor which could be called "external" to scientific research has also had a significant impact on this field since Matiskainen *et al.*'s (1989) original study. The opening up of scientific and cultural contacts with former Soviet republics has provided access to a much greater number and diversity of geological reference samples of flint (Berzins 1999; Zagorska 1997). Here is a chance to significantly increase knowledge of possible prehistoric exchange systems in Fennoscandia and northern Europe in general. Before integrating this mass of newly available data and harnessing the expertise of newfound colleagues, it would be worthwhile to carry out an assessment of the present situation and a pilot project.

Shackley (1998) has recently discussed what he calls "the sourcing myth". His discussion is part of ongoing arguments about the possibility of identifying the source of any given lithic material by chemical fingerprinting. In essence, the debate is between those who argue that it is possible and those who argue that one can, on a geochemical basis, rule out a given geological source for a given archaeological sample, and that at most one can suggest a range of sources from which it might have come. That range may be wide or narrow, but the assignment of a sample to a known source can never be certain. According to this second, more conservative view, one should always keep in mind that there may be (or may have been, in prehistory) currently unknown sources of raw material which might completely upset the clustering of known geological sources which we can achieve on the basis of geochemistry.

I am in substantial agreement with this second, more conservative position, and the intent is not here to positively identify sources or even source areas for flints found in archaeological context in northern Finland. The object is rather merely to determine whether flints can be grouped according to composition, and whether these groups coincide with known source areas.

The present study

The present study is part of a larger ongoing international effort on the origin, chronology and development of metal technology in northern Fennoscandia (Ylimaunu & Costopoulos 1998). As part of that project, new chemical composition data were obtained for the first time for flint material from archaeological contexts in northern Finland. I originally took interest in the results provided by Matiskainen *et al.* for comparative purposes. After discussing the matter, however, Doc. Matiskainen and I agreed that both studies could benefit from a reanalysis of the 1989 study's original results.

In the summer of 1997, I analysed the chemical composition of flint material drawn from three sites in the Oulu region of northern Finland. The samples included the basal portion of a flint biface from Olhava Hiidenkangas, and a flake from Muhos Halonen. The composition analysis was performed at the Institute of Electron Optics of Oulu University, using an electron microprobe.

Muhos Halonen was excavated by Aarne Kopisto of the Museum of the Northern Ostrobothnia (Pohjois-Pohjanmaan Museo) in 1968. It is a large occupation, shore-line dated at approximately 3700 BP. It is located in the present Oulu River valley and lay on an estuarine island at the time of occupation. It includes traces of metal use and perhaps even of metal production

(Costopoulos, Ylimaunu & Okkonen 1997). Muhos Halonen is currently considered to be an Early Metal Age site. The collection includes several flakes of flinty material whose macroscopic appearance ranges from typical fine-grained pale flint to dark jasperoid material. A single flake was obtained from the Pohjois-Pohjanmaan Museo, and two fragments detached for analysis.

Olhava Hiidenkangas represents a somewhat later occupation. It is located north of Oulu and is the site of several cairns and a moraine-top residential occupation. It was excavated between 1988 and 1990 by an Oulu University team led by Eero Jarva and Jari Okkonen. The excavation yielded a large basal biface fragment, probably the largest single piece of flint ever recovered from an archaeological context in northern Finland. The piece was drawn from the collection held at the archaeology laboratory of Oulu university. Four small fragments were detached for electron micro-probe analysis.

RE-ANALYSIS OF THE 1989 DATA

Introduction

The re-analysis aims at applying an updated set of statistical techniques to the original data and is an opportunity to publish more detail about the results. Three main questions were considered. First, can the original discrimination between eastern and western reference materials be replicated using updated techniques? Second, can the originally analysed southern Finnish archaeological samples be classified as eastern or western in relation to the reference material? Third, what is the cause of the discrimination, or lack thereof, as the case may be?

The original report makes it quite plain that discrimination is possible and it strongly suggests that there is a change in origin of flint over time. However, it does not provide a detailed account of the clustering of each archaeological sample in relation to the reference material. It does not, furthermore, explore in any great detail the question of the causes of the achieved discrimination. It was therefore expected that discrimination would be possible using updated techniques and that the present format of reporting would make possible a more detailed account as well as a fuller discussion of the mechanism which lies behind the observed discrimination (if any).

Statistical methodology (re-analysis)

The elemental concentrations reported in the original work (20 elements) were obtained using Atomic Absorption Spectrophotometry (AAS) and expressed as parts per million (PPM). A detailed account of the methodology for obtaining these concentrations is available in the original report (Matiskainen *et al.* 1989).

The procedure used for re-analysis was very similar to that originally employed. Both studies used Principal Component Analysis (PCA) as a data reduction technique, and again both studies used Canonical Discriminant functions as discriminant tools.

In the present study, PCA and discriminant analysis were performed using SPSS 9.0.1 for Win95. PCA used the principal components method of extraction, analysing the correlation matrix. The factors were unrotated. The elemental concentration values were transformed into z scores prior to PCA. Only 18 of the originally reported elements were used in the re-analysis (Table 1). Vanadium showed a variance of 0 for all reference samples and lead had 0 values for all reference samples save 1 and therefore had limited use for the purposes of the analysis.

Table 1: List of elements used in reanalysis (Full element set)

Ti, P, Fe, Na, K, Ca, Mg, Sr, Zn, Cu, Li, Mn, Al, Cr, Ni, Co, Cd, Rb
Elements listed in Matiskainen et al. (1989) but dropped from reanalysis: V, Pb

PCA was first run using only the elemental concentrations of the geological reference samples. The original report shows data from three reference samples from the Moscow area, four reference samples from Fulgelsand, Denmark (all drawn from a single boulder), two samples drawn from one pebble from Gotland Island, Sweden, and one sample from Skanor, southern Sweden. One last sample was included as a reference sample in the original study. This is a “gunflint” found in archaeological context on Suomenlinna Island in the mouth of Helsinki harbour. It was presumably found in the Swedish fortress on the island and is therefore treated by the authors as a “western” reference sample. The reanalysis treats it as an archaeological sample and it was therefore not included in the reference PCA. The factor scores produced by the PCA for each element were saved as variables and then used for a first discriminant analysis in order to find out whether the set of reference samples could reliably be discriminated into eastern and western groups.

Following the reference PCA and discriminant analysis, PCA was run using elemental concentrations for all reference and archaeological samples included in the original study. The factor loadings thus derived for the reference samples were used to develop canonical discriminant functions which were applied to the PCA factor scores derived for the archaeological samples, including the Suomenlinna gunflint.

Inserting the new data

Next, the new elemental composition data for northern Finnish archaeological samples were introduced. These were obtained using an electron microprobe (EMP) and energy dispersive spectrometer (EDS), and therefore have characteristics different from the original study’s AAS data. The EMP/EDS keeps track of a more limited number of elements, for a single sample and duration of reading, than the AAS. The present study tracked 14 elements to the original study’s 20.

The two methods also have different detection limits for given elements and are differentially adapted to the tracking of various elements. For example, EMP/EDS is more reliable for concentrations of heavy elements than for concentrations of light elements. The reporting formats of the two methods are also different. EMP/EDS provides oxygen percentage and weight percentage readings, while AAS gives PPM. Conversions are possible but induce some amount of error.

Since the methods of geochemical analysis used in both studies differed in several respects, it would have been inappropriate to directly compare reported elemental concentrations. Differing detection limits for individual elements and systematic differences between the methods in sensitivity to element weight, would have induced artificial variance and produced clustering related to method of analysis rather than composition of samples.

The need for data reduction, in this case, happens to create factor loadings. These summarize, in the form of eigenvectors, the variance contained in the data and the direction of that variance, thereby representing and abstracting the absolute elemental concentrations. It is hoped that discrimination by factor loadings rather than absolute concentrations will produce clustering representative of chemical composition rather than of method of analysis. The z scoring of the absolute values further dampens the effects of the differences between the two methods by reducing the effect of scale differences. These are imperfect solutions to very serious problems. The success or failure of these solutions can be gauged in some part through the consistency of the results.

New PCA factor scores were determined using a restricted set of elements which were common to both studies and for which sufficient data were available (Table 2). Discriminant functions were developed for reference samples and applied to all samples, including geological, southern Finnish and northern Finnish material. The revised groupings, based on the limited element set, were then compared to the original full element set groupings.

Table 2: Restricted element set

Ti, Fe, Na, K, Ca, Mg, Zn, Cu, Cr, Ni, Cd

RESULTS

East-west discrimination of reference material

The east-west discrimination between sources reported in the original study was successfully replicated in reanalysis (Fig. 1). In fact, there is even some amount of discrimination to be seen between the two western sources. The observed discrimination is preserved when both the geological and archaeological material presented in the original study are

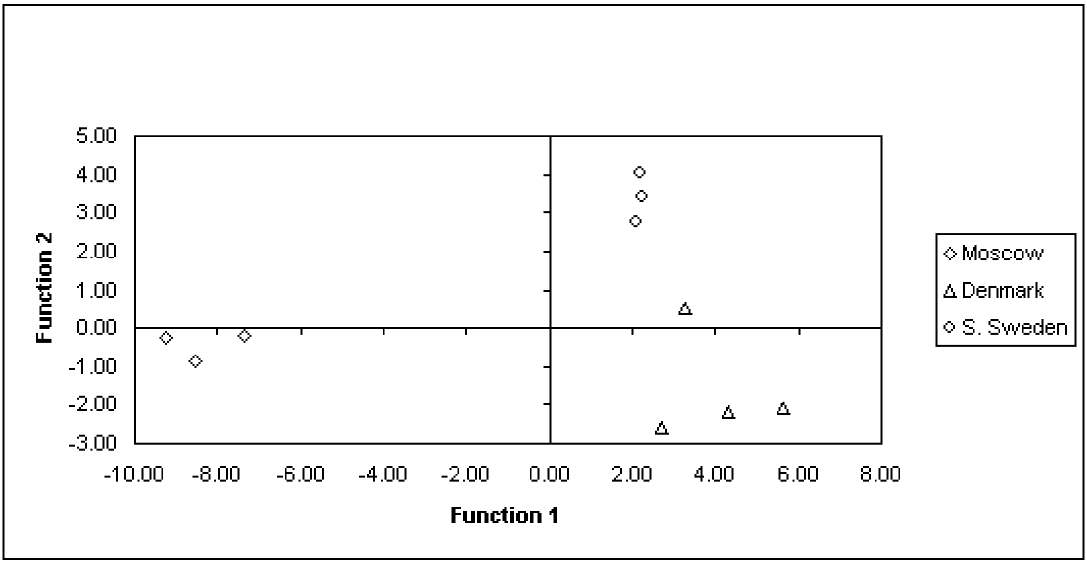

Fig. 1. Canonical Discriminant functions, reference samples, using PCA factor scores for reference samples.

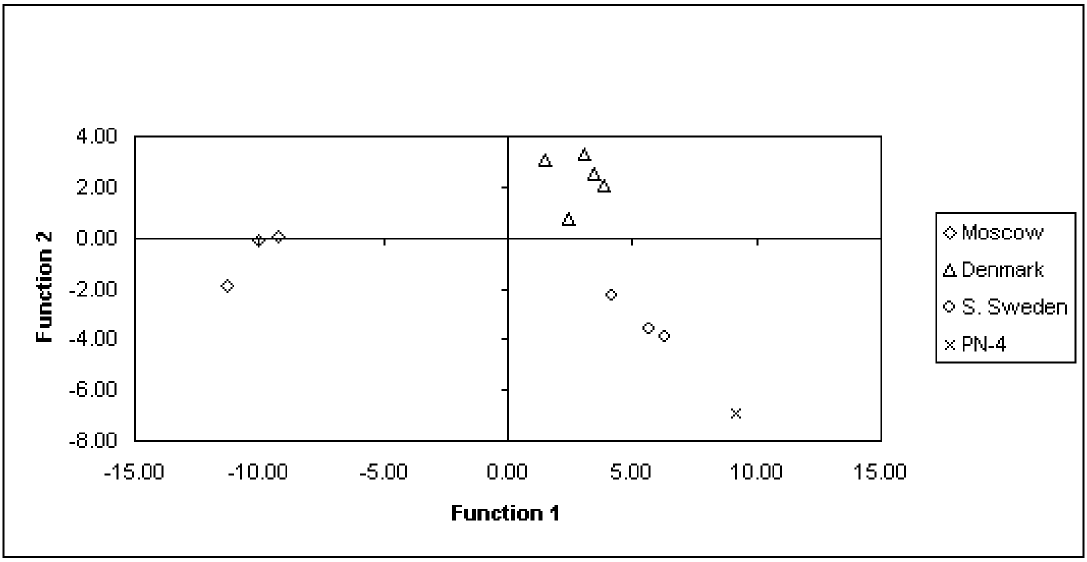

Fig. 2. Canonical Discriminant Function, full element set, using PCA factor scores for reference and Southern Finnish samples.

used to determine PCA factor scores. Figure 2 shows that PN-4, the sample found in archaeological context on Suomenlinna and assumed to be Swedish in the original study, does in fact cluster west, and is nearest the Swedish reference material.

Clustering of the South Finnish archaeological material

Figures 3, 4, 5 and 6 show the dispersal of all samples included in the original study (Appendix A for a key of abbreviations). These graphs are based on PCA using the full element set. A glance

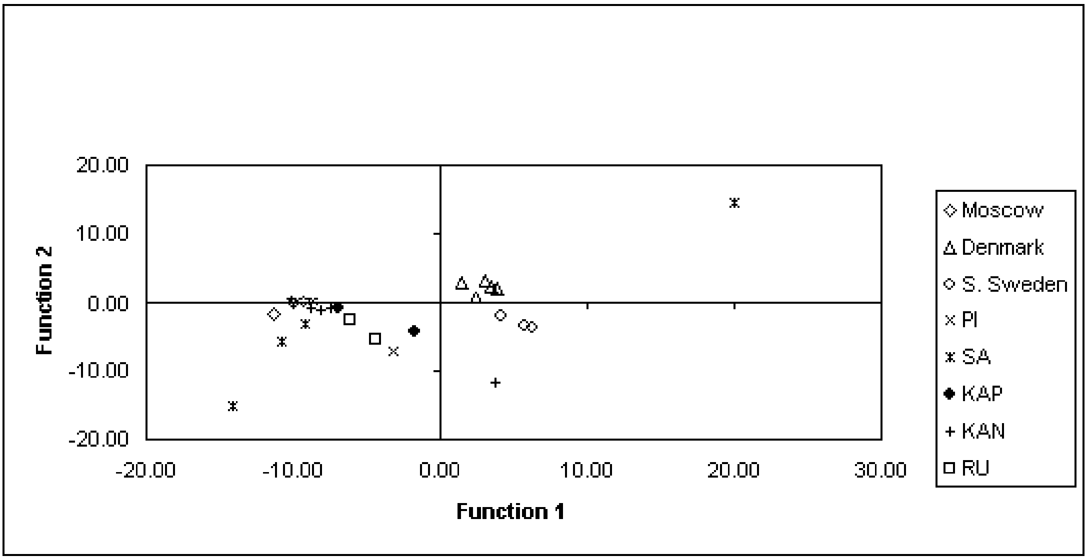

Fig. 3. Canonical Discriminant Function, full element set, using PCA factor scores for reference and Southern Finnish samples Reference samples and South Eastern Inland samples shown.

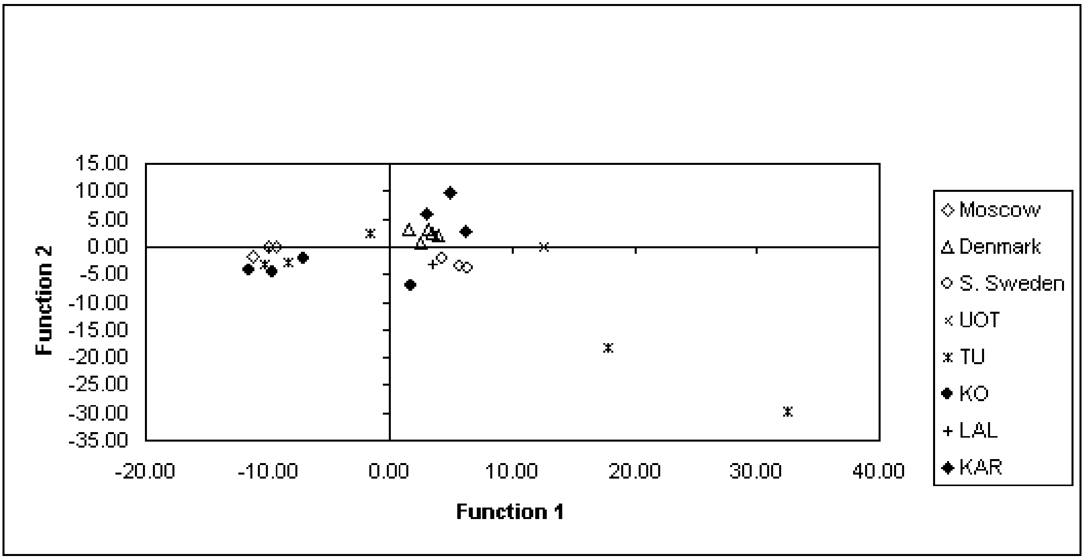

Fig. 4. Canonical Discriminant Function, full element set, using PCA factor scores for references and Southern Finnish samples References samples and South Western coastal samples shown.

at these suggests that a preponderance of the material plots relatively near the Moscow source and can therefore be hypothesised to originate from eastern sources. Figure 7 lends this initial impression some support. It shows the squared Euclidean distances between all southern Finnish material and each individual reference sample. The distances were calculated two-dimensionally, using discriminant scores for both functions plotted along a z curve. The distances are sorted in ascending order for each reference sample. The slope of the curve for all three Moscow reference samples is much gentler than that for all Danish and Swedish samples. This indicates that a great number of

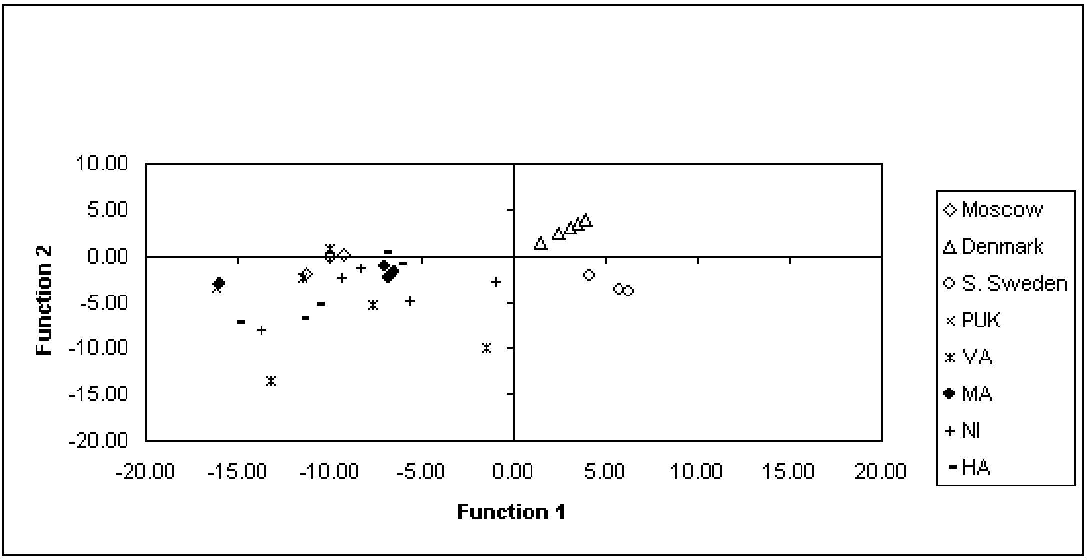

Fig. 5. Canonical Discriminant Function, full element set, using PCA factor scores for reference and Southern Finnish samples Reference samples and South Eastern coastal samples shown.

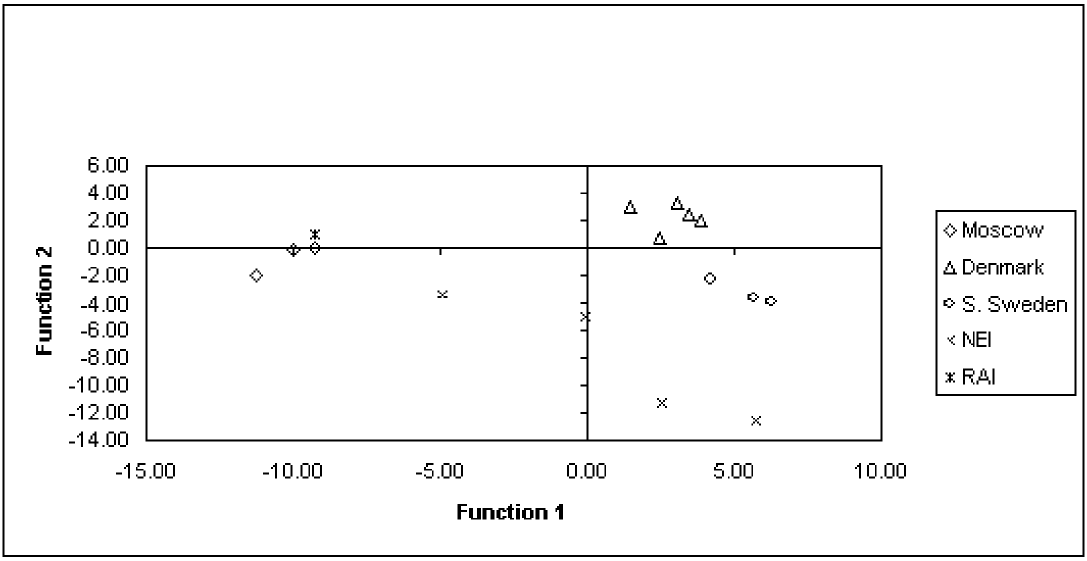

Fig. 6. Canonical Discriminant Function, full element set, using PCA factor scores for reference and Southern Finnish samples Reference samples, NEI and RAI.

archaeological samples are indeed relatively close to the Moscow reference samples.

In fact, the only tightly clustered group of "western" archaeological samples is from Maaria Kärsämäki (KAR, samples 1,4, and 5) in the southwestern coastal portion of Finland. It is also interesting to note that the only sample (RAI) considered western in the original study, but which was assigned to the eastern group by the original discriminant functions, also falls to the east in the present study. It falls very close to the Moscow reference material (Fig. 6), with z scored squared Euclidean distances of 0.142, 0.021, and 0.013 to the Moscow reference samples.

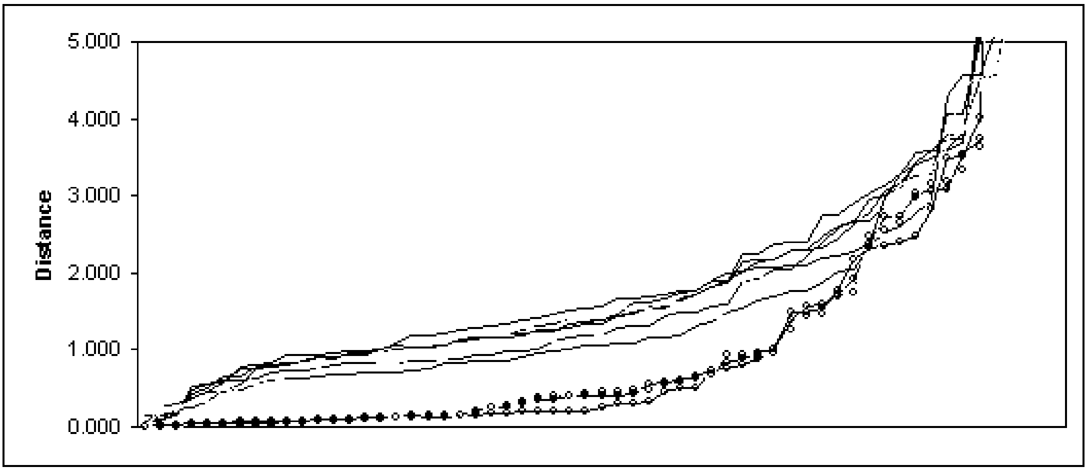

Fig. 7. Sorted squared Euclidean distances from reference samples, Moscow distance curves shown with circles.

Table 3. z scored squared Euclidean distances between reference samples, using discriminant scores (full element set).

	74:MO-1	75:MO-2	76:MO-3	77:D-66	78:D-67	79:D-68	80:D-69	81:D-70	82:PN-1	83:PN-3	84:PN-2
74:MO-1		0.054	0.079	1.799	1.761	1.778	1.446	1.398	2.193	2.039	1.667
75:MO-2	0.054		0.004	1.395	1.344	1.332	1.039	1.082	2.022	1.865	1.458
76:MO-3	0.079	0.004		1.250	1.201	1.189	0.914	0.957	1.878	1.726	1.328
77:D-66	1.799	1.395	1.250		0.004	0.024	0.054	0.037	0.491	0.432	0.240
78:D-67	1.761	1.344	1.201	0.004		0.009	0.032	0.048	0.576	0.511	0.294
79:D-68	1.778	1.332	1.189	0.024	0.009		0.019	0.087	0.727	0.654	0.402
80:D-69	1.446	1.039	0.914	0.054	0.032	0.019		0.077	0.779	0.693	0.416
81:D-70	1.398	1.082	0.957	0.037	0.048	0.087	0.077		0.373	0.312	0.136
82:PN-1	2.193	2.022	1.878	0.491	0.576	0.727	0.779	0.373		0.003	0.063
83:PN-3	2.039	1.865	1.726	0.432	0.511	0.654	0.693	0.312	0.003		0.038
84:PN-2	1.667	1.458	1.328	0.240	0.294	0.402	0.416	0.136	0.063	0.038	

Table 4. z scored squared Euclidean distances between reference samples, using discriminant scores (limited element set).

	74:MO-1	75:MO-2	76:MO-3	77:D-66	78:D-67	79:D-68	80:D-69	81:D-70	82:PN-1	83:PN-3	84:PN-2
74:MO-1		0.562	0.949	2.667	2.982	2.608	2.535	2.378	2.247	2.641	2.823
75:MO-2	0.562		0.625	2.110	2.420	2.046	1.974	1.901	2.044	2.402	2.443
76:MO-3	0.949	0.625		2.120	2.309	1.965	1.933	2.194	2.603	2.934	2.855
77:D-66	2.667	2.110	2.120		0.502	0.321	0.232	0.978	2.308	2.346	1.719
78:D-67	2.982	2.420	2.309	0.502		0.378	0.482	1.477	2.810	2.844	2.193
79:D-68	2.608	2.046	1.965	0.321	0.378		0.140	1.237	2.524	2.598	2.010
80:D-69	2.535	1.974	1.933	0.232	0.482	0.140		1.099	2.384	2.458	1.876
81:D-70	2.378	1.901	2.194	0.978	1.477	1.237	1.099		1.353	1.368	0.808
82:PN-1	2.247	2.044	2.603	2.308	2.810	2.524	2.384	1.353		0.412	1.008
83:PN-3	2.641	2.402	2.934	2.346	2.844	2.598	2.458	1.368	0.412		0.787
84:PN-2	2.823	2.443	2.855	1.719	2.193	2.010	1.876	0.808	1.008	0.787	

Clustering of North Finnish archaeological material

For reasons discussed above, the inclusion of the northern samples in the scatterplots required the elaboration of a limited element set and the calculation of new PCA factor scores and of new discriminant functions. It was to be expected that the removal of information from the data set would weaken the resolving power of the east-west discrimination tools. Figure 8 shows, however, that while discrimination is not as strong using the limited element set, it is still

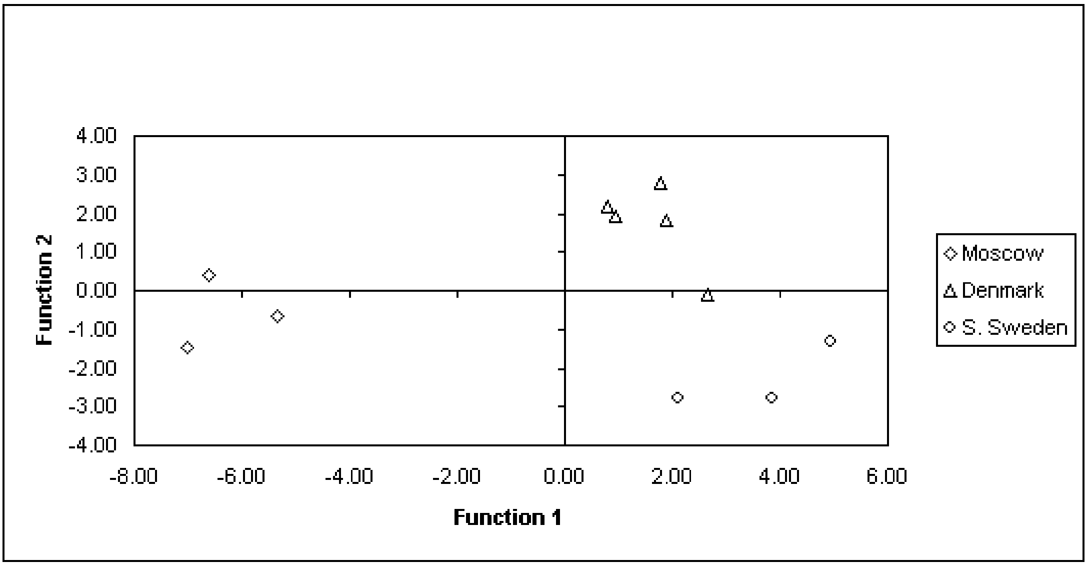

Fig. 8. Canonical Discriminant functions, limited elements set, reference samples, using PCA factor scores for all samples.

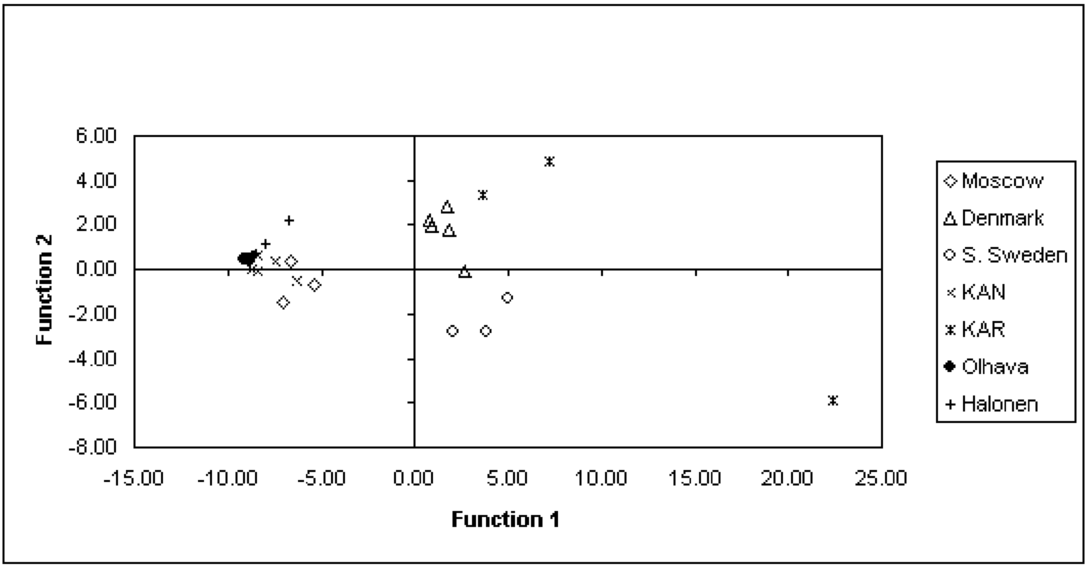

Fig. 9. Canonical Discriminant functions, limited element set, using PCA factor scores for all samples, KAN, KAR, and Northern Finnish samples shown.

clear enough to serve our purposes. The loss of information seems to affect mostly the discrimination between the two western sources, namely Denmark and southern Sweden. Tables 3 and 4 present the distance matrices for reference samples using full and limited element sets respectively. Both sets of distances were determined using z scored discriminant scores as coordinates.

In order to further test the reliability of the limited element set for discrimination, two sets of samples which clearly clustered east and west using the full element set, were plotted along with the reference samples. Figure 9 shows that,

Table 5. Total variance explained, using reference samples only, full element set .

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.958	49.769	49.769	8.958	49.769	49.769
2	4.508	25.046	74.815	4.508	25.046	74.815
3	1.699	9.438	84.253	1.699	9.438	84.253
4	1.166	6.476	90.729	1.166	6.476	90.729
5	.772	4.291	95.020			
6	.416	2.312	97.332			
7	.237	1.319	98.651			
8	.163	.903	99.554			
9	4.522E-02	.251	99.805			
10	3.504E-02	.195	100.000			

Table 6. Component Matrix, reference samples only, full element set.

	Component			
	1	2	3	4
TI	.986	-3.426E-02	-9.632E-02	-7.863E-02
P	3.467E-02	-.903	.233	8.076E-02
FE	-.125	.850	-.253	.376
NA	.694	-.481	-.285	.338
K	.793	-.448	-.363	9.717E-02
CA	.926	.173	.226	-4.615E-02
MG	.705	.581	.140	6.388E-02
SR	.921	-2.632E-02	.320	-6.608E-02
ZN	.710	-.301	7.468E-02	-.179
CU	.341	.885	6.339E-02	.174
LI	.969	1.224E-02	-6.701E-04	-.108
MN	-.349	.350	-.139	-.839
AL	.893	-.194	-.395	2.780E-02
CR	-.529	.600	.360	.264
NI	.781	.127	.584	-1.040E-02
CO	.743	.595	.176	-.149
CD	-.165	-.598	.694	8.044E-02
RB	.842	.222	-.133	-6.317E-03

as with the full element set, KAR still plots as western and that KAN is still very close to the Moscow area reference samples.

Figure 9 also shows the northern Finnish material. Like much of the southern Finnish archaeological material, it clusters fairly tightly around the Moscow area sources. This would tend to indicate that the northern material originates with eastern sources.

DISCUSSION

The mechanism of discrimination

While the results of the original analysis and the reanalysis are similar in some ways, they also differ. The main difference lies in the interpretation of the causes of discrimination. The original study gives Na, Mg, Zn, Al, K, and Co as the best discriminating elements. That result is only partially consistent with the findings of the present study. As will become clear in a later section, this may be an artifact of methodological difference.

The reanalysis proceeded in several steps. Considering at first only the geological reference samples, PCA gives two factors accounting for 73% of the observed variance (Table 5). Of these two factors, the first is most heavily correlated with Ti, Ca, Sr, Li, and Al (Table 6). The second is most heavily correlated with P, Fe, and Cu. This is in sharp contrast to the elements identified as discriminant in the original study.

Considering now the PCA performed using only reference samples and the limited element set, two factors are still found to account for 73% of observed variance (Table 7).

The first factor is still heavily correlated with Ti, and now shows correlation to Na, K, Ca, Ni, and Zn (Table 8). Of these however, only Zn shows simple structure. The second factor correlates mainly with Fe.

These results suggest that Ti, Zn, and Fe are the best discriminators when the limited element set is used. Figure 10 establishes that these three elements can indeed be used to get some amount of discrimination. Zinc seems to act as the main east-west discriminator, while Titanium and Iron provide discrimination between the two western sources.

The final step in the analysis consists of testing the discrimination power of the limited element set when all archaeological samples are included in the PCA. Predictably, the results are not as clear cut as in the previous steps of the PCA (Table 9). The first four factors only account for

Table 7. Total Variance Explained, using reference samples and limited element set .

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.026967	50.26967	50.26967	5.026967	50.26967	50.26967
2	2.321355	23.21355	73.48322	2.321355	23.21355	73.48322
3	1.345203	13.45203	86.93525	1.345203	13.45203	86.93525
4	0.702245	7.02245	93.9577			
5	0.227855	2.278552	96.23625			
6	0.185167	1.851667	98.08792			
7	0.149999	1.499992	99.58791			
8	0.023374	0.233736	99.82165			
9	0.017537	0.175372	99.99702			
10	0.000298	0.002981	100			

Table 8. Component Matrix, using reference samples and limited element set.

	Component		
	1	2	3
TI	.972	.160	-7.180E-02
FE	-.306	.838	-.282
NA	.762	-.299	-.295
K	.868	-.265	-.343
CA	.863	.366	.228
MG	.560	.740	.159
CR	-.663	.504	.330
NI	.723	.276	.599
CD	-5.378E-02	-.643	.713
ZN	.795	-8.976E-02	5.503E-02

75% of the variance. The first two components did this when only the reference samples were used. This result suggests that some of the southern Finnish archaeological samples may be from sources which are very different from those represented in the reference material.

Two hypotheses can be constructed in response to this result. Some of the southern Finnish material may originate in areas for which no reference material is available in this study, or some sources which are radically different from the ones represented here may exist in those general areas.

Interestingly, the Component Matrix for the

Table 9. Total Variance Explained, using all reference and southern Finnish samples, limited element set.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.921512	39.21512	39.21512	3.921512	39.21512	39.21512
2	1.449045	14.49045	53.70557	1.449045	14.49045	53.70557
3	1.189974	11.89974	65.60531	1.189974	11.89974	65.60531
4	1.025651	10.25651	75.86182	1.025651	10.25651	75.86182
5	0.83447	8.344699	84.20652			
6	0.529576	5.295762	89.50228			
7	0.46546	4.654603	94.15689			
8	0.277189	2.771891	96.92878			
9	0.227893	2.278927	99.2077			
10	0.07923	0.792296	100			

Table 10. Component Matrix, using all reference and southern Finnish Material, limited element set.

	Component			
	1	2	3	4
TI	.817	-.383	1.722E-02	-4.251E-02
FE	.422	-.475	.223	.472
NA	.864	4.320E-02	-.201	-1.575E-02
K	.884	-.278	5.001E-02	-.149
CA	.358	.673	-.248	-.274
MG	.747	1.192E-02	.115	-.390
ZN	.732	.168	-.175	.369
CR	-1.881E-02	.277	.867	.143
NI	.539	.506	.408	-2.886E-02
CD	.189	.429	-.272	.627

PCA using all reference and southern Finnish material (Table 10) is very consistent with the discrimination mechanism presented in the original study (Matiskainen *et al.* 1989:636). Titanium still shows up as an important discriminator in this study. However, Na, Mg, and K emerge as potential discriminators as well, and those are mentioned as important in the original study. Zinc was already mentioned as important at a prior step. Only Al and Co are now missing from the list presented by Matiskainen *et al.* (1989). Both were dropped from the limited element set because they

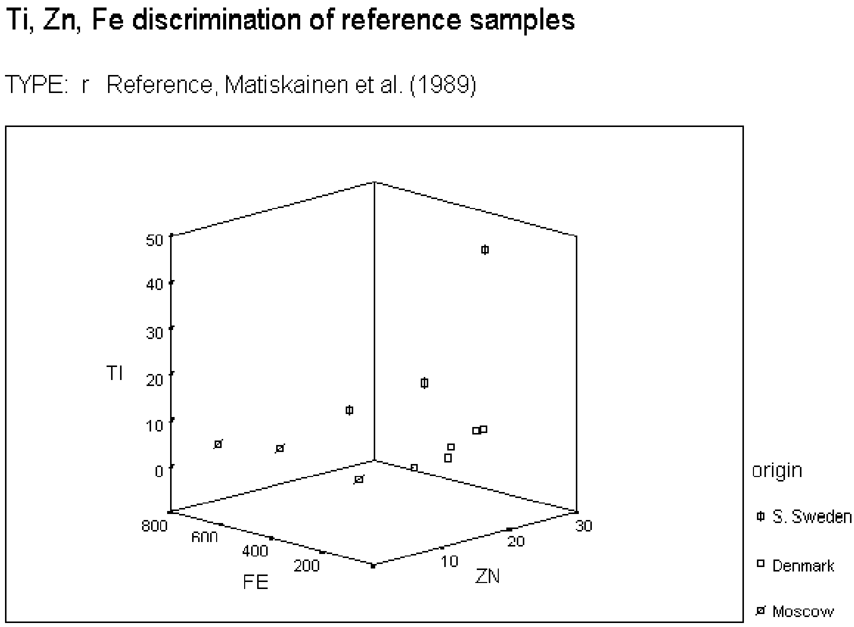

Fig. 10.

were not compatible with the northern Finnish data.

The list of discriminators found in the first step of the reanalysis, using only reference material and full element set, is closer to that presented in Sieveking *et al.* (1972) and used by Matiskainen *et al.* (1989) for contrast. Matiskainen *et al.* quote Sieveking *et al.* as identifying specific elements as causes of discrimination. My own reading of the same article did not reveal this. However, I will use Matiskainen *et al.*'s reading of Sieveking *et al.*, as they use it for contrast to their own results. Of the elements presented by Sieveking *et al.* as being discriminant (as quoted in Matiskainen *et al.*), K and Na are problematic in the reanalysis. But the present reanalysis is in substantial agreement with Matiskainen *et al.*'s (1989) reading of Sieveking *et al.* (1972) as to the importance of Al, Fe, Mg, Li, and P.

This result suggests that Matiskainen *et al.* (1989) may have included all archaeological samples in all their statistical procedures rather than proceeding by gradually more inclusive steps. This progressive strategy was made possible in the case of the present study by the increased availability and power of computer based statistical analysis tools.

Pending a reanalysis (forthcoming) of the original concentrations provided by Sieveking *et al.* (1972), it is difficult to explain why Titanium should be so important at all steps of the reanalysis and yet appear minor in both the original study and in Matiskainen *et al.*'s (1989) reading of Sieveking *et al.* (1972).

Implications of the results for the chronology of contacts in northern Fennoscandia

Both northern archaeological samples tested cluster tightly with the eastern source of raw material. Furthermore they are both drawn from sites which can be assigned to the Early Metal Age. Muhos Halonen has yielded traces of metal working (Costopoulos, Ylimaunu & Okkonen 1997; Huurre 1982; Kehusmaa 1985). Olhava Hiidenkangas is located nearby and is chronologically later than Muhos Halonen.

All these elements, although fragmentary and merely suggestive, do nevertheless raise the possibility that, at least in the North, there was no re-alignment of trade networks associated with the early transition to metal technology. Even in the case of the southern Finnish archaeological material analysed, few of the tested samples actually cluster tightly with the known western sources.

The original study reports 8 samples as clustering in the western group. One must consider that this result may be an artifact of an a-priori expectation of two clusters. As the present study shows, finer discrimination is possible. The Danish and southern Swedish material differ slightly. Of the 10 samples which do fall on the western end of the scatterplot in the present study, only 5 can be seen to cluster tightly with the known western sources. The others plot far away and may be quite different. They could easily belong to some unknown eastern group or be from altogether different and unsuspected sources (Poland or the Carpathians for example).

CONCLUSION

These two combined studies establish that it is possible to discriminate, in the Finnish context, eastern and western sources of flint. They also suggest that sources of flint in northern Europe can be plotted along an east-west continuum which allows interpolation of material from unknown sources.

This "flint source interpolation hypothesis" must now be tested. Geochemical determinations for geological reference material from intermediate sources will allow the rejection of this hypothesis. Such material is now available and has been provided to the archaeology laboratory of Oulu University by Valdis Berzins and Professor Ilga Zagorska of the Latvian Academy of Sciences. In the next step of the present project, more than 60 samples representing a dozen source areas will be analysed. The data thus produced will be treated using the procedures developed in Matiskainen *et al. (*1989) and refined in the present study.

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Appendix A

Abbreviations used in Matiskainen *et al.* (1989)

HÄ	Viipuri Häyrynmäki
KAN	Kerimäki Kankaanlaita
TU	Köyliö Tuiskula
KO	Honkilahti Kolmhaara
RU	Sulkava Ruunapäänniemi
KAP	Sulkava Kapakkamäki
NEI	Kemijärvi Neitilä
VA	Inkoo Vahrs
NI	Kymi Nyskasuo
SÄ	Kuusjärvi Sätös
PI	Ilomantsi Syväys
MA	Vantaa Maarinkunnas
KÄR	Maaria Kärsämäki
UOT	Kiukainen Uotinmäki
PUK	Uskela Pukkila
RAI	Pirttikylä Rainesäsen
LAL	Laitila Lalla