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POTTERY STYLES DURING THE EARLY JOMON PERIOD: GEOCHEMICAL PERSPECTIVES ON THE MOROISO AND UKISHIMA POTTERY STYLES*

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Energy-dispersive X-ray fluorescence (EDXRF) was used to determine the minor and trace element chemistry of 92 Early Jomon pottery sherds. The sherds came from four contemporary sites in the Kanto region and belong to either the Moroiso or Ukishima style of pottery. Principal components analysis (PCA) and discriminant analysis indicate that there are four major groups in the data set, which correspond to site location. Furthermore, for sites having both Moroiso and Ukishima pottery, the statistical tests indicate that both styles of pottery were made from the same or geochemically similar raw materials. This suggests that both styles were probably made at the same site, and indicates that if the different pottery styles are reflecting ethnic identity, then intermarriage between ethnic groups is occurring. Alternatively, the pottery styles could be reflecting some sort of social interaction between groups.

KEYWORDS: ENERGY-DISPERSIVE X-RAY FLUORESCENCE (EDXRF), JAPAN, JOMON POTTERY, KANTO REGION, MOROISO POTTERY, PRINCIPAL COMPONENTS ANALYSIS (PCA), UKISHIMA POTTERY

INTRODUCTION

For over six decades now, numerous archaeologists have been working on the typological and chronological aspects of Jomon pottery (see, e.g., Yamanouchi 1939, 1969; Kidder 1968; Okawa *et al.* 1996). While researchers have discovered distinct regional style zones of Jomon pottery (Kamaki 1965), and linked the various styles to tribal or ethnic groups (Yamanouchi 1969; Kobayashi 1992), serious studies focusing on the use of pottery and its social significance have gone unanswered. Likewise, questions regarding the production and circulation of Jomon pottery have largely been unexamined.

While there is a strong tradition of archaeometric studies on historic- and protohistoric-period Japanese pottery and porcelains (see, e.g., Mitsuji 1986, 1995; Doherty and Maske 1998), this is not the case for Jomon pottery. Kojo (1981, 1986) and Shimizu (1997) have done a series of petrographic studies on Jomon pottery from across Japan but, to date, there are only a handful of published compositional studies of Jomon pottery (Ishikawa 1988; Habu and Hall 1999; Imamura *et al.* 1999). As has been demonstrated in numerous other studies, chemical and petrographic studies are essential in order to provide information on the materials used to manufacture pottery, and in defining both inter- and intraregional contacts between contemporary settlements (see, e.g., Bishop, Rands and Holley 1982; Jones 1986; Neff, Bishop and Arnold 1988; Neff 1992; Pollard and Heron 1996).[1]

The subjects of this study are 92 sherds of Moroiso- and Ukishima-style pottery from four

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[1] This is not intended to be an exhaustive list by any means. These are just examples of articles and books that the author has found useful.

Early Jomon sites in the eastern Kanto region (Fig. 1). Fifteen minor and trace elements were determined using quantitative energy-dispersive X-ray fluorescence (EDXRF). Exploratory data analysis was then done on the data in order to see what chemical groups exist in the data set, and their relationship to either site location or the pottery style. If the pottery was locally produced, we should expect to find statistically significant differences in the chemical composition between potsherds from different sites. If there are no significant statistical differences between sites, then we can assume that the Jomon potters utilized raw materials that were geochemically similar, or that the pottery was part of a trade/exchange/redistribution network between settlements. Along similar lines, if a given style of pottery found at several sites has the same chemical 'signature', then it is possible that some sort of 'productive specialization' occurred amongst the sites in the study group (Costin 1991, 4).

ARCHAEOLOGICAL MATERIALS

The Jomon period in Japan dates from approximately 10 500 BC to 300 BC. The time period is divided into six sub-periods: the Incipient Jomon (*c.* 10 500–8000 BC), the Earliest Jomon (*c.* 8000–5000 BC), the Early Jomon (*c.* 5000–2500 BC), the Middle Jomon (*c.* 2500–1500 BC), the Late Jomon (*c.* 1500–1000 BC) and the Final Jomon (*c.* 1000–300 BC).[2] During this time, Japan was occupied by relatively sedentary hunter–gatherers, who produced and used pottery, lived in settlements of varying sizes and developed a very rich material culture. More details on the archaeology of the Jomon period can be found in Aikens and Higuchi (1982), Pearson (1990), Habu (1995, 1996), Imamura (1996) and Barnes (1993, 69–91).

The Moroiso and Ukishima styles of Jomon pottery are contemporary with each other and were in use during the later half of the Early Jomon (Nishimura 1986; Seido 1996a,b). Radiocarbon dates place the floruit for Moroiso pottery at 4300–2800 BC.[3] Moroiso pottery is subdivided into three sub-phases and is characterized by deep and shallow bowls, and caliper-shaped jars (Seido 1996a). Decoration was done by bamboo marking, cord marking, nail marking or comb marking. The pottery is found primarily in western Kanto in the modern-day prefectures of Gunma, Kanagawa, Nagano, Saitama and Tokyo. The floruit for Ukishima pottery was from 4500 BC to 2600 BC.[4] Ukishima-style pottery is similarly decorated with shell impression, nail marking, cord marking and incision, but vessel forms are much simpler and are characterized by having straight or everted rims (Nishimura 1986; Seido 1996b). This style is distributed primarily in Chiba and Ibaraki Prefectures.

All of the samples examined in this study came from recent excavations in Chiba Prefecture (Fig. 1). The sites are all located in an area of Late Pleistocene gravels, muds, sands and volcanic ash (Geological Survey of Japan 1982, 15).

The Ariyoshi-kita shell midden was excavated in the late 1980s by the Chiba Prefectural Cultural Properties Center (Chibaken Bunkazai Senta 1998). The site was in use from the

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[2] These dates are based primarily on artefact typologies with the incorporation of some radiocarbon dates. While radiocarbon dating is commonly done in the course of post-excavation work, aside from the Incipient Jomon sub-period, radiocarbon dates have been underutilized in constructing the chronology for the Jomon period. As demonstrated below, a thorough re-examination of the radiocarbon for the Jomon period is sorely needed.

[3] The radiocarbon dates used to calculate the floruit are from Keally and Muto (1982). The floruit was calculated using the OxCal program, version 3.3. The floruit is based on eight radiocarbon dates; four from charcoal and four from marine shells. While the marine curve was used to calibrate the four radiocarbon dates from shells, a value of $\Delta R = 0$ was used. Most archaeologists would consider the floruit as being too long and starting at too early a date.

[4] The dates used to calculate the floruit with the OxCal calibration program are taken from Keally and Muto (1982). The floruit is based on five radiocarbon dates; one from charcoal and four from marine shells. The four radiocarbon dates from shells were calibrated using the marine curve with $\Delta R = 0$. Likewise, most archaeologists would consider the floruit as being too long.

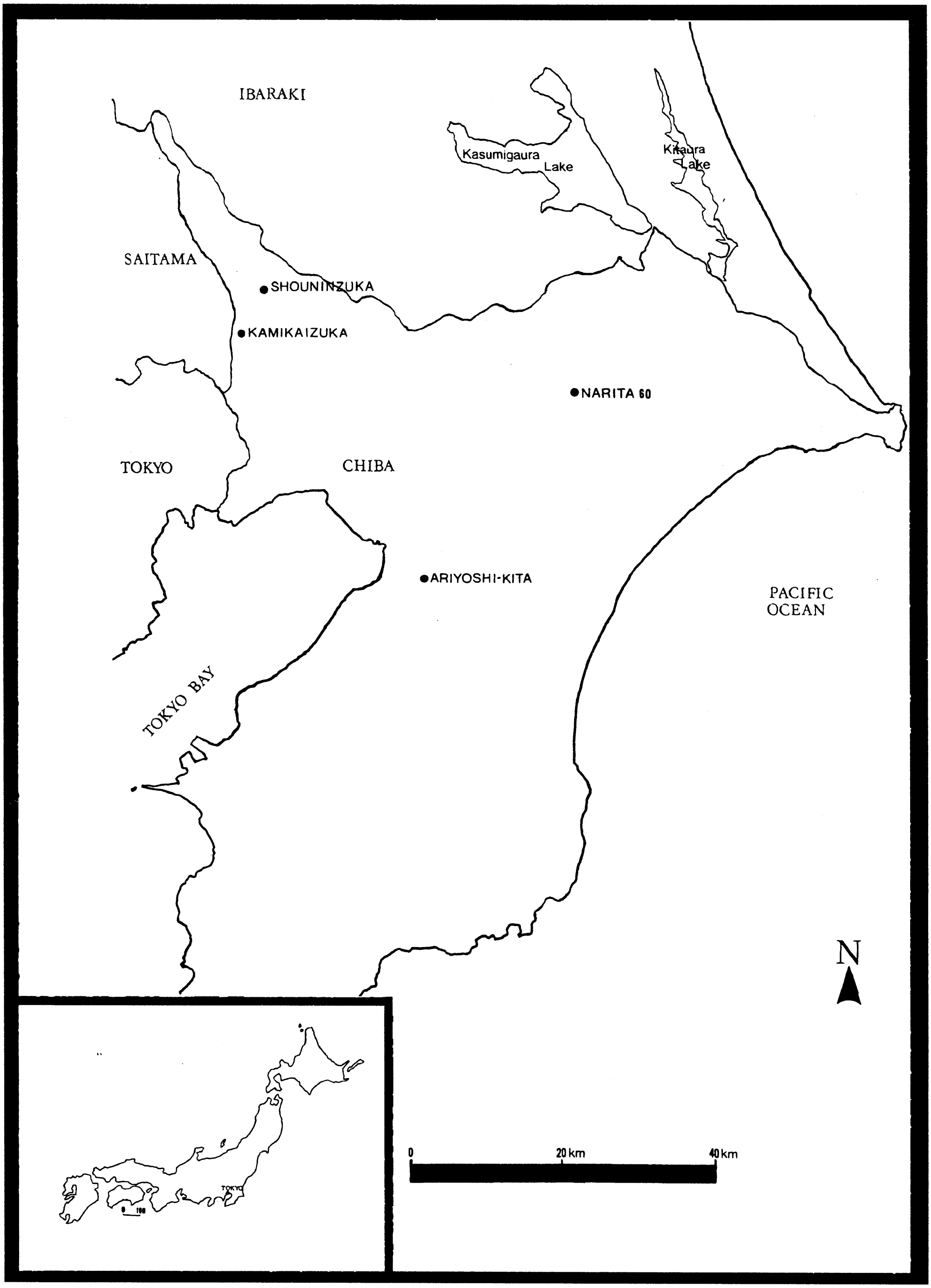

Figure 1 *A map of the sites. The inset locates the eastern Kanto region in relation to the rest of Japan. The modern prefecture names are in the larger capital letters.*

Earliest Jomon through to the Late Jomon, with intense occupation during the Middle Jomon sub-period. For the Early Jomon sub-period, excavations revealed one house pit, several hearths and small pits. These features yielded over 7000 sherds that were dateable to the Early Jomon period.

The Kamikaizuka shell midden is on the outskirts of the town of Matsudo. Only limited excavations, in response to railway construction, have been done here (Chibaken Bunkazai Senta 1996). Pottery recovered from the excavations indicates that the site was in use during the Early and Middle Jomon sub-periods.

The Narita 60 site was discovered during the construction of the Narita International Airport (Chibaken Bunkazai Senta 1994). It was occupied during the Earliest Jomon and Early Jomon periods. No house pits were discovered during the course of excavation, but 23 hearths and 20 small pits were discovered.

Less than 10 km north-east of Kamikaizuka is the Shouninzuka site (Chibaken Bunkazai Senta 1986, 186–292). Excavations revealed a variety of features ranging in date from the Earliest Jomon (Yoritomon phase) to the Final Jomon (Angyo 3 phase). No house pits were found that date to the Early Jomon period. The majority of the Early Jomon pottery was recovered from several small pits, approximately 1 m in diameter, in the northern half of the site.

Due to higher sea levels during the Early Jomon period, all of these sites were much closer to the ocean than today (Imamura 1996, 68, 69). Kamikaizuka, Narita 60 and Shouninzuka are all in the Tone River drainage; during the Early Jomon period, this area was a saltwater bay. Ariyoshi-kita bordered an extended Tokyo Bay.

ANALYTICAL PROCEDURE

The elemental analyses were performed on the cross-section of the sherds using a Philips PV9550 EDXRF machine equipped with a rhodium X-ray tube, a 0.1 mm silver filter and an EDAX DX-4 X-ray analyser located at the National Museum of Japanese History. The X-ray tube was operated at 50 kV, 100 μA at 500 s livetime to generate X-ray intensity data. The incident X-ray beam is approximately 1 cm in diameter. The K_α and L_α intensity data was collected for the following elements: barium (Ba), copper (Cu), gallium (Ga), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), niobium (Nb), rubidium (Rb), strontium (Sr), thorium (Th), titanium (Ti), yttrium (Y), zinc (Zn) and zirconium (Zr).[5] The X-ray intensities are converted to concentration values using a Compton scatter matrix correction and the linear regression of a set of Geological Survey of Japan (GSJ) standards. Inter-element effects are accounted for by using a Lucas-Tooth and Price correction. The estimated detection limits are listed in Appendix A. Appendix A also contains the X-ray counting and least squares linear regression fitting error uncertainty estimates.

To monitor the operation of the EDXRF unit, standards of known composition were run with the unknowns. The results are presented in Appendix B. The accuracy and precision, as measured by the coefficient of variation, are less than 20% for the majority of the elements measured in this study.

Since the sherds used in this study are classed as cultural properties, destructive analyses were not permitted. Before irradiation, each potsherd was rinsed with distilled, de-ionized water, and part of its cross-section lightly abraded with 180 grit silica paper. The abraded cross-section was

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[5] While calcium could be measured under these operating conditions, the majority of GSJ standards have less than 1% calcium or more than 5.5%. The absence of a calcium determination is unfortunate but probably not serious. However, calcium was measured in Late Jomon pottery from the Kanto region and proved to be an important element.

then scrubbed with distilled, de-ionized water and a nylon brush, and then rinsed with distilled, de-ionized water again. The sherds were air-dried.

While post-depositional chemical alteration could be a concern, it is not considered to be a significant one. First, many of the samples came from shell middens; the surrounding 'soil' would have been neutral or basic. Second, raw clay has a cation exchange capacity of 1–5%, but fired clay has a much lower cation exchange capacity (Hedges and McLellan 1976). Finally, gallium (Ga), niobium (Nb), thorium (Th), titanium (Ti), yttrium (Y) and zirconium (Zr), all elements measured in this study, are only mobile in extreme metamorphic conditions (Winchester and Floyd 1977).

All statistical operations were carried out with SPSS Release 8.0.

COMPOSITIONAL DATA AND ANALYSIS

Table 1 contains the trace element data for each sherd. All values are listed in parts per million (ppm). The elemental values were transformed to log base 10 values. The log transformation compensates for the differences in magnitude between the minor and trace elements, and is believed to 'normalize' the data (Wilson 1978, 226, 227; Peisach *et al.* 1982, 355, 356; Pollard 1986, 69–71). For cases below the detection limit, one half of the detection limit was used in the transformation and subsequent data analysis.

Principal components analysis (PCA) is a commonly used technique in ceramic studies to examine the structure in the data set and examine the relationship between the archaeological variables and chemical composition (Baxter 1994, 48). PCA was done on the correlation matrix of the log-transformed data. The log-transformed niobium concentration was left out of the analysis due to the high number of cases being below the detection limit. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy equals 0.634. The KMO measure compares the magnitudes of the observed correlation coefficient to the partial correlation coefficients (Norušis 1993, 52, 53). Values approaching one are considered excellent, while values below 0.5 indicate that there is little correlation in the data and that PCA is not a suitable statistical technique. A value between 0.60 and 0.70 is considered mediocre.

Varimax rotation was done to enhance the group separation. The varimax-rotated component matrix is presented in Table 2; the first five principal components account for 74% of the variation in the data.

Visual examination of the bivariate and trivariate plots of the principal components indicates that there are possibly four main groups and some outliers in the data set (Figs 2 and 3). While there is overlap, the four groups correspond with site location. Outliers in the PCA are a:mb:002, k:uk2:008, n:uk:137 and s:mb:007. No obvious patterns were visible in the plots of the PCA scores and pottery type.

Discriminant analysis was carried out on the log-transformed variables in order to assess group validity. The groups used are based on site location. The four outliers were not included in the analysis. Linear discriminant analysis (LDA) with cross-validation correctly classifies 80.7% of the cases (see Fig. 4). The misclassified cases and their predicted groups are in Table 3. Stepwise discriminant analysis (SDA) with cross-validation was done to determine which variables were the most important discriminators. For a probability of F-to-enter of 0.05, a probability of F-to-remove of 0.10, and maximizing the Mahalanobis distance between groups, SDA correctly classifies 81.8% of the cases. SDA identifies Cu, Ga, Rb, Sr, Zn and Zr as the most discriminating elements.

Table 1 *Minor and trace element compositional data from the 92 potsherds. All values are in parts per million (ppm) and were determined as described in the text*

Sample	*Site*	*Type*	*Ti*	*Mn*	*Fe*	*Ni*	*Cu*	*Zn*	*Ga*	*Pb*	*Th*	*Rb*	*Sr*	*Y*	*Zr*	*Nb*	*Ba*
s:ma:001	Shouninzuka	Moroiso A	11 035	1065	40 145	43	131	114	33	68	16	54	143	26	212	9	892
s:ma:002	Shouninzuka	Moroiso A	9 958	574	37 170	21	70	70	23	50	10	44	88	18	177	7	748
s:mb:001	Shouninzuka	Moroiso B	10 147	851	68 136	40	108	73	23	32	13	59	76	13	185	6	1069
s:mb:002	Shouninzuka	Moroiso B	9 861	885	77 148	91	97	91	25	34	13	73	89	13	186	6	1162
s:mb:003	Shouninzuka	Moroiso B	8 272	1124	47 248	90	229	105	29	28	12	61	85	25	175	8	1011
s:mb:004	Shouninzuka	Moroiso B	8 458	872	64 675	32	104	94	21	24	14	129	77	nd	180	6	1084
s:mb:005	Shouninzuka	Moroiso B	10 328	1057	48 837	103	128	126	25	25	11	73	148	14	161	6	922
s:mb:006	Shouninzuka	Moroiso B	11 302	961	113 690	596	111	83	21	13	nd	12	97	18	139	nd	1019
s:mb:007	Shouninzuka	Moroiso B	2 678	307	22 607	46	19	25	15	12	nd	23	40	21	88	24	222
s:mb:008	Shouninzuka	Moroiso B	10 839	1196	84 529	260	105	140	29	68	17	64	87	19	211	10	1279
s:mb:009	Shouninzuka	Moroiso B	12 236	866	43 837	171	115	110	28	63	14	38	121	22	206	7	826
s:mb:010	Shouninzuka	Moroiso B	9 348	892	68 397	60	103	87	25	31	13	71	82	11	181	7	1132
s:mb:011	Shouninzuka	Moroiso B	10 922	921	78 517	63	78	94	23	33	14	54	76	12	191	7	1202
s:mb:012	Shouninzuka	Moroiso B	8 518	944	61 901	41	84	83	28	21	10	77	76	11	176	8	1102
s:mb:013	Shouninzuka	Moroiso B	8 031	979	60 546	27	79	79	26	15	10	74	84	10	184	7	1048
s:uk:001	Shouninzuka	Ukishima	12 054	899	34 690	39	228	81	25	37	11	48	117	25	140	nd	799
s:uk:002	Shouninzuka	Ukishima	9 515	1161	60 337	54	125	81	27	24	11	43	92	19	187	nd	1046
s:uk:003	Shouninzuka	Ukishima	11 984	572	41 721	36	79	108	27	26	10	39	81	19	157	6	839
s:uk:004	Shouninzuka	Ukishima	8 534	1457	42 779	54	91	79	28	27	12	78	65	20	196	7	1059
s:uk:005	Shouninzuka	Ukishima	10 994	666	35 720	52	109	91	27	17	13	65	88	23	152	7	892
s:uk:006	Shouninzuka	Ukishima	10 031	795	49 254	56	92	93	29	16	10	59	57	17	199	7	1026
s:uk:007	Shouninzuka	Ukishima	9 773	1416	56 462	32	95	97	30	78	16	46	100	19	174	7	1007
s:uk:008	Shouninzuka	Ukishima	9 164	782	42 308	24	146	60	26	61	12	65	70	23	227	7	956
s:uk:009	Shouninzuka	Ukishima	10 509	1036	37 918	24	207	65	22	71	14	69	75	20	152	nd	951
s:uk:010	Shouninzuka	Ukishima	11 843	824	45 764	28	89	101	25	47	12	46	85	18	154	5	930
s:uk:011	Shouninzuka	Ukishima	9 397	625	37 696	31	79	61	22	41	12	54	69	18	193	6	868
s:uk:012	Shouninzuka	Ukishima	10 224	1139	35 713	40	83	78	26	32	11	53	111	16	143	nd	820
s:uk:013	Shouninzuka	Ukishima	8 881	1076	45 511	42	138	58	22	21	11	34	131	17	151	nd	877
s:uk:014	Shouninzuka	Ukishima	9 736	670	33 715	23	138	64	25	20	11	61	58	23	186	7	850
s:uk:015	Shouninzuka	Ukishima	11 756	748	40 132	48	77	93	28	21	nd	36	97	17	162	6	910
s:uk:016	Shouninzuka	Ukishima	8 978	856	40 317	42	173	80	26	58	13	58	71	23	200	6	930
s:uk:017	Shouninzuka	Ukishima	9 207	647	46 574	24	96	60	22	15	12	55	61	17	170	7	963
s:uk:018	Shouninzuka	Ukishima	10 382	1370	54 485	62	85	80	30	20	9	40	102	17	188	6	1001

Table 1 *(continued)*

Sample	*Site*	*Type*	*Ti*	*Mn*	*Fe*	*Ni*	*Cu*	*Zn*	*Ga*	*Pb*	*Th*	*Rb*	*Sr*	*Y*	*Zr*	*Nb*	*Ba*
n:uk:136	Narita 60	Ukishima	10 347	1356	37 448	29	106	53	24	23	9	50	90	14	212	7	839
n:uk:137	Narita 60	Ukishima	9 196	633	44 217	70	54	25	nd	11	nd	35	70	nd	186	nd	691
n:uk:138	Narita 60	Ukishima	10 865	795	61 372	29	86	63	21	27	12	38	52	16	200	6	967
n:uk:139	Narita 60	Ukishima	12 033	937	56 866	32	106	52	24	26	10	44	69	16	185	nd	957
n:uk:140	Narita 60	Ukishima	10 859	693	45 380	32	69	35	15	25	5	41	51	15	184	6	753
n:uk:141	Narita 60	Ukishima	8 402	867	54 928	41	102	60	21	26	8	37	59	13	200	nd	1040
n:uk:142	Narita 60	Ukishima	9 754	982	48 281	29	80	33	17	18	7	38	68	12	190	nd	913
n:uk:143	Narita 60	Ukishima	14 815	1140	58 695	28	70	66	21	18	11	34	56	20	160	6	946
n:uk:144	Narita 60	Ukishima	9 500	965	46 317	24	88	39	18	56	13	41	79	15	192	nd	884
n:uk:145	Narita 60	Ukishima	10 828	742	54 509	29	103	46	23	35	10	39	60	15	180	5	896
n:uk:146	Narita 60	Ukishima	6 018	678	38 157	20	64	32	18	42	9	27	45	12	138	6	716
n:uk:147	Narita 60	Ukishima	8 817	541	53 998	32	81	49	29	50	13	34	45	14	183	nd	847
n:uk:148	Narita 60	Ukishima	5 451	533	42 760	21	42	40	21	60	9	34	57	12	130	6	793
n:uk:149	Narita 60	Ukishima	14 834	1118	62 141	28	86	92	25	59	nd	36	46	14	142	nd	941
n:uk:150	Narita 60	Ukishima	14 701	918	55 777	29	81	50	23	55	7	30	54	14	154	nd	830
k:mb:001	Kamikaizuka	Moroiso B	11 026	617	43 359	24	69	77	23	14	9	45	89	13	219	8	800
k:mb:002	Kamikaizuka	Moroiso B	10 793	1002	47 342	30	79	94	28	24	13	59	101	14	222	9	901
k:mb:003	Kamikaizuka	Moroiso B	7 514	579	34 254	31	43	86	25	29	15	132	123	12	181	nd	975
k:mb:004	Kamikaizuka	Moroiso B	10 112	540	42 847	29	49	68	27	24	11	37	169	13	241	10	772
k:mb:005	Kamikaizuka	Moroiso B	8 518	566	73 591	32	53	78	20	21	9	44	107	nd	209	6	1017
k:mb:006	Kamikaizuka	Moroiso B	7 890	720	33 262	41	77	100	20	18	15	122	124	16	205	8	838
k:mb:007	Kamikaizuka	Moroiso B	8 832	822	41 053	23	79	81	29	59	15	75	66	18	178	8	897
k:mb:008	Kamikaizuka	Moroiso B	8 751	772	65 304	70	64	62	23	58	15	35	107	16	153	6	920
k:mb:009	Kamikaizuka	Moroiso B	10 304	714	45 812	32	64	76	25	90	15	59	92	12	218	8	887
k:mb:010	Kamikaizuka	Moroiso B	8 380	3037	48 533	29	72	80	27	70	17	74	94	20	172	12	1051
k:mb:011	Kamikaizuka	Moroiso B	5 890	657	50 781	41	49	65	15	54	14	62	84	15	129	8	766
k:uk:001	Kamikaizuka	Ukishima	7 597	756	44 612	30	62	65	20	27	nd	64	89	13	186	nd	930
k:uk:002	Kamikaizuka	Ukishima	8 471	762	28 020	36	60	57	24	38	12	66	101	12	145	nd	818
k:uk:003	Kamikaizuka	Ukishima	5 834	587	10 272	77	55	31	25	48	9	26	28	nd	68	nd	637
k:uk:004	Kamikaizuka	Ukishima	9 412	782	29 304	16	83	58	17	20	8	51	100	13	147	nd	765
k:uk:005	Kamikaizuka	Ukishima	10 990	686	39 004	22	55	81	24	84	15	57	153	14	158	nd	836
k:uk:006	Kamikaizuka	Ukishima	10 196	570	34 320	21	39	44	18	58	9	56	106	16	143	nd	737
k:uk:007	Kamikaizuka	Ukishima	9 317	681	47 117	29	42	66	22	66	13	74	77	12	190	6	931

Table 1 *(continued)*

Sample	*Site*	*Type*	*Ti*	*Mn*	*Fe*	*Ni*	*Cu*	*Zn*	*Ga*	*Pb*	*Th*	*Rb*	*Sr*	*Y*	*Zr*	*Nb*	*Ba*
k:uk:008	Kamikaizuka	Ukishima	9 293	433	42 666	26	42	45	nd	31	8	54	68	nd	169	nd	933
k:uk:009	Kamikaizuka	Ukishima	7 528	532	17 918	11	22	31	nd	46	12	40	91	15	135	nd	686
k:uk2:001	Kamikaizuka	Ukishima	7 241	462	53 903	43	50	48	19	48	9	53	60	nd	144	nd	941
k:uk2:002	Kamikaizuka	Ukishima	8 507	710	49 361	39	45	68	17	81	10	39	113	nd	115	nd	988
k:uk2:003	Kamikaizuka	Ukishima	6 914	490	38 300	20	57	51	20	56	14	88	162	15	269	6	971
k:uk2:004	Kamikaizuka	Ukishima	8 595	499	35 987	24	63	74	25	59	16	67	117	13	148	nd	826
k:uk2:005	Kamikaizuka	Ukishima	8 399	584	48 298	32	77	55	24	62	15	55	105	12	144	nd	929
k:uk2:006	Kamikaizuka	Ukishima	6 598	368	25 350	32	21	54	18	56	13	47	101	18	131	nd	691
k:uk2:007	Kamikaizuka	Ukishima	8 806	351	45 460	22	19	46	20	67	12	62	95	9	149	nd	893
k:uk2:008	Kamikaizuka	Ukishima	8 936	788	36 543	62	86	68	24	88	12	42	80	nd	174	nd	984
k:uk2:009	Kamikaizuka	Ukishima	9 821	805	70 481	29	90	98	23	38	11	60	172	11	163	nd	1041
k:uk2:010	Kamikaizuka	Ukishima	9 940	453	33 539	20	95	49	21	30	11	46	103	15	160	nd	748
a:mb:001	Ariyoshi-kita	Moroiso B	16 765	1160	102 504	170	117	208	30	27	12	50	134	27	251	10	1379
a:mb:002	Ariyoshi-kita	Moroiso B	9 018	465	39 137	59	60	91	nd	13	nd	49	243	nd	127	nd	771
a:mb:003	Ariyoshi-kita	Moroiso B	12 414	1008	77 895	54	89	134	19	18	11	82	92	17	178	9	1254
a:mb:004	Ariyoshi-kita	Moroiso B	11 379	1023	47 812	58	89	132	28	19	11	86	257	15	177	6	878
a:mb:005	Ariyoshi-kita	Moroiso B	11 441	892	48 573	53	98	174	25	18	12	85	271	12	168	6	980
a:mb:006	Ariyoshi-kita	Moroiso B	9 220	1748	55 549	55	269	130	23	21	14	136	214	15	173	nd	1103
a:mb:007	Ariyoshi-kita	Moroiso B	11 793	963	62 767	70	77	148	23	15	12	91	208	15	179	7	1091
a:mb:008	Ariyoshi-kita	Moroiso B	8 524	547	31 475	23	56	84	27	43	9	46	663	15	141	nd	585
a:mb:009	Ariyoshi-kita	Moroiso B	7 483	1619	56 633	37	88	133	22	84	20	116	188	16	190	7	1148
a:mb:010	Ariyoshi-kita	Moroiso B	9 852	2017	56 908	61	115	138	20	73	17	89	158	16	176	nd	1193
a:mb:011	Ariyoshi-kita	Moroiso B	12 257	1415	38 982	152	141	164	22	36	11	47	324	21	187	6	862
a:mb:012	Ariyoshi-kita	Moroiso B	7 198	726	25 846	29	55	106	17	75	11	100	186	14	131	nd	791
a:mb:013	Ariyoshi-kita	Moroiso B	9 578	1187	62 394	31	111	61	20	54	nd	58	226	15	125	nd	984
a:mb:014	Ariyoshi-kita	Moroiso B	8 898	736	35 151	27	61	135	21	73	9	55	194	nd	144	nd	803

Table 2a *Factor loading matrix after varimax rotation*

Variable (log-transformed)	*Component 1*	*Component 2*	*Component 3*	*Component 4*	*Component 5*
Ti	0.804	0.053	0.069	−0.054	0.014
Mn	0.804	0.387	0.244	0.043	0.028
Fe	0.804	0.031	−0.019	0.273	−0.309
Ni	0.394	0.246	0.336	−0.283	−0.454
Cu	0.688	0.053	0.153	−0.077	0.003
Zn	0.456	0.319	0.713	0.217	−0.064
Ga	0.315	0.716	0.072	0.094	0.265
Pb	−0.068	0.091	0.022	0.016	0.826
Th	0.094	0.455	0.233	0.511	0.533
Rb	0.022	0.002	0.513	0.713	0.191
Sr	0.048	−0.071	0.881	0.048	0.036
Y	0.137	0.814	−0.006	−0.030	−0.018
Zr	0.491	0.181	−0.094	0.656	−0.146
Ba	0.824	−0.042	0.141	0.412	0.139

Table 2b *Eigenvalues and percentage of total variance explained*

Component	*Eigenvalue*	*% Variance*	*% Cumulative variance*
1	3.551	23.671	23.671
2	2.294	15.296	38.967
3	1.840	12.268	51.236
4	1.711	11.406	62.642
5	1.675	11.164	73.806

Table 4 lists the average elemental values for each group. The elemental values for the outliers are also presented in Table 4.

DISCUSSION

The results of the statistical analyses point to there being four distinct groups in the chemical data that coincide with the four sites. Both the PCA and LDA indicate that there is overlap between the chemistry of the pottery from Kamikaizuka and Shouninzuka. Given the proximity of these two sites, it is likely that the potters at each of these two sites were using the same raw material resources or nearby raw materials, that had a very similar geochemistry. Ethnographic work by Arnold (1971, 1989, 1992) has demonstrated that potters will exploit raw materials within 10 km of their residence. The remaining two groups correspond to Ariyoshi-kita shell midden and the Narita 60 site respectively. Like the previous work by Habu and Hall (1999) and Kojo (1981, 1986), these results support the hypothesis that each settlement produced its own pottery, utilizing local clay and temper resources.

The trace element chemistry of the outliers points to them having an origin outside of the four sites studied here. None of the sherds have any unusual features for their respective styles. Th and Y contents below the detection limit of the EDXRF unit characterize three of the four

Table 3 *Misclassified cases from the linear discriminant analysis*

Sample number	*Site*	*LDA, predicted group*
a:mb:001	Ariyoshi-kita	Shouninzuka
k:mb:001	Kamikaizuka	Narita 60
k:mb:006	Kamikaizuka	Ariyoshi-kita
k:mb:007	Kamikaizuka	Shouninzuka
k:mb:010	Kamikaizuka	Shouninzuka
k:uk:001	Kamikaizuka	Shouninzuka
k:uk:003	Kamikaizuka	Shouninzuka
k:uk2:002	Kamikaizuka	Ariyoshi-kita
k:uk2:009	Kamikaizuka	Ariyoshi-kita
n:uk:141	Narita	Shouninzuka
n:uk:148	Narita	Kamikaizuka
s:mb:002	Shouninzuka	Kamikaizuka
s:mb:004	Shouninzuka	Kamikaizuka
s:mb:005	Shouninzuka	Narita 60
s:mb:006	Shouninzuka	Ariyoshi-kita
s:mb:011	Shouninzuka	Kamikaizuka

outliers. The outlier s:mb:007 is characterized by a higher Y and Nb content and a lower Fe, Mn, Ti and Zr content than the four groups.

The Kamikaizuka and Shouninzuka sites both contain Moroiso- and Ukishima-style pottery that belong to the same geochemical group. This would indicate that both styles of pottery were made from the same or geochemically similar raw materials, and were probably made at the

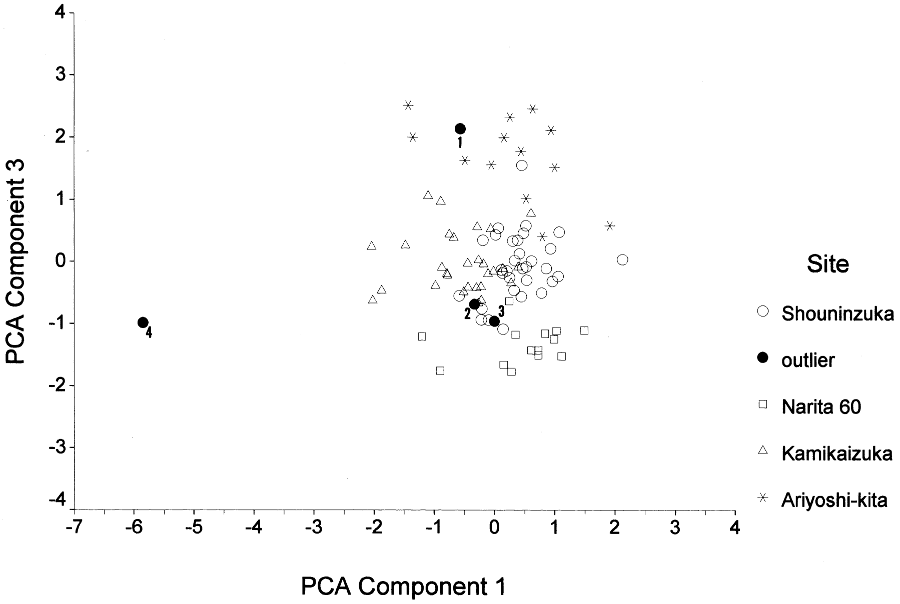

Figure 2 *A plot of the first and third principal component scores. The outliers are noted as follows: 1, a:mb:002; 2, k:uk2:008; 3, n:uk:137; 4, s:mb:007.*

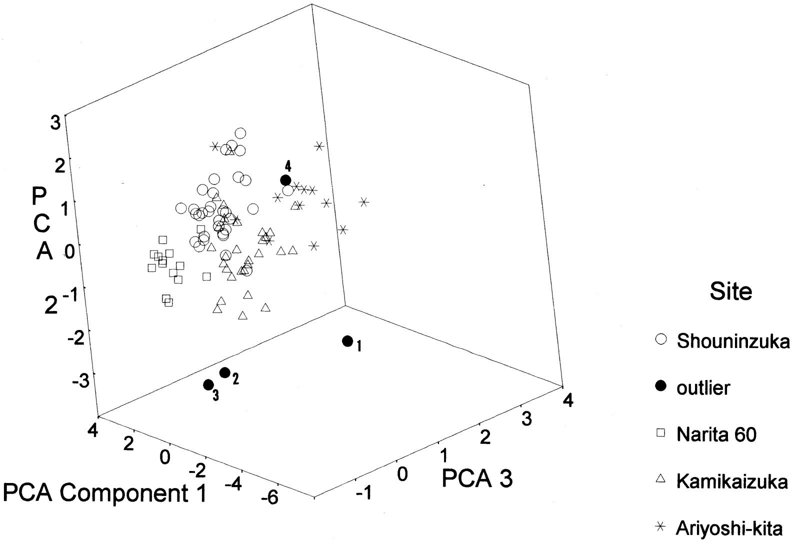

Figure 3 *A plot of the first three principal component scores. The outliers are noted as in Figure 2.*

same site. Similar results were obtained in Kojo's (1986) study of pottery from the Okitsu site. At that site, petrographic analysis indicated that similar materials were used to manufacture Ukishima- and Okitsu-style pottery, and possibly some of the Moroiso-style pottery.

If, as advocated by Kobayashi (1992) and Yamanouchi (1969), the different pottery styles

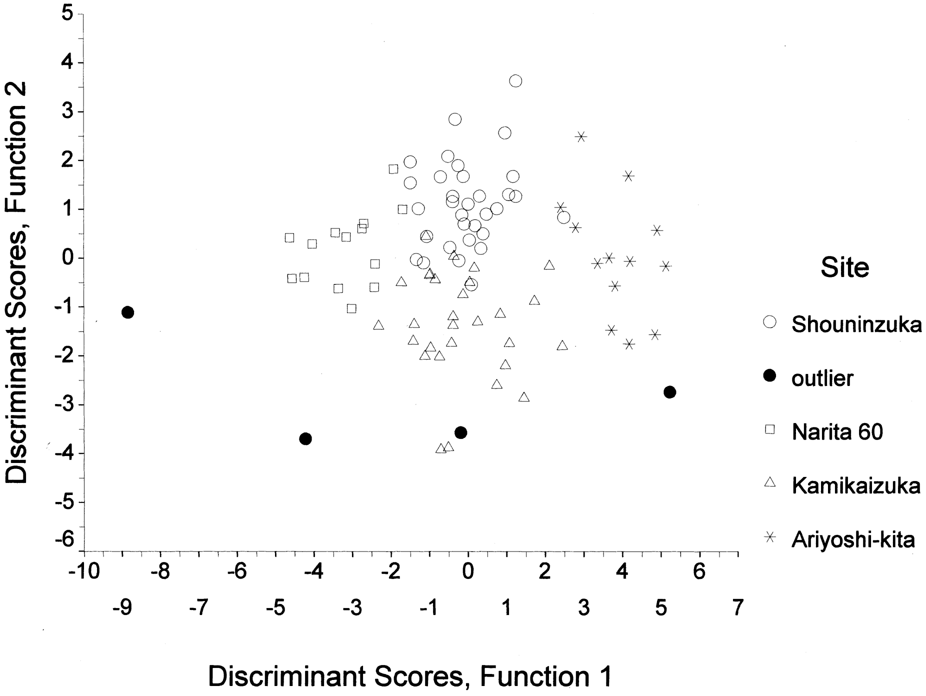

Figure 4 *A plot of the first two discriminant functions for the four geochemical groups based on site location.*

Table 4 *Mean elemental values with the standard deviation for the four groups and the outliers. All values are in parts per million (ppm). The number of cases forming each group is represented by n*

Element	*Ariyoshi-kita (n = 13)*	*Kamikaizuka (n = 30)*	*Narita 60 (n = 14)*	*Shouninzuka (n = 33)*	*a:mb:002*	*k:uk2:008*	*n:uk:137*	*s:mb:007*
Ti	10 523 ± 2 561	8 659 ± 1 419	10 516 ± 2 937	10 069 ± 1 188	9 018	8 936	9 196	2 678
Mn	1 157 ± 433	720 ± 469	876 ± 234	935 ± 231	465	788	633	307
Fe	54 038 ± 20 488	41 859 ± 13 854	51 188 ± 8 141	52 371 ± 17 832	39 137	36 543	44 217	22 607
Ni	63 ± 46	33 ± 15	29 ± 5	73 ± 106	59	62	70	46
Cu	105 ± 55	59 ± 20	83 ± 18	115 ± 42	60	86	54	19
Zn	134 ± 37	65 ± 18	50 ± 16	87 ± 19	91	68	25	25
Ga	23 ± 4	22 ± 4	21 ± 4	26 ± 3	nd	24	nd	15
Pb	43 ± 26	49 ± 22	37 ± 16	35 ± 19	13	88	11	12
Th	12 ± 3	12 ± 3	9 ± 2	12 ± 2	nd	12	nd	nd
Rb	80 ± 28	60 ± 24	37 ± 8	57 ± 20	49	42	35	23
Sr	240 ± 140	104 ± 31	59 ± 13	89 ± 23	243	80	70	40
Y	16 ± 4	13 ± 4	14 ± 2	18 ± 5	nd	nd	nd	21
Zr	171 ± 32	160 ± 41	175 ± 26	178 ± 22	127	174	186	88
Nb	5 ± 2	5 ± 3	4 ± 1	6 ± 2	nd	nd	nd	24
Ba	1 004 ± 219	868 ± 111	880 ± 89	976 ± 124	771	984	691	222

reflect group or ethnic identity, then the above results imply that ‘Moroiso people’ and ‘Ukishima people’ were residing with one another. One possible explanation for this could be inter-community marriage (Sasaki 1981, 1982). Harunari’s (1986) study of Jomon tooth extraction patterns suggests that there was uxorilocal residence in eastern Japan during the Early Jomon period. Following this line of evidence then, we would then have to conclude that men were involved in making pottery.

Alternatively, the pottery styles could be reflecting something other than ethnic or group identity. As has been noted by a variety of authors (Clarke 1978, 299–315; Cullen 1985; Hodder 1986, 354; Hodder 1990), ethnic or tribal identity does not always have direct material correlates. Pottery styles could be ways of maintaining alliances, ceremonial ties or exchange relationships, or could reflect the level of social interaction (Cullen 1985, 77–9; Earle 1990, 73–6; Plog 1990, 62).

While the misclassification in the discriminant analyses between the Kamikaizuka and Shouninzuka sites could be due to using the same raw material resources, the remaining misclassifications could be due to some form of contact between the four Early Jomon groups. The driving force behind the pottery movement is not clear. It is feasible that pottery could have been used as containers for exchange goods during the Early Jomon. Long-distance trade of obsidian, jade and amber was practiced throughout the Jomon period (Suzuki 1973, 1974; Warashina and Higashimura 1995; Osawa *et al.* 1977). Given the fact that most of Chiba Prefecture and the Tone river basin lacks any stone resources whatsoever, Jomon groups residing in this area had to have exchange or trade networks for stone or stone tools.

Alternatively, it must also be kept in mind that the accuracy and precision of the EDXRF analyses could be causing the overlap and misclassification. As noted by both Bishop *et al.* (1990, 540) and Wilson (1978, 222), when the precision and accuracy of an analytical method are greater than 5%, the method can often fail to distinguish geochemically similar, but chemically different, groups.

CONCLUSIONS

The results of this study suggest that the majority of Early Jomon pottery found at four sites in Chiba Prefecture was made from locally available raw materials. This is similar to the findings of Habu and Hall (1999) and Kojo (1981, 1986) for other Early Jomon sites in the Kanto region. While the Kamikaizuka and Shouninzuka groups overlap, both sites are less than 10 km apart and their potters could have shared the same raw material sources. Both discriminant analysis and outlier detection methods suggest that the movement of pottery between settlements appears to be limited.

With the Moroiso and Ukishima pottery from the Kamikaizuka and Shouninzuka sites being made from the same raw materials, the simple notion of equating style with ethnic identity is challenged. It is quite possible that style is not only reflecting ethnic identity in the Early Jomon period, but also reflecting social ties between different ethnic groups. Further studies on Moroiso and Ukishima pottery from sites elsewhere in the Kanto plain are needed to resolve this issue.

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APPENDIX A

Estimated detection limits and X-ray counting and least squares linear regression error. The detection limits are the smallest amounts that can be quantitatively measured. These limits are defined as the signal that is six standard deviation units above the background. For Fe and Ti, though, these are the lowest concentrations in the GSJ standard used to calibrate the EDXRF unit

Element	*Detection limit*	*Error*
Ti	260	300
Mn	50	100
Fe	500	1900
Ni	10	7
Cu	7	8
Zn	20	7
Ga	15	1
Pb	10	3
Th	8	2
Rb	7	7
Sr	10	13
Y	10	2
Zr	6	6
Nb	6	3
Ba	100	85

APPENDIX B

Elemental values for two GSJ standards run with the unknowns. All values are in parts per million (ppm). The term 'nd' stands for not detected, while 'na' stands for 'not available'

Variable	*JG3 (Hallet and Kyle 1993)*	*JG3 (this study, n = 9)*	*Accuracy (%)*	*JB3 (Hallet and Kyle 1993)*	*JB3 (this study, n = 6)*	*Accuracy (%)*
Ti	3 086	3 057	0.9	8 633	8 292	3.9
Mn	610	542	12.6	1 316	1 251	5.0
Fe	24 448	27 418	10.8	82 184	77 126	6.2
Ni	16	14.3	9.6	33.8	34	1.6
Cu	7	7	0	201	165	18
Zn	48	42	14.8	95	83	13
Ga	17	17	0	18.2	16	12.1
Pb	12	12	0	4.5	nd	na
Th	10	8	22.2	1.2	nd	na
Rb	74	67	11.1	14	14	0
Sr	377	365	3.4	417	392	6.1
Y	18	18	0	28	20	29.2
Zr	130	140	7.3	97	91	6.4
Nb	5	7	30.2	4.7	nd	na
Ba	426	471	9.5	245	306	24.8