

## CALIBRATED <sup>14</sup>C AGES OF JOMON SITES, NE JAPAN, AND THEIR SIGNIFICANCE

Kunio Omoto<sup>1</sup> • Kenji Takeishi<sup>2</sup> • Shigeru Nishida<sup>3</sup> • Junichi Fukui<sup>3</sup>

**ABSTRACT.** The traditional archaeological chronology in the Japanese Islands during the Jomon period was essentially based on the relative age given to cord-impressed patterns marked on pottery, as well as the shape of the pottery and the thickness of the cultural layers that were excavated. We aimed to correlate the classical archaeological chronology with calibrated radiocarbon dates, to posit a new chronology for the Jomon period in northeastern Japan. We calibrated 80 accelerator mass spectrometry (AMS) <sup>14</sup>C dates from NE Japan and reconstructed a chronological timetable for Hokkaido and the Tohoku District. We collected 43 samples from 5 shellmounds and 2 archaeological sites on Hokkaido Island and 4 shellmounds in the Tohoku District in order to determine the calibrated age of their sites.  $\Delta R$  values used on Hokkaido Island and the Tohoku District were between 282 and -158 yr and between  $\pm 0$  and -40 yr, respectively. The large  $\Delta R$  value for the eastern part of Hokkaido Island indicates the influence of the Oyashio Current, while an anomalous  $\Delta R$  value was obtained from northern Hokkaido Island. These figures show larger apparent  $\Delta R$  values than those from southwest Japan (Nakamura et al. 2007). The calibrated Jomon period in the investigated area was from 2000 to 200 yr younger than the previous chronology. Calibrated <sup>14</sup>C ages of the shellmounds investigated ranged between ~6000 and 3000 yr, correlating to the Early Jomon and Final Jomon periods as indicated by the former archaeological chronology of Honshu Island.

### INTRODUCTION

Archaeologists have employed numerous methods to determine the age of excavated sites. The study of archaeological timescales is very important, especially in classifying the time period of a culture and its correlation to other sites. After World War II, many Japanese people were taught that their prehistoric culture was classified into the Stone Age (Paleolithic and Neolithic), the Jomon period, and the Yayoi period. Archaeologists estimated that the beginning of the Jomon and the Yayoi should be dated to 4500 and 2500 BP, respectively.

The first reported radiocarbon age of archaeological samples in Japan was skeptically received. According to Crane and Griffin (1960), Sugihara and Serizawa from Meiji University submitted sent to the University of Michigan shell and charcoal samples collected from Natsushima shellmound, Yokohama. The shell samples were collected from the second or first cultural layer from the bottom of the mound, and designated Natsushima I. This assemblage was considered the earliest manifestation of the Jomon period, the earliest known ceramic culture in Japan (Serizawa 1959). The oyster shell sample was dated  $9450 \pm 400$  BP (M-769) while the charcoal was  $9240 \pm 500$  BP (M-770). Most Japanese archaeologists were surprised at this report and few believed in the accuracy of the dates. Many at that time continued to believe that the earliest Jomon period began ~4500 BP.

Some 40 yr later, <sup>14</sup>C dates from the earliest Jomon period have been revealed. The Odaiyamamoto I Site Excavation Team (1999) excavated a site in Kanita, Aomori Prefecture, named the Odai Yamamoto I site. At the site, they found several fragments of charcoal and pottery without cord-impressed patterns. Nakamura and Tsuji (1999) reported <sup>14</sup>C ages of charcoal samples accelerator mass spectrometry (AMS) dated at Nagoya University. The oldest calibrated date was given as 16,520 cal BP (Nakamura and Tsuji 1999; Nakamura et al. 2001). The age of this sample revealed that the pottery was the oldest known in Japan, preceding by 4500 yr the common view that prevailed among Japanese archaeologists at that time. Following the above report, the National

<sup>1</sup>Department of Geography, College of Humanities and Sciences, Nihon University, Setagaya, Tokyo 156-8550, Japan. Corresponding author. Email: omoto@chs.nihon-u.ac.jp.

<sup>2</sup>Department of History, College of Humanities and Sciences, Nihon University, Setagaya, Tokyo 156-8550, Japan.

<sup>3</sup>Inquiry Section, Hokkaido Archaeological Operations Center, Ebetsu, Hokkaido 069-0832, Japan.

Museum of History and Culture of Japan announced in March 2003 that the Yayoi period began 500 yr prior to the chronology accepted at the time. The  $^{14}\text{C}$  dates of Nakamura and Tsuji (1999) were also verified at several AMS  $^{14}\text{C}$  facilities in order to confirm their accuracy and reliability. The samples used for dating were from soot attached to pottery fragments collected mainly from Kyusyu Island (western Japan).

The  $^{14}\text{C}$  dating method was introduced in Japan in the beginning of the 1960s; however, most Japanese  $^{14}\text{C}$  laboratories reported their results without measuring isotope fractionations. This means that they reported not conventional ages but raw measured ages. Without isotope correction, we are unable either to report the correct  $^{14}\text{C}$  age or to calibrate it to a calendar age. Archaeologists collected different kinds of materials from the same layer in the site and sent them for  $^{14}\text{C}$  analysis. They expected to receive similar ages for materials collected from the same layer; thus, when they received unexpectedly different  $^{14}\text{C}$  ages, they felt they could no longer trust  $^{14}\text{C}$  ages.

Since W F Libby and his colleagues established the  $^{14}\text{C}$  dating method in the late 1940s, many advances in  $^{14}\text{C}$  dating techniques have been made. At present, it is possible to date carbon material as small as 1 mg with great precision by AMS  $^{14}\text{C}$  dating. However, many Japanese archaeologists still prefer their own relative chronology instead of the calibrated  $^{14}\text{C}$  ages. Recently, the situation has improved and more archaeologists are relying on AMS  $^{14}\text{C}$  data. Considering this historical background, we strongly urge the use of AMS  $^{14}\text{C}$  data and the correlation of classical archaeological chronology with calibrated  $^{14}\text{C}$  ages to reconstruct a new archaeological chronology for north-eastern Japan. In this paper, we report the results of our study carried out in the northern part of Japan.

## **METHODS AND RESULTS**

### **Methods**

Prehistoric people might have collected their food from not only hills and mountains but also lowlands, such as lagoons, rivers, lakes, and coasts. Many fish bones, empty shells, and other disposed items were dumped near their settlements. These places are usually called "shellmounds" and are very common sites in the Japanese Islands. The Japanese Islands face the Pacific Ocean, the Sea of Japan, the Sea of Okhotsk, and the East China Sea. Therefore, sample materials collected from the above coastal regions might have been subject to different environmental marine reservoirs. Without reservoir correction, we are unable to obtain correct ages or to construct an accurate chronology of archaeological sites. Fortunately, several reports exist with reference to reservoir correction around the Japanese Islands. To determine the reservoir correction of Hokkaido Island, 3 pairs of charcoal and marine samples were collected from the Asahi-Tokoro shellmounds, the Tenneru site (with shellmounds), and the Esan shellmounds. We also collected 2 pairs of charcoal and marine samples from the Sakiyama and Daigikakoi shellmounds in order to determine the reservoir correction on the east coast of Tohoku District. We used the marine data set of Hughen et al. (2004) to calculate the reservoir correction and the IntCal04 data set (Reimer et al. 2004) to calibrate conventional ages.

We calibrated 80 AMS  $^{14}\text{C}$  dates from sites in NE Japan in order to establish a new chronology for the Jomon period. We also collected 43 samples from 5 shellmounds and 2 archaeological sites in Hokkaido Island, as well as from 4 shellmounds in the Tohoku District. See Figure 1 for details.

$^{14}\text{C}$  dating and measurements of isotope fractionation of collected materials from the above-mentioned sites were carried out at the Radiocarbon Dating Laboratory of Nihon University by the  $\beta$ -

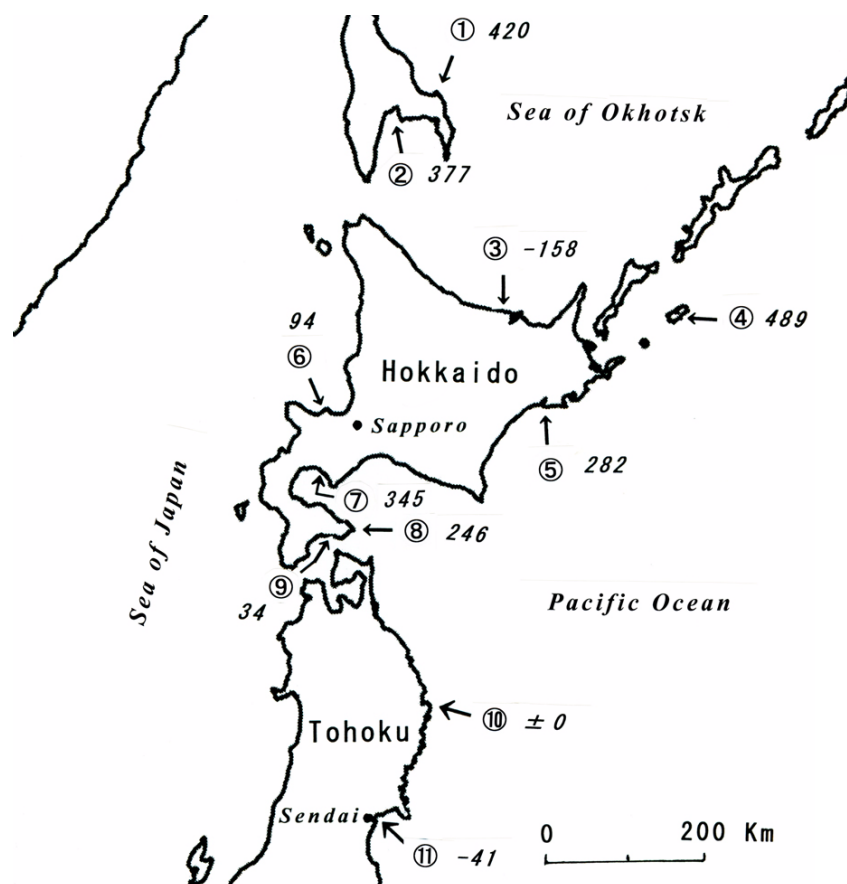


Figure 1  $\Delta R$  values given for Hokkaido Island and the Tohoku District. Five  $\Delta R$  values were newly added to the sites of 3, 5, 8, 10, and 11. Other  $\Delta R$  values in the figure were compiled from Kuzmin et al. (2007) and Yoneda et al. (2007). The  $\Delta R$  value for location 3 is temporal (see text). Locations: 1. Svobodnaya, Sakhalin; 2. Gulf of Aniva, Sakhalin; 3. Asahi-Tokoro shellmounds, Kitami, Hokkaido; 4. Shikotan Island, Hokkaido; 5. Tenneru site, Kushiro-cho, Hokkaido; 6. Otaru, Hokkaido; 7. Kitakogane shellmounds, Ponma site, and Takasago shellmounds, Hunka Bay; 8. Esan shellmounds, Esan-cho, Hokkaido; 9. Hokuto site, Hakodate, Hokkaido; 10. Sakiyama shellmounds, Miyako, Iwate Prefecture; 11. Daigikakoi, Satohama, and Nishihata shellmounds, Sendai Bay.

counting method. The equipment used for  $\beta$ -counting were 4 fully automatic gas counting systems and one Quantulus 1220<sup>TM</sup> machine. In order to determine reservoir corrections for surveyed sites, 3 pairs of charcoal and marine samples were sent to Nagoya University for AMS  $^{14}\text{C}$  dating. Isotope fractionations were measured by an IsoPrime mass spectrometer. We used NIST samples for checking the modern standard value, and IAEA and Oztech standard samples for isotope analysis. Sample pretreatments were carried out based on Omoto (1996). After isotope fractionation correction, ages of marine samples indicated very similar values.

## Results

Kuzmin et al. (2001) reported a  $\Delta R$  of  $711 \pm 46$  yr for Kunashir Island, northeast of Hokkaido, and pointed out the need for a greater value of reservoir correction for marine carbonates. More recently, Kuzmin et al. (2007) reported a  $\Delta R$  value of 578 yr for eastern Sakhalin Island and the Lesser Kuriles. Yoneda et al. (2001) reported apparent age differences between Japanese deer and northern

fur seals from 4500 to 800 BP with estimated  $\Delta R$  values  $\sim 380$  yr. Thereafter, Yoneda et al. (2004) reported a 720-yr reservoir correction based on marine organisms collected from the Kitakogane shellmounds, although they had reported a 860-yr  $\Delta R$  value based on northern fur seals and Japanese deer. More recently, Yoneda et al. (2007) reported significant variability in  $\Delta R$  for the western North Pacific and surrounding regions (Figure 1). The  $\Delta R$  values of the East Sakhalin Current, which flows from north to south, was 399 yr, while the Oyashio Current, which flows east off of Hokkaido, was 392 yr. The Soya Current and Tsugaru Current, on the other hand, gave smaller  $\Delta R$  values of 94 and 34 yr, respectively.

Comparisons of relative archaeological timetables with  $^{14}\text{C}$  ages have been made by several archaeologists. A  $^{14}\text{C}$  chronology based on archaeological materials collected from the prehistoric Japanese Islands was first reported by Watanabe (1963) who introduced 20  $^{14}\text{C}$  dates measured in the USA. He stated that several  $^{14}\text{C}$  dates previously reported had included incomprehensible ages compared with the former theory of the Archaeological Association of Japan. The  $^{14}\text{C}$  chronology of the Jomon and Yayoi periods was also presented by Watanabe (1966) who classified the Jomon period of Hokkaido and Honshu into the Initial, Early, Middle, and Late; and Early, Middle, Late, and Final periods, respectively. He also pointed out an important discrepancy in which  $^{14}\text{C}$  ages indicated younger ages when compared with dendrochronological ages. After Keally and Muto (1982) reported the first comprehensive summary of the Jomon period with  $^{14}\text{C}$  dates, Kobayashi (2006) compiled previous reports and correlated the former chronological table of the Jomon period with AMS  $^{14}\text{C}$  data.

Coauthor Fukui has prepared a data set listing more than 100 AMS  $^{14}\text{C}$  dates collected mainly from research reports of the Hokkaido Archaeological Operation Center (Hokkaido Maizoubunkazai Center), Aomori Prefecture Archaeological Operation Center, research reports of the City and Town Board of Education in NE Japan, reports of a scientific grant-in-aid of the Monbukagakusho (Usuki 2007; Nishimoto et al. 2009), and archaeological publications (Kobayashi 2006, 2008). (See the Appendix for full references information.) The lead author compiled and calibrated these ages using the IntCal04 calibration data. The results are shown in Table 1. The beginning of the Jomon period listed in Table 1 is based on the charcoal samples collected from Odai Yamamoto I site, Aomori Prefecture, whose age was 16,520 cal BP (Nakamura and Tuji 1999).

## DISCUSSIONS

### Reservoir Correction

The studies of  $\Delta R$  values around the Japanese Islands that were carried out by Yoneda et al. (2001, 2004, 2007) are highly regarded. However, there are no valuable data for both the Pacific and the Sea of Japan coast along the Tohoku District. We prefer to accept a  $\Delta R$  value of 345 yr (Yoneda et al. 2004) rather than accepting the 380-yr (Yoneda et al. 2001) or 720-yr  $\Delta R$  values (Yoneda et al. 2004) for the Kitakogane shellmounds along Hunka Bay, southern Hokkaido Island. They showed significant values for the sedentary marine organisms including porpoises and Japanese sea lions. However, porpoises, Japanese sea lions, and salmon often travel through oceans horizontally and vertically, and grow up eating many kinds of marine organisms. This means they have obviously been influenced by different marine reservoir environments and would indicate different older ages as compared with the ages of shallow water shells and fishes. Considering these ideas, we prefer not to use the 720-yr reservoir correction given for the Kitakogane shellmounds.

The  $\Delta R$  value for the north coast of Hokkaido Island (Asahi-Tokoro shellmounds) indicated an anomalous negative value ( $-158$  yr) compared with 377 yr (Yoneda et al. 2007), and 95 and 578 yr

Table 1 Division of the Jomon period based on calibrated ages of investigated sites in NE Japan. Full references are listed in the Appendix.

Period	Site name	cal BP		Lab code	cal BP	Material <sup>a</sup>	"Shape" (design)	Ref. <sup>b</sup>	
		(med)	Conv. BP						
Incipient	Odai Yamamoto 1	16,023	13,480 ± 70	Beta125550	16,000~16,270	charred wood	fragment of pottery	1	
	Taisyo 3	14,078	12,220 ± 40	Beta194627	14,110~14,290	Adh	nail-marked	2	
Initial	Pitarupa	9388	8410 ± 120	Beta159070	9072~9559	charred walnut	Akatuki	3	
	Nakano B	9031	8100 ± 90	Beta101800	8655~9250	charred walnut	Sumiyoshi-cho (Low)	4	
	Tomino 3	8905	8040 ± 50	Beta126225	8718~9034	charred seed	Monomidai	5	
	Taisyo 3	7994	7185 ± 35	PLD11927	7935~8050	charred wood	Urahoro	6	
	Tomino 3	7826	6990 ± 50	Beta126222	7700~7770	charred wood	Higashikushiro II	5	
	Taisyo 8	7881	7040 ± 40	Beta226591	7790~7950	carbide	Higashikushiro II, III	7	
	Kiusu 7	7747	6910 ± 60	Beta112927	7675~7810	charred wood	Kottaro	8	
	Yukanboshi E14	7604	6740 ± 50	IAAA51502	7563~7673	charred wood	Kottaro	9	
	Toyooka 6	7525	6640 ± 40	Beta150149	7497~7568	charred wood	Nakacharo?	10	
	Kamaya-cho 3	7239	6310 ± 60	Beta152884	7200~7280	charred wood	Higashikushiro IV	11	
	Ohiwa 5	7353	6420 ± 50	Beta186224	7315~7418	charred wood	Ko-g lower	12	
	Early	Kikyo 2	6889	6040 ± 50	Beta239903	6750~7000	Adh	Kikyono	13
Ohiwa 5		6581	5780 ± 50	Beta186223	6529~6640	charred wood	Ko-f lower	12	
Ryamunai 3		6084	5305 ± 30	PLD3415	5990~6180	charred walnut	Kasugacho	14	
Tenneru 1		5815	5085 ± 33	IAAA62002	5740~5920	charred wood	Higashikushiro V	15	
Kojohama 2		5817	5080 ± 40	Beta150487	5737~5914	charred wood	lower of cylinder-a	16	
Ohyasawanoda		5815	5050 ± 40	Beta119438	5804~5889	carbonate	lower of cylinder-a	17	
Sannaimaruyama		5508	4780 ± 70	Beta127603	5465~5594	carbonate	lower of cylinder-b	17	
Yamazaki 5		5514	4780 ± 50	Beta150466	5447~5603	carbonate	lower of cylinder-b	18	
Yamazaki 5		5506	4760 ± 50	Beta150463	5446~5593	carbonate	lower of cylinder-c	18	
Higashiyama 1		5407	4670 ± 50	Beta174642	5344~5423	charred wood	lower of cylinder-c?	19	
Sannaimaruyama		5395	4640 ± 60	Beta112351	5350~5466	charred wood	lower of cylinder-d2	17	
Middle		Sannaimaruyama	5400	4640 ± 50	Beta112348	5374~5455	charred wood	upper of cylinder-a	17
		Sannaimaruyama	5403	4678 ± 40	NUTA2-625	5343~5418	Adh	upper of cylinder-b	17
		Tateno 4	5162	4520 ± 40	IAAA51664	5046~5310	charred wood	upper of cylinder-b	20
		Yukanboshi E14	5177	4560 ± 40	IAAA51503	5049~5324	charred wood	Saibesawa VI	9
		Sannaimaruyama	5144	4469 ± 40	NUTA2-623	5168~5278	Adh	upper of cylinder-c	17
		Nigorikawa Sagan	5122	4455 ± 30	PLD3389	4976~5271	charred wood	Saibesawa VII	21
	Yamakoshi 4	4970	4400 ± 40	Beta160080	4876~5038	charred wood	Saibesawa VII	22	
	Sannaimaruyama	5026	4420 ± 60	Beta112340	4870~5051	charred wood	upper of cylinder-d	17	
	Ishikura 1	4903	4340 ± 25	PLD12080	4849~4970	charred wood	Miharashicho	53	
	Kurachigawa R	4921	4350 ± 40	Beta174463	4840~5030	charred wood	Miharashicho	24	
	Yamakoshi 2	4845	4270 ± 40	Beta150573	4825~4867	charred wood	Miharashicho- Enokibayashi	25	
	Sannaimaruyama	4626	4100 ± 50	Beta112344	4525~4647	charred wood	Enokibayashi	17	
	Tateno	4680	4144 ± 63	NU-1798	4521~4838	charred wood	Enokibayashi	2 <sup>c</sup>	
	Usujiri Pri. Sch.	4717	4170 ± 25	PLD4816	4615~4765	charred wood	Oanzai B	26	
	Tateno	4548	4060 ± 40	Beta186245	4430~4800	charred wood	Oanzai B	27	
	Asahitokoro	4656	4125 ± 80	NU-1788	4499~4838	charred wood	E trench of Tokoro 10 A,B		
	Kashiwagigawa 13	4648	4120 ± 90	IAAA190	4528~4711	charred wood	Yoichi	28	
	Kashiwagigawa 13	4747	4230 ± 100	IAAA191	4514~5043	charred wood	Yoichi	28	
	Sannaimaruyama	4340	3910 ± 50	Beta186244	4285~4416	charred wood	Saibana	17	
	Asahitokoro	4656	4125 ± 80	NU-1788	4499~4838	charred wood	Enokibayashi	2 <sup>c</sup>	
Toi shellmound	4363	3930 ± 80	MTC08754	4225~4525	animal bone	Renngadai	29		
Late	Sakaehama 2	4301	3880 ± 80	Beta189375	4228~4418	carbonized mat.	Tenyuji-Wakimoto	30	
	Izumisawa 2	4081	3730 ± 50	Beta149828	3920~4240	carbide	Tenyuji-Wakimoto	31	
	Yamazaki 4	4174	3790 ± 40	Beta150577	4144~4236	charred wood	Tenyuji?	32	
	Zunashigawa	4047	3710 ± 40	Beta160418	3958~4155	charred wood	Hokuto III Dateyama	33	
	Zunashigawa	4171	3790 ± 40	Beta160419	4075~4296	charred wood	Hokuto III Dateyama	33	
	Zunashigawa	4254	3840 ± 40	Beta160420	4148~4411	charred wood	Hokuto III Dateyama	33	
	Ishikura 1	3947	3635 ± 30	PLD12076	3865~4000	charred wood	Wakimoto	23	
	Sakaehama 1	3986	3660 ± 40	Beta163072	3874~4090	charred wood	Wakimoto	34	
	Tenneru 1	4090	3736 ± 36	IAAA61997	3980~4160	charred wood	Hokuto V	15	
	Sakaehama 1	3871	3570 ± 40	Beta163071	3816~3978	charred wood	Torisaki	34	
	Kurachigawa R	3843	3550 ± 40	Beta174470	3710~3920	charred wood	Torisaki	24	
	Ishikura 1	3787	3525 ± 25	PLD12080	3719~3880	charred wood	Torisaki	23	
	Uwada 1	3561	3340 ± 40	Beta186266	3486~3635	charred wood	Ohtsu	36	

Table 1 Division of the Jomon period based on calibrated ages of investigated sites in NE Japan. Full references are listed in the Appendix. (Continued)

Period	Site name	cal BP		Lab code	cal BP	Material <sup>a</sup>	Shape (design)	Ref. <sup>b</sup>
		(med)	Conv. BP					
	Washinoki	3562	3330 ± 40	Beta213963	3470~3620	soil	Shirasaka	37
	Usujiri Pri. Sch.	3600	3360 ± 40	Beta201633	3550~3690	charred wood	Hokkema	38
	Nodaai 1	3562	3330 ± 40	Beta163044	3460~3650	charred wood	Hokkema	39
	Usujiri Pri. Sch.	3460	3245 ± 25	PLD4817	3395~3490	charred wood	Doubayashi	40
	Kiusu 4	3379	3150 ± 40	Beta150594	3440~3640	charred wood	Doubayashi	41
	Yahurai 7	3397	3170 ± 30	IAAA51914	3349~3449	charred wood	Doubayashi	42
	Hamanaka 2	3256	3035 ± 35	PLD6457	3160~3355	charred wood	Doubayashi?	43
	Karinba 3	3204	3002 ± 32	NUTA2-5461	2996~3080	varnish	Gotennyama	44
Final	Kawaratai 1	3136	2960 ± 30	MTC06395	3060~3220	Adh	Ohora B	45
	Namabuchi 2	3024	2890 ± 30	PLD3201	2920~3110	charred wood	Kaminokuni	46
	Tenneru 1	2989	2866 ± 35	IAAA61996	2930~3070	charred wood	older than Nusamai	15
	Tuishikari 2	2989	2685 ± 20	PLD6631	2750~2845	charred walnut	Hamanakaomagari	47
	Namabuchi 2	2746	2610 ± 35	PLD3208	2700~2790	charred wood	Hamanakaomagari	46
	Higashi9sen 6	2745	2610 ± 40	Beta150884	2722~2763	carbonized mat.	Tannetou L	48
	Higashi9sen 6	2576	2490 ± 40	Beta150885	2349~2462	carbonized mat.	Tannetou L	48
	Higashi9sen 6	2428	2390 ± 40	Beta150886	2349~2462	carbonized mat.	Tannetou L	48
	Tsuishikari 2	2426	2410 ± 25	PLD3374	2350~2500	charred walnut	Obora A	49
	Kamicharo	2540	2455 ± 15	PLD6831	2360~2550	charred wood	Midorigaoka	50
Zoku-Jomon (Post-Jomon)	H37 Sakaemachi	2093	2110 ± 70	Beta90897	1991~2155	carbonized mat.	Nimaibashi	51
	Esan shellmound	2321	2300 ± 40	PLD3157	2307~2357	charred wood	Esan	52
	Tokorogawa-Kako	2144	2150 ± 30	IAAA52406	2109~2157	charred wood	Utsunai Ila	53
	Esan shellmound	1999	2040 ± 40	Beta186174	1920~2116	deer bone	Esan	54
	K435(2nd)	1842	1900 ± 50	Beta126132	1715~1947	charred wood	KouhokuC2D	55
	K39	1682	1770 ± 30	IAAA52375	1605~1745	charred wood	KouhokuC2D	56

<sup>a</sup>Adh = adhesive to the pottery fragments.<sup>b</sup>See Appendix for full references information.<sup>c</sup>Omoto, unpublished data.Table 2 Results of  $\Delta R$  determinations for the sites 3, 5, 8, 10, and 11 in Figure 1.

Lab code	Material	$\delta^{13}\text{C}$ (%)	Conv. age	cal terrestrial	Marine $^{14}\text{C}^a$	$\Delta R$ (yr)	Remarks
<b>Asahi Tokoro shellmound</b>							
NUTA-14266	Charcoal	-24.90	4031 ± 26 <sup>b</sup>	4482 ± 57	4341		NU-1788
NUTA-14267	<i>Meretrix lusoria</i>	1.30	4183 ± 26			-158	NU-1789
NU-1788	Charcoal	-24.90	4135 ± 80	4656 ± 73	4475		NUTA-14266
NU-1789	<i>Crassostrea gigas</i>	1.30	4197 ± 71			-278	NUTA-14267
<b>Esan shellmound</b>							
Beta-186174	Thighbone of deer	-23.50	2040 ± 40	1999 ± 54	2384		
Beta-186175	Vertebrae of <i>Bothidae</i>	-13.00	2630 ± 40			246	
<b>Tenneru site</b>							
IAAA-61997	charred wood	-26.34	3736 ± 36				
IAAA-70583	charred walnut	-27.53	3615 ± 32				
	Average		3666 ± 48 <sup>b</sup>	3997 ± 44	4004		
IAAA-70581	<i>Crassostrea gigas</i>	-0.63	4256 ± 32			252	
IAAA-70582	<i>Spipura solidissima</i>	1.01	4312 ± 32			308	
NU-1787	<i>Mya (Arenomya) japonica</i> Jay	-0.60	4290 ± 75			286	
	Average		4286 ± 88			282	
<b>Sakiyama shellmound</b>							
NUTA-14275	Charcoal	-25.00	4926 ± 27 <sup>b</sup>	5642 ± 26	5296		
NUTA-14268	<i>Anthocardaris crassipina</i>	-2.40	5296 ± 27			±0	
<b>Daigikakoi shellmound</b>							
NUTA-14270	Charcoal	-28.60	5001 ± 28 <sup>b</sup>	5726 ± 53	5370		
NUTA-14269	<i>Crassostrea gigas</i>	1.80	5329 ± 27			-41	

<sup>a</sup>Marine median  $^{14}\text{C}$  age.<sup>b</sup>10 yr were extracted from each charcoal sample due to uncertainty of years lost by burning.

(Kuzmin et al. 2007) given for the southern coast of Sakhalin. This suggests an influence of meteoric water or contamination of the sample material, or otherwise a result of  $^{14}\text{C}$  dating by unsuitable paired samples. We then checked samples collected from the Asahi-Tokoro shellmounds and noticed that unsuitable paired samples might have caused such an anomalous figure. That is, a charcoal sample (NUTA-14266) was collected from E trench (E-113) in layer 5 on 20 October 1958, while a *Meretrix lusoria* (NUTA-14267) sample was collected from A Trench (A-19/20) in layer 6 on 23 October 1958. The charcoal sample was collected 10 cm below the shell layer. The authors consider the accumulated time lag between the charcoal and shell layers negligible. The age of *Meretrix lusoria* ( $4166 \pm 26$  BP; NUTA-14267) seems to show a reasonable age as the age is similar to sample NU-1789,  $4197 \pm 71$  BP (Table 2). This results indicates that charcoal sample NUTA-14266 shows an obviously older age, which was quite reasonable because it was located at a lower layer than the shell layer. Thus, we conclude that the  $\Delta R$  value of  $-158$  yr for the north coast of Hokkaido Island is obviously anomalous and should be treated as temporal. However, we are unable to completely rule out the other 2 possibilities: i.e. the influence of meteoric water and contamination of sample materials.

We obtained  $\Delta R$  values of 88 and 282 yr for the Esan shellmounds and Tenneru site, respectively (Table 2). These figures seem well matched with figures given for eastern Hokkaido and the southern part of Hokkaido (Hakodate) by Yoneda et al. (2007). We also used a  $\Delta R$  of 282 yr for the east coast of Hokkaido instead of the 392 yr value (Yoneda et al. 2007), and we used a 254-yr value for the northern coast of Hunka Bay instead of 345 yr (Yoneda et al. 2004). The  $\Delta R$  value was calculated based on  $\Delta R$  values from the Tenneru site and Esan shellmounds. We calculated 0 yr and  $-40$  yr of  $\Delta R$  for the Sanriku coast and Sendai Bay, respectively. The figures were calculated from the data set of the Sakiyama and Daigikakoi shellmounds. The  $\Delta R$  values for the investigated areas are summarized and shown in Table 2 and Figure 1. The large  $\Delta R$  on the east and north of Hokkaido Island indicate the strong influence of the Oyashio Current. These results express apparently larger  $\Delta R$  values than those of SW Japan reported by Nakamura et al. (2007).

### Calibrated Chronology of Sites in NE Japan

The beginning of the Jomon period was determined to be 16,520 cal BP, given for the age of Odai Yamamoto I site, but the original  $^{14}\text{C}$  ages used for calibrations were  $13,780 \pm 170$  (NUTA-6510) and  $13,480 \pm 70$  (Beta-12550) (Nakamura and Tsuji 1999). The 16,520 cal BP (Nakamura and Tsuji 1999) date does not indicate a median provable age but only indicates the uppermost provable age. Considering our confidence in  $^{14}\text{C}$  counting and standard deviation, we strongly propose using a median value of 16,020 cal BP instead of 16,520 cal BP.

The boundary ages of each Jomon period are given in Table 1 and determined mainly on the relative ages estimated by the characteristic shape and design of pottery excavated from the sites of NE Japan. The former chronological table for Hokkaido (Hokkaido Archaeological Operations Center 2009) was given with conventional ages. We calibrated about 80 AMS  $^{14}\text{C}$  data sets related to the archaeological chronology for Hokkaido and the Tohoku District. The original data set was primarily based on charcoal or charred wood samples, and we used the IntCal04 program for calibration. After calibration, we found slight time shifts between the old and new timetables. The oldest site in Hokkaido is Taisyo-3, near Obihiro City, whose calibrated age was 14,078 cal BP (Beta-194627; Table 1). The pottery from Taisyo-3 was characterized with a “nail-marked” relief on it. It is generally accepted among Japanese archaeologists that the “nail-marked” design followed the “plain (non-marked)” pottery. Considering the climatic environment in the last glaciations, several hundred years of time lag might have occurred when the “nail-marked” design was transferred from Honshu to Hokkaido.

Table 3 Divisions of the Jomon period and their correlations with different regions in Japan. Correlations of Keally and Muto (1982), Sahara (1987), Yamamoto (2001), and Kobayashi and Nishimoto (2003) were reported by Kobayashi (2006).

Divisions	Keally and Muto 1982	Sahara 1987	Yamamoto 2001	Kobayashi and Nishimoto 2003	Hokkaido <sup>a</sup> 2009	This study
Incipient	12,800	12,000	—	15,000	14,000	16,000
Initial	10,500	10,000	—	12,500	9000	>10,000
Early	6900	6000	7150	7000	6000	7000
Middle	4500	5000	5350	5470	5000	5400
Late	3500	4000	4350	4420	4000	4300
Final	2700	3000	2950	3200	3000	3200
Yayoi	2550	2300	2650	2350	—	2400 <sup>b</sup>
Region	Kyushu	—	Hokuriku	East Japan	Hokkaido	Hokkaido, Tohoku

<sup>a</sup>Hokkaido Archaeological Operation Center.

<sup>b</sup>Beginning of the Post-Jomon period in Hokkaido.

According to the calibrated data set, the Incipient, Initial, Early, Middle, Late, and Final Jomon periods in Hokkaido and the Tohoku District dated 2000, 1000, 1000, 300, and 200 yr earlier, respectively, compared to the former chronological table (Table 3). In Honshu Island, the Post-Jomon period is called the Yayoi period, and is characterized by rice paddy crops in the alluvial lowland. However, Hokkaido Island was in a cold enough geographical zone to cultivate rice. The Post-Jomon culture in Hokkaido Island is therefore termed the Zoku Jomon (Post-Jomon). Calibrated dates suggest that the beginning of the Post-Jomon in Hokkaido Island was 2400 cal BP (Table 4). Dates in Table 4 range between about 6000 and 3000 cal BP and are correlative with the Early Jomon and Final Jomon periods as indicated by the former archaeological chronology of Honshu Island (Table 3).

Table 4 Calibrated ages of investigated sites in Hokkaido Island and Tohoku District.

Code nr	Material <sup>a</sup>	$\delta^{13}\text{C}$ (‰)	Conv. age	cal BP <sup>b</sup>	$\Delta\text{R}^c$	cal BP <sup>d</sup>	Location
<b>Asahi Tokoro shellmound</b>							
NU-1788	Charcoal	-24.52	4135 ± 80	4666	—	—	E trench
NU-1789	<i>Meretrix lusoria</i>	-0.12	4197 ± 71	4284	-158	4502	A trench
NU-1790	<i>Meretrix lusoria</i>	-0.59	4052 ± 70	4082	-158	4299	A trench
NU-1791	<i>Crassostrea gigas</i>	-0.05	4117 ± 70	4176	-158	4387	A trench
NU-1792	<i>Crassostrea gigas</i>	-0.17	4124 ± 72	4186	-158	4397	B trench
NU-1793	<i>Meretrix lusoria</i>	1.92	4352 ± 59	4493	-158	4699	C trench
NU-1794	<i>Crassostrea gigas</i>	-0.03	4179 ± 79	4261	-158	4477	C trench
NU-1804	<i>Meretrix lusoria</i>	-0.05	4112 ± 60	4169	-158	4380	A trench
NU-1805	<i>Meretrix lusoria</i>	-0.61	4146 ± 58	4223	-158	4430	A trench
NU-1806	<i>Meretrix lusoria</i>	0.97	4081 ± 70	4124	-158	4336	C trench
<b>Tenneru site</b>							
IAAA-61997	charred wood	-26.34	3736 ± 36	4090	—	—	
IAAA-70583	charred walnut	-27.53	3615 ± 32	3925	—	—	
IAAA-70581	<i>Crassostrea gigas</i>	-0.63	4256 ± 32	4366	282	3975	
IAAA-70582	<i>Spipula solidissima</i>	1.01	4312 ± 32	4443	282	4049	
NU-1787	<i>Mya (Arenomya) Japonica Jay</i>	-0.60	4290 ± 75	4409	282	4025	
<b>Kitakogane shellmound</b>							
NU-1830	<i>Crassostrea gigas</i>	1.40	5813 ± 64	6232	254	5956	No.17 Shell M. R36-3
<b>Ponma site</b>							
NU-1829	<i>Crassostrea gigas</i>	1.61	4090 ± 70	4137	254	3792	H-5-003 grid



Table 4 Calibrated ages of investigated sites in Hokkaido Island and Tohoku District. (Continued)

Code nr	Material <sup>a</sup>	δ <sup>13</sup> C (‰)	Conv. age	cal BP <sup>b</sup>	ΔR <sup>c</sup>	cal BP <sup>d</sup>	Location
<b>Takasago shellmound</b>							
NU-1832	<i>Meretrix lusoria</i>	2.44	4520 ± 72	4710	254	4374	A table
<b>Esan shellmound</b>							
Beta-186174	Japanese deer thighbone	-23.50	2040 ± 40	1999	—	—	
Beta-186175	Vertebrae of <i>Bothidae</i>	-13.00	2630 ± 40	2365	246	2015	
<b>Hokuto site</b>							
NU-1795	Charcoal	-25.31	4002 ± 69	4261	—	—	H-1
NU-1796	Charcoal	-23.75	4201 ± 53	4726	—	—	H-2
NU-1797	Charcoal	-23.91	4109 ± 70	4640	—	—	H-5
NU-1798	Charcoal	-27.32	4144 ± 63	4680	—	—	H-7
<b>Sakiyama shellmound</b>							
NU-1811	<i>Mytilus coruscus</i>	0.36	4712 ± 70	4957 ± 0	—	—	SMS-1S No.5G 011
NU-1814	<i>Anthocardis crassipina</i>	-3.31	4835 ± 69	5127 ± 0	—	—	SMS-2SU No.6G 064
NU-1815	<i>Mytilus coruscus</i>	0.70	5158 ± 64	5517 ± 0	—	—	SMS-3S No.5G 131
NU-1816	<i>Anthocardis crassipina</i>	-3.58	4942 ± 62	5280 ± 0	—	—	SMS-3SU No.5G 131
NU-1817	<i>Mytilus coruscus</i>	0.69	5132 ± 64	5494 ± 0	—	—	SMS-4S No.5G 249
NU-1818	<i>Anthocardis crassipina</i>	-3.20	5098 ± 63	5459 ± 0	—	—	SMS-4SU No.5G 249
NU-1819	<i>Mytilus coruscus</i>	1.28	5338 ± 62	5726 ± 0	—	—	SMS-5S No.3G 322
NU-1820	<i>Mytilus coruscus</i>	1.43	5448 ± 73	5816 ± 0	—	—	SMS-6A No.3G 331
<b>Satohama shellmound</b>							
NU-1810	<i>Crassostrea gigas</i>	0.29	4338 ± 72	4477	-41	4536	Daikakoi 140-R2
<b>Nishihata shellmound</b>							
NU-1828	<i>Ruditapes philippinarum</i>	0.08	3217 ± 67	3033	-41	3088	42R1
<b>Daigikakoi shellmound</b>							
NU-1821	<i>Gemmula deshaysi</i>	0.72	5238 ± 62	5602	-41	5646	CS77L14a
NU-1822	<i>Turbo comatus coreensis</i>	2.14	5243 ± 62	5608	-41	5651	CS77L14d
NU-1823	<i>Crassostrea gigas</i>	3.10	5239 ± 75	5604	-41	5649	CS77L14f
NU-1825	<i>Ruditapes philippinarum</i>	3.83	5282 ± 62	5646	-41	5691	CS77L6a
NU-1826	<i>Turbo comatus coreensis</i>	2.46	5275 ± 62	5639	-41	5684	CS77L6a
NU-1827	<i>Meretrix lusoria</i>	0.08	5263 ± 63	5628	-41	5672	CS77L6a
NU-1835	<i>Crassostrea gigas</i>	0.74	5529 ± 76	5916	-41	5969	CS77L15c
NU-1836	<i>Turbo (Lunella)</i>	2.47	5322 ± 62	5686	-41	5734	CS77 a 8d
NU-1837	<i>Gemmula deshaysi</i>	1.53	5291 ± 62	5655	-41	5701	CS77 a 10b

<sup>a</sup>Species names in italics are marine shells or animals.

<sup>b</sup>Median value without ΔR correction.

<sup>c</sup>Italic letters indicate estimated ΔR value.

<sup>d</sup>Median value after ΔR correction.

Table 5 shows that very good agreement exists between the calibrated ages and estimated archaeological ages, except for the Ponma site. The calibrated age of Ponma site is 74 yr older than the estimated archaeological age (Table 4). This slight time shift may due to the estimated ΔR value (254 yr) given for the north coast of Hunka Bay, for which we need a more accurate ΔR value. It is now possible to correlate archaeological sites and events already reported with a newly constructed chronological timetable.

## CONCLUSION

Conventional ages of different kinds of marine samples give very similar results, irrespective of how the raw <sup>14</sup>C ages indicated different ages without isotope fractionation. This proves that isotope fractionation is indispensable in obtaining accurate ages and constructing chronological tables for the sites.

Table 5 Comparison of the calibrated ages with relative archaeological ages of the investigated sites in NE Japan.

Site name	Incipient	Initial	Early	Middle	Late	Final	Post-Jomon <sup>a</sup>
Start (cal BP)	14,000	10,000	7000	5400	4300	3200	2400
End (cal BP)	10,000	7000	5400	4300	3200	2400	—
Asahi Tokoro				b			
Tenneru					b		
Kitakogane			b				
Takasago				c	d		
Ponma					b		
Esan							b
Tateno				b			
Sakiyama			b	b			
Satohama				b			
Nishihata						b	
Daigikakoi			b				

<sup>a</sup>Hokkaido Island only.

<sup>b</sup>Indicates calibrated age coincident with archaeological age.

<sup>c</sup>Indicates calibrated age.

<sup>d</sup>Indicates estimated archaeological age.

The  $\Delta R$  values for Hokkaido Island and the Tohoku District ranged between 282 and  $-158$  yr (temporal data) and between  $\pm 0$  and  $-40$  yr, respectively. The large  $\Delta R$  values for eastern Hokkaido Island indicate the strong influence of the Oyashio Current, while the negative  $\Delta R$  value for the northern coast of Hokkaido Island indicates anomalously low values, suggesting the influence of meteoric water or contamination of sample material, or are the result of  $^{14}\text{C}$  dating by unsuitable paired samples. We believe unsuitable paired samples might have caused the anomalous figures. However, we are unable to contradict completely the 2 causes discussed. The  $\Delta R$  values given for Hokkaido Island indicate apparently larger local reservoir collections than those of SW Japan reported by Nakamura et al. (2007). We need to collect new paired samples in order to determine the correct  $\Delta R$  values for north of Hokkaido Island and north of Hunka Bay, southern Hokkaido Island.

The calibrated Incipient, Initial, Early, Middle, Late, and Final Jomon periods in Hokkaido Island and the Tohoku District were set 2000, 1000, 1000, 400, 300, and 200 yr earlier, respectively, compared with the former chronological table (Hokkaido Archaeological Operations Center 2009). The calibrated ages of collected samples from archaeological sites on Hokkaido and the Tohoku District ranged between about 6000 and 3000 yr, correlative with the Early Jomon and Final Jomon periods as indicated by the archaeological chronology of Honshu Island.

In order to reconstruct a precise archaeological chronology for NE Japan, we need more accurate data related to the reservoir corrections and calibrated  $^{14}\text{C}$  data for archaeological sites in the investigated areas. AMS  $^{14}\text{C}$  data will undoubtedly contribute to the development of archaeological studies. Therefore, we strongly recommend reporting calibrated  $^{14}\text{C}$  data for archaeological studies.

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#### APPENDIX: REFERENCES FOR TABLE 1 (ALL IN JAPANESE)

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