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The significance of obsidian hydration dating in assessing the integrity of Holocene midden, Hokkaido, northern Japan

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Abstract

Since its novel invention in 1960, obsidian hydration dating is now recognized as the chronometric method to give dates of archaeological sites, based on measurements of hydration rim thickness. Contrary to the increased awareness of various factors that affect hydration rates and reliability in measurements, the question whether and the extent to which the validity in the rim thickness measurements corresponds to the interested event has been less discussed. Here, validity of obsidian hydration dates that designate event of human site occupations is discussed in terms of site integrity of the Early Jomon midden in the Holocene site of Ocharasenai (OCH), Hokkaido, northern Japan. Expected integrity of the midden evidently left by prehistoric hunter-gatherers is tested through a comparison of microscopically-measured average rim thicknesses between the primarily extracted specimens and those chosen after assessing the validity. No statistical difference in estimated hydration dates between these two groups supports high integrity of the midden. The estimated date for the Early Jomon occupation at the OCH is 4388-4942 BP, fallen into the end of Middle Holocene. Results of the present examination indicate that obsidian hydration dating will aid to understand site formation processes.

Keywords: obsidian hydration dating; rim thickness; validity; site integrity; Holocene; midden

1. Introduction

Obtaining reliable dates from archaeological sites is critical in anthropological and archaeological inquiries, notably regarding cultural chronology, cultural transmission, human evolution, and human-environment interactions. Because site dates are derived from various contexts, archaeologists who are concerned with cultural event of site occupation will examine formation processes to see whether available dates from archaeological sites are reliable enough to make statements about valid entities of human past what they are interested in (Schiffer, 1986, 1987). Moreover, since archaeological assemblage or archaeological site often include multiple classes of artifacts (e.g., ceramics, lithics, metals) and ecofacts (e.g., seeds, nuts, woods, faunal remains), dating specimens are not necessarily equivalent with the representative of an archaeological site or assemblage. For example, even in an archaeological site with a single occupational surface, cooking activity using ceramic vessels conducted inside a pit-house is plausible to represent the date of hearth-use event, while it is not necessarily same with the event of core reductions performed just outside the pit-house. An examination of site formation processes provides critical basis for evaluating whether obtained date represents human activities that legitimately correspond to cultural event of human occupation. The present paper discusses whether and the extent to which obtained dates represent event of human occupation, through an assessment of obsidian hydration dates of the obsidian flakes sampled from the terrestrial midden in the Holocene open-air site of Ochrasenai, central Hokkaido, northern Japan.

2. Background

2.1. A brief history of research on obsidian hydration dating in the globe and Japan

Along with the radiocarbon dating, the obsidian hydration dating (OHD) is one of the most long-standing dating methods in archaeology. Since the implication of the presence of hydration in obsidian (Ross and Smith, 1955) and the new dating method in using observed hydration rinds introduced into archaeology in 1960 (Friedman and Smith, 1960), over the last five decades, OHD has been popularized to furnish the dates for prehistoric sites and assemblages. Obsidian artifacts both in buried and surface contexts have been used in regions where obsidian artifacts are ubiquitously found, notably in southern Pacific coast of North America (e.g., Bettinger, 1980; Hull, 2001; Meighan, 1983; Origer, 1989; Rogers and Yohe, 2011), Great Basin (Jones and Beck, 1990; Jones et al., 2003), American Southwest (Findlow et al., 1975; Ridings, 1996), East Africa (Ambrose, 2012; Michels et al., 1983), Mesoamerica (Braswell, 1992; Freter, 1993; Riciputi et al., 2002; Webster and Freter, 1990), coastal Peru (Eerkens et al., 2008), central Andes (Tripcevich et al., 2012), Oceania (Ambrose, 1994; Clark et al., 1997), interior Alaska (Clark, 1984), and Japan (Katsui and Kondo, 1965, 1976; Suzuki, 1971). The major reasons why OHD is accepted by archaeologists are: (1) relative easiness in the procedure of observations, measures, and calculations of dates, (2) specimens can be coupled with temporally sensitive techno-typological units such as projectile points (e.g., Jones and Beck, 1990), (3) while analysts can accommodate a large number of specimens for dates, the cost to obtain dates is not expensive (lower than the radiometric dates such as radiocarbon dating), and (4) depending on the effective hydration temperature, the applicable range of dating is deep enough to cover from the Middle Pleistocene (780,000 BP) to historic period (Friedman and Smith, 1960; Michels and Tsong, 1980; Origer, 1989).

OHD is largely dependent on the hydration rate. If the obsidian artifact is treated as an “organism”, hydration rate is subject to change depending on exogenous and endogenous factors. The exogenous factors include temperatures, soil pH, and humidity (Friedman et al., 1994). Among these, it has been considered that the ambient temperature surrounding the obsidian has been the most effective factor to the rate of hydration, and a number of studies have addressed the issue of how the effective hydration temperature is accurately determined (e.g., Fredrickson et al., 2006; Jones et al., 1997; Ridings, 1991, 1996; Rogers, 2007, 2008a). The endogenous factors that can influence the hydration rate are intrinsic water content and geochemistry. Although the effect of geochemical variation on hydration rate has been investigated in the earlier days of research (Friedman and Long, 1976; Friedman and Trembour, 1983; Suzuki, 1971), recent investigations regard the water content as the significant endogenous factor (e.g., Rogers, 2008b, 2013; Steffen, 2005; Stevenson et al., 1998; Zhang et al., 1997). For example, empirical studies of measuring water content of obsidian suggest that intrinsic water content of individual obsidian specimens are varied not only between the sources but also within a single source (Stevenson et al., 1993, 1998, see also Hughes, 1988). Given the variation in intrinsic water content in between geochemical sources of obsidian sources, it is strongly recommended that chemically distinctive sources need to be distinguished before calculating dates to control the effect of inter-source variation of intrinsic water content (Rogers, 2007).

Because the hydration rate is dependent on temperature, models of diffusion have developed to make the relationship between elapsed time and temperature. The default model of time calculation using temperature and measured rim thickness is the Arrhenius equation (e.g., Friedman and Long, 1976, 1978; Rogers, 2007). Through induced hydration experiments (e.g., Michels 1986; Michels et al. 1983; Rogers and

Duke, 2011; Stevenson et al. 1998) and application of new measurements of hydration rims, notably SIMS, the secondary ion mass spectrometry (e.g., Anovitz et al. 1999, 2004; Liritzis, 2006; Stevenson et al., 2001), precise measurements of hydration rims quantified by the amount of hydration ions are provided. Thorough examinations of diffusion profiles have suggested that the diffusion of water molecules to create hydration rims is accurately described by the Fick's law (e.g., Anovitz et al., 1999, 2004; Liritzis, 2006).

Artifacts made of obsidian are abundantly recovered from the prehistoric Japanese sites where obsidian was produced by active volcanic activities because the entire Japanese Archipelago was situated on the multiple tectonic plates (Izuho and Hirose, 2010, Taira, 2001). Taking this advantage, since its introduction into archaeology, obsidian hydration dating was actively employed in the practice of Japanese archaeology. It was in the early 1960's when the first application of OHD to archaeological specimens was achieved in Japan (Katsui and Kondo 1965). Since the initial introduction of OHD to Japanese archaeology, two researchers have consistently pursued the study of OHD: Masao Suzuki, and late Yuko Kondo. Suzuki is the geochemist specialized in dating methods using obsidian, and Kondo was the soil scientist with the solid knowledge of obsidian geochemistry. Suzuki (1971) used the OHD to build the cultural chronology of the prehistoric Japanese sites. He measured rim thicknesses of the total of 733 obsidian specimens from the deeply buried Pleistocene and Holocene sites in the Kanto district (area in and around Tokyo). Measured rim thicknesses were used to obtain the hydration rates by different obsidian sources, assuming that the chronometric dates obtained by the fission-track method of the same site' specimens represent the dates of study sites. This made him reconstruct hydration rates varying depending on the five source groups (i.e., Wadatoge, Kirigamine, Kozushima or Asama, Old Hakone, and New Hakone) that were standardized by the relationship between hydration rates and effective hydration temperatures reported in Friedman et al. (1966). He is the one of the pioneers who investigated the effects of obsidian geochemistry in consideration with source differences (using the neutron activation analysis and source-specific crystallites) and fluctuations of ambient temperatures in evaluating the obsidian hydration dates. Katsui and Kondo (1976) also estimated the hydration rate for the obsidian artifacts sampled from a total of 30 prehistoric sites in Hokkaido, based on the correlations between radiocarbon dates and hydration rim thickness. Assuming that the rate of hydration for rhyolitic obsidian from Hokkaido does not vary with geochemistry of obsidian, they plotted the estimated hydration curve in Hokkaido to be placed below the plot of “Temperate Zone II” and above that of the “Subarctic Zone”, presented in Friedman and Smith (1960: 492). Moreover, they suggested that the Pleistocene (Paleolithic) obsidian artifact collected at the fifth terrace of Shirataki site was later scavenged by Holocene people, because two of the seven measurements of hydration rim were evidently thinner than those of the rest. Despite the efforts, knowledge of these early methodological studies promoted by Suzuki and Kondo was not further explored among the archaeologists and geoscientists, as well as rarely passed on to next generations.

2.2. Valid specimens for obsidian hydration dating toward assessing site integrity

The studies of OHD for the last five decades have greatly enhanced the reliability of hydration dating. As potential errors were carefully assessed, the status of OHD changed from relative dating method to the more rigorous chronometric dating method

(Anovitz et al., 1999; Michaels et al., 1983b; Rogers, 2010a). In his recent article, Rogers (2010a) listed rim measurement, radiocarbon measurement, temperature history, hydration rate, intrinsic water content, and site formation processes (especially, tool reuse, old wood problem, and post-depositional displacement of artifacts) for the major sources of errors that need to be carefully assessed to increase the accuracy and precision of OHD. As these error sources are all controlled to increase the reliability of archaeological dates, OHD will become a promising chronometric dating method. Nevertheless, contrary to the efforts to increase the reliability of OHD, the validity of OHD is less discussed in the literatures. Validity refers to the consistency between the research interest and unit of measurement (Ramenofsky and Steffen, 1998). In other words, what you measure must be what you are interested in (Nance, 1987; VanPool and Leonard, 2011). In the study of OHD, validity is the correspondence between measured rim thickness and site date. The question is as to whether and the extent to which obsidian specimens represent temporal dimensions of targeted entities (e.g., cultural period, duration of site occupation, use length of feature, dates for excavated lithic assemblages and surface collections) what Remenofsky (1998: 78) calls “target event”. Determination of represented specimens for the date of study site is dependent on context. As long as basic context of the sampled specimen whether the specimen is from surface or subsurface is known, the validity of calculated date will be established in some degree. Because scientifically standardized measurements (in this case chronometric dates) are established both by explicit evaluation of reliability and validity (Nance, 1987), a further evaluation of validity is now required given the circumstance of increased reliability of OHD. Below, I address the question of how validity of dates is assessed through the examination of site integrity on the Holocene open-air site of

Ocharasenai (OCH), recently excavated Jomon site with large pit houses, a midden, and artifact scatters (ceramic sherds, and lithic artifacts) in central Hokkaido, northern Japan. Site integrity, here, defined as the status of features and artifacts that have secure coherence to serve for analytical units to allow reconstruct human behavior.

3. Materials and methods

3.1 The Ocharasenai (OCH) site, central Hokkaido, northern Japan

Unlike other temperate regions in the Japanese Archipelago, Hokkaido is in subarctic climate, similar to the northern North America, northern/eastern Europe, and Siberia. Due to the influence of continental cool air drifted from the Siberia of northeast and warm Tsushima Current that runs from south to north in the Japan Sea, it is generally cool and humid climate that makes winters last long and bring heavy snows.

The OCH is on the right river terrace of the Atsuma River that runs from western skirt of the Yubari Mountain and meanders down to the Pacific coast approximately 20 km to the southwest (N42°46’, E141°59’, 70-76 m asl, see Figure 1). Under the cultural resource law in Japan, having consulted the impact by the construction of water reservoir in the Atsuma River, potentially impacted sites inside the water reservoir were assigned to be investigated. Archaeologists affiliated with the Atsuma Board of Education undertook full excavations of the OCH during the five field seasons during the years of 2008 and 2012 (Amakata and Inui, 2013a, b; Amakata et al. 2014). The total excavated area is 15,698 m^2 (3.88 acres). Site sediments contain human occupational surfaces that were all blanketed by the distinctive pumice layers accumulated by the volcanic eruptions. Excavations revealed a total of four cultural periods at the site. These are medieval Ainu, Satsumon, Epi-Jomon, and Jomon, from the younger to older. Among these cultural periods, occupations during the Jomon were the most intensive in terms of the number of artifacts and features. The occupational level of Jomon was blanketed by the Ta-c pumice, a Holocene tephra in Hokkaido erupted in 2.5 – 2.0 ka (Machida and Arai, 2003). More than 100,000 artifacts were recovered, and a total of 13 pit houses were excavated. The peculiar feature in this site is the extensive midden measuring 17 by 10 m (Figure 2). The midden consists of multiple classes of artifacts and ecofacts: ceramic sherds, lithic artifacts, faunal remains, and ash dumps. The chipped stone artifacts mainly consist of projectile points, bifaces, and tanged scrapers. While the ground stones (e.g., anvils, hammerstones) are mostly made from local sandstones, the dominant raw material used for chipped stone artifacts is obsidian that was not locally available, imported to the site from any sources that are located more than 100 km away from the site. Because of the abundance of the obsidian debitage left in the midden, I extracted obsidian flakes from the lithic scatter deposited in the midden. The midden (called "VBB-03" in Amakata and Inui [2013a: 302]) is characterized by the abundant bone fragments of deer (*Cervus nippon*) that were associated with concentrations of pot sherds, and scatter of lithic debitage (Figure 2). The excavated deer bones were only teeth and burnt fragments. Charred seeds were identified from the bulk floated sample. Unlike the other prehistoric terrestrial open-air sites in Japan, the good preservation of faunal remains is presumably achieved by the low soil acidity because ash deposit is encompassed in this midden. A total of 35 unmodified obsidian flakes for hydration observations were collected from a 2.5 by 2.5 m excavation unit which included the lithic artifact scatter situated in northwestern edge of the midden (Figure 2). The distribution of lithic scatter is partially overlapped with the distribution of faunal remains. The lithic scatter is encompassed in the Layer Vb of the midden which measures approximately 10-15 cm in thickness. Overlapped with the deposit of faunal remains, three clusters of pottery sherds were identified (Amakata and Inui, 2013a). The typological examination of the pottery suggested that they are all attributed to the types of the late Early Jomon: Ento Lower-d2, Oasa V, Fugoppe Shell-midden, and Miyamoto. Among these, Ento Lower-d2, the well-know Jomon pottery widely distributed in northern Japan (i.e., Hokkaido and northern Tohoku), and Oasa V, the local pottery type only distributed in Hokkaido are the dominant in the midden deposits. The refitting study of pot sherds identified at least 32 individual vessels (mostly used for cooking jars) from the midden (Amakata and Inui, 2013a).

Figure 1

Figure 2

As described above, OCH is the large open-air settlement of Early Jomon. Large pit-houses with an extensive midden encompassing various cultural and natural remains, are well coordinated with the picture of Jomon lifeways of hunter-gatherers which often regarded as sedentary (Habu, 2004; Nishida, 1983; Rowley-Conwy, 2001, see also Crawford and Bleed, 1998). As sedentism designates the mobility strategy that a site is continuously occupied throughout the year, sedentary hunter-gatherers are often coupled with increases in resource intensification, diet breadth, resource storage, exchange, fertility rates, and population (e.g., Kelly, 1995; Lieberman, 1998). Sedentary lifeways tend to create refuses as duration of occupation and residential population increase (e.g., Hayden and Cannon, 1983). Given the assumption that natural formation processes, if any, were constantly operated across the occupational surface, here two competent expectations with respect to the integrity of midden in sedentary lifeways of hunter-gatherer societies are proposed.

Expectation A: Because the midden is little disturbed (retaining high integrity), distribution of dates is tight.

Expectation B: Because the midden is disturbed (integrity is low), distribution of dates is dispersed.

These two expectations are tested by a comparison of distributions of dates between the group of obsidian artifacts primarily extracted from the excavation unit and those of secondarily chosen as valid analytical specimens. The secondarily chosen group of obsidian artifacts is the specimens retaining rim thicknesses unvaried between dorsal and ventral sides of flakes. The criteria to choose these specimens are the Criterion a and b, as explained in the following section. Then, the integrity of the site is assessed by comparing date ranges of the primarily extracted group and secondarily chosen group. If there is no difference in the range of dates between the two groups, Expectation A is supported. If date ranges are tighter in the secondary chosen group than the primarily extracted group, Expectation B is supported.

3.2 Measuring hydration rims

For the research conducted in 2013, petrographic thin-sections were made from the total of 29 specimens from OCH, by H. Nomura (Thin Section Technician’s Lab in the Graduate School of Science, Hokkaido University). Using the filar eyepiece attached to the petrographic microscope (MT9300, Meiji Techno Co., LTD.) with the magnification of 500×, I took three measurements of the hydration rims for each side of a flake: three measurements for rim of dorsal surface, and three for that of ventral surface. In order to ascertain that the measurements validly represent the date of study site, measurements are expected to be indifferent among the specimens. Given the fact that the rim thicknesses often vary inside a specimen, it is generally expected that all measurement for the specimens are not significantly different among the chosen specimens. In other words, the measured rim thickness is inappropriate for representing the site date if difference in rim thicknesses among the specimens is significantly larger than the differences in each specimen. To evaluate the variation in hydration rim measurements within and between the specimens, means, standard deviations (s), and coefficient variation (CV) were computed using the measurements of rim thicknesses for each side of flake. The variation in measurements is assessed by (1) extent of difference in the mean hydration thicknesses between dorsal and ventral surfaces, and (2) how the hydration thicknesses are deviated from the mean thickness. I set the criteria whether or not the variation in measurements is good enough to serve for dating.

Criterion a: If the difference in mean rim thicknesses between dorsal and ventral surfaces is smaller than 0.5 microns, the specimen is good.

Criterion b: When the CVs for dorsal and ventral surfaces are smaller than 10, the specimen is good.

Setting 0.5 microns for Criterion a is rather arbitrary, although it is smaller the threshold in other case studies. For example, Stevenson et al. (2004: 558) reported that the average difference as 1.39 microns for 26 measurable specimens from the Mound 13 in Mound City, central Ohio. Because measurements are read for two sides of an obsidian flake (i.e., dorsal and ventral surfaces), four combinations are emerged.

Pattern 1: Both Criterion a and Criterion b are satisfied.

Pattern 2: Criterion a is satisfied, while the Criterion b is *not* satisfied.

Pattern 3: Criterion a is *not* satisfied, while Criterion b is satisfied.

Pattern 4: Neither Criterion a nor b is satisfied.

In terms of determining the valid measurement for providing appropriate site date, I use values of mean and CV to assess intra-specimen variation of rim thicknesses. For Pattern 1, mean rim thickness for all measurements is accepted. For Patterns 2 and 3, only the mean rim thickness for one side (either dorsal or ventral surface) having smaller CV is employed. For Pattern 4, no measurements for the specimen are employed. Through the assessment of intra-specimen variation, I examine a total of 29 specimens in order to choose the valid samples for dating.

3.3 Estimating the effective hydration temperature for OCH

Determination of effective hydration temperature (EHT) is critical in OHD, as hydration rate is temperature dependent as shown in Arrhenius equation. Both direct and indirect measurements of EHT have been developed (Friedman and Long, 1976). Direct measurement of EHT is the method to measure the soil temperatures from study sites and regions. It includes methods that bury artifact-embedded cells into study site (Ambrose, 1976; Anovitz et al., 2004; Ridings, 1991, 1996; Stevenson et al., 1998), and thermal cells that periodically record subsurface temperatures (Fredrickson et al., 2006; Jones et al., 1997). Indirect measurements of EHT, on the other hand, use temperatures recorded in surrogate station that is expected to have proximate climatic regime to study site (e.g., Friedman and Long, 1976; Lee, 1969; Rogers, 2007). To calculate EHT, here I use indirect measurement of EHT, employing the mathematical equations developed by Rogers (2007, 2010b), which is the climatic model based on a Fourier series of sinusoidal terms in consideration with annual and diurnal variations in temperatures recorded in local surrogate station.

3.4. Obsidian hydration dates

The diffusion equation of obsidian hydration is

$$x^2 = kt \tag{1}$$

where x is hydration rim thickness, k is hydration rate, and t is the time (Friedman and Smith, 1960). Because k is the hydration rate dependent on temperature, it follows the Arrhenius equation given by:

$$k = Ae^{-E/RT} \tag{2}$$

where A is a constant, E is the activation energy (kJ/mol), R is the universal gas constant (8.317 J/mol), and T is the temperature (°K). In the present study, since induced hydration rate specifically for obsidian of the specimens and EHT specifically for the OCH are used, the following form of equation (6) is presented (Michels et al. 1983):

$$k' = k\, exp[E/R(1/T-1/T')] \tag{3}$$

where k' is the hydration rate under T', T' is EHT for study site, k is the hydration rate at T determined by induced hydration, T is the induced hydration temperature, E is the activation energy determined by induced hydration, and R is gas constant.

4. Results

Having eliminated three obsidian specimens that do not retain clear hydration rims, the number of specimens that are valid for representing site date comes down to be 16 (Table 1). The average rim thickness of the chosen specimens ($n = 16$) is 2.68 μm with the standard deviation (s) of 0.497. As shown in Figure 3, a further comparison of variation in rim thicknesses of intra-specimen measurements with those of among the specimens exhibit that there is significant difference in average rim thicknesses among the specimens (One-way ANOVA: $F = 5.6396, df = 15, p<0.001$). Consequently, the chosen specimens are judged to retain valid measurements.

Table 1

Figure 3

Implemented temperature history of last 30 years (1983-2013) that was recorded in the local meteorological station (Automated Meteorological Data Acquisition System at Atsuma Town) into the Roger’s equations (Rogers, 2007), the estimated EHT for the Ocharasenai site is 7.94 °C. This is approximately 1°C higher than the recorded annual average temperature (6.87 °C).

A provenance analysis of sampled obsidian using the portable ED-XRF maintained by M. Izuho (Tokyo Metropolitan University) shows that the majority of obsidian (87%, 25 from the total of 29) is from the Oketo-Tokoroyama, the large obsidian source in northeastern Hokkaido, at least 150 km away from the site. Having eliminated the specimens not assigned to the Oketo-Tokoroyama from the total of 16 valid specimens, the number of specimens for dating shrinks to 13. The average is 2.73 µm and the standard deviation (s) is 0.511.

According to the accelerated hydration experiments conducted by Watanabe and Suzuki (2006: 6), obsidian from Oketo has: $k = 1.57\ \mu\mathrm{m}^2 \times 10^{-3}$ (per year), $E = 76.45$ (kJ/mol), $T = 377.15$ (°K), $T' = 281.09$ (°K). Having put these numbers into equation (3),

$$k' = 1.56\ \mu\mathrm{m}^2 \times 10^{-3} \tag{4}$$

This means that the hydration rim develops 1.56 μm^2 per 1000 years. Having equated $k' = k$ and $x = 2.73$ (μm), date is calculated using Equation (1) and (4):

$x^2 = k't$

$t = x^2 / k'$

$t = 2.73^2 / (1.56 \times 10^{-3})$

$= 4.7775 \times 10^3$

$= 4777.5$

$= 4778$ years ago

The 95% confidence interval (CI) of the date is given as $t \pm 1.96s$, where $s = 0.511$. Then, the range of age is 4451-5105 years ago.

5. Discussion

The obsidian hydration date for the Early Jomon occupation of OCH is further compared with radiocarbon date. The radiocarbon date of a charred walnut shell floated from the sediment fill of the pit-house (VH-03) adjacent to the study midden is 4597 ± 30 cal. BP (IAAA-102689) (Amakata and Inui, 2013b). The pit house fill yielded approximately 9000 artifacts including pot sherds, chipped stone artifacts, and grinding stones (see Figure 2). The pottery fragments are typologically attributed to the Ento Lower-d2 type (Early Jomon) that is compatible with the pottery type from the midden where the OHD specimens were from. Thus, the radiocarbon date of the charred walnut shell should correspond with the obsidian hydration date. A comparison of two dates suggests that the average of obsidian hydration date (4715 BP, which is comparable to radiocarbon date, because 1950 AD is 63 years older than 2013 AD when thin-sections of specimens were made) is 181 years older than the radiocarbon date (i.e., 4597 cal.

BP), while the radiocarbon date is fallen in 95% CI of the obsidian hydration date.

In the same token, when validity of specimens for dating is not considered, the average rim thickness becomes $x = 2.7$ μm (n = 25, excluding the 5 specimens that do not retain measurable hydration rims), and $s = 0.377$. Hence, calculated average hydration date is 4673 ± 178 years ago, and 95% CI is 4495 – 4851 years ago. The date range of the primarily extracted specimens is more narrowly distributed than the secondarily chosen specimens. A comparison of distributions of dates between the primarily extracted specimens and secondarily chosen specimens that retain small intra-variation in rim thicknesses is performed by t-test. The null hypothesis is that there is no difference in average hydration dates between the primarily extracted specimens and those of secondarily chosen were concerned. The t statistics calculated is 0.1341. The critical value is $t_{[.05,1]} = 12.706$. Because the computed t-value is smaller than the critical value, the null hypothesis is not rejected. Thus, there is no difference in average hydration dates between the specimens that were primarily extracted and those of secondarily chosen. Regarding the expected relationship between degree of midden integrity and range of dates (i.e., Expectations A and B), when the midden retains low integrity the secondarily chosen group should have tighter range of dates (Expectation B), and vice versa. The present result of no difference between the primarily and secondarily groups of samples suggests the situation that the midden integrity is high, and therefore supports Expectation A. That is, the midden of OCH is little disturbed and certain level of integrity is maintained.

High integrity of midden at OCH is rather contradictory to the perception of Jomon as sedentary hunter-gatherers. Even though occupants redundantly disposed foods, artifacts, and ashes on this specific area of OCH, activities not relevant to food/artifact disposals that would in turn invited human trampling and artifact-scavenging were less likely occurred. While small amount of walnuts and berries from deciduous trees (e.g., Amur cork-trees) and river fishes (e.g., salmon, carp) identified from the midden deposits (Takahashi, 2013; Tsubakizaka, 2013) gives signature of the broad spectrum diet, the dominance of deer in faunal assemblage suggests that Jomon hunter-gatherers intensively exploited specific games, which is described as specialization in resource exploitation (e.g., Mellars, 1996). Given the situation of specialized hunting with little disturbance of midden, Jomon hunter-gatherers occupying the site heavily relied on hunting strategy to exploit predictable mobile resource. This kind of resource-use strategy was highly beneficial under the Holocene climate in which seasonality became more pronounced than the Pleistocene (cf. Kelley and Todd, 1988; Miracle and O'Brien, 1998). Indeed, in terms of human-environment relationships, the date range of 4388-4942 BP, which is converted from 4451-5105 years ago by subtracting 63 years, is reasonably placed to the end of Middle Holocene (the Middle Holocene is bounded by climatically deteriorative events occurred at 8.2 and 4.2 ka) defined by the current synthetic study of proxy records (Walker et al., 2012). Because the present examination of obsidian hydration dates not necessarily support the idea of year-round occupation on the study site of OCH, it is hypothesized that the site was functioned as seasonal camp to exploit the single predictable resource, namely deer (*Cervus nippon*).

6. Conclusions

An assessment of validity in obsidian hydration measurement is necessary to reliably determine the date of archaeological site/assemblage. This procedure will be beneficial before dated obsidian specimens are sorted according to the different geochemical groups to standardize the potential variation in intrinsic water content (Rogers, 2010a). Negation of the reliability in OHD to give site dates (e.g., Ridings, 1996) will be revisited through a series of steps that assess context of specimens, sampling strategy, accuracy and precision of measurements, intra and inter variation in rim measurements, and comparisons with other chronometric dates. Moreover, results of the present study imply that the use of obsidian hydration dating has great potential to provide substantial knowledge of site formation processes.

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Figure1

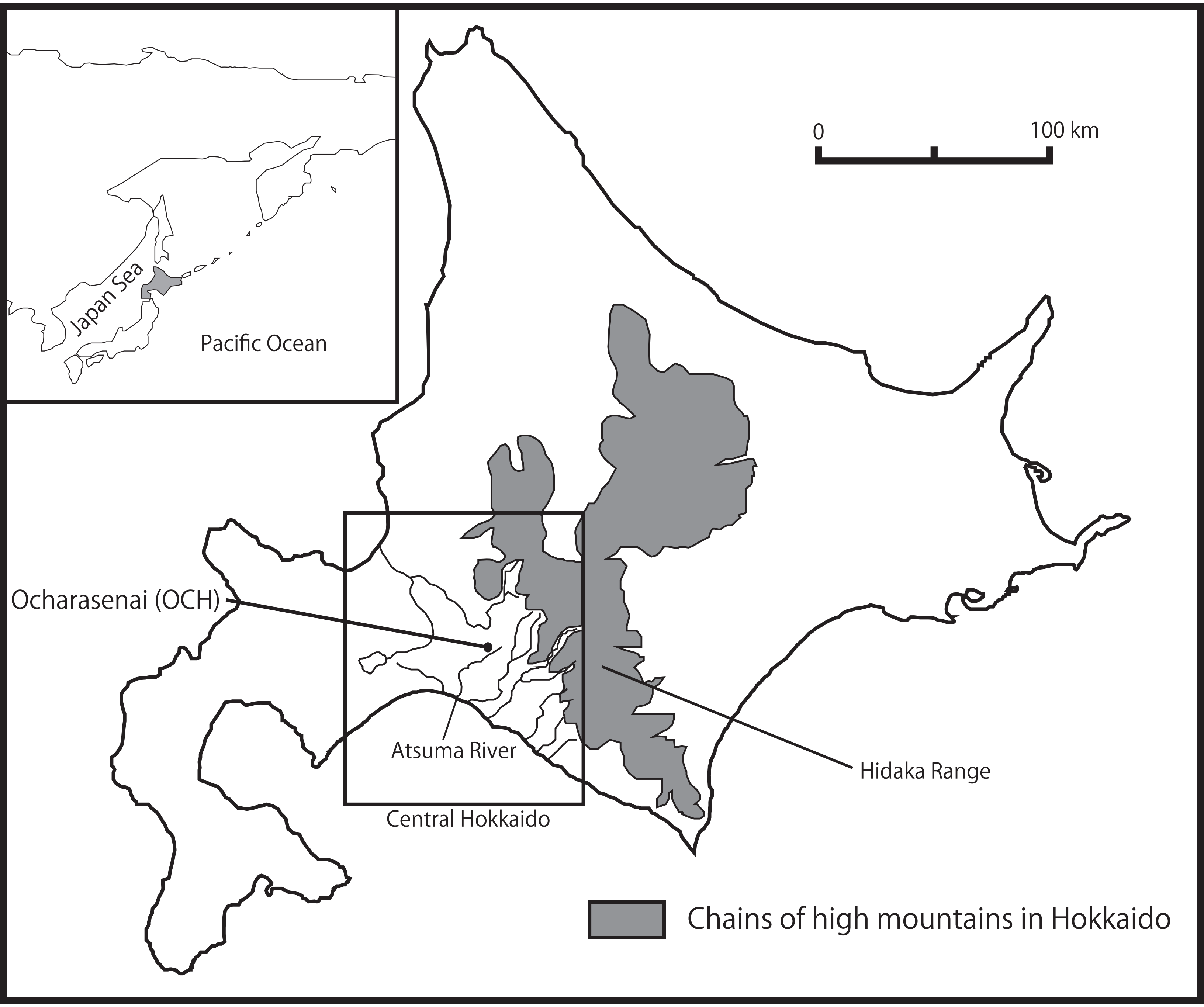

Japan Sea
Pacific Ocean
0
100 km
Ocharasenai (OCH)
Atsuma River
Central Hokkaido
Hidaka Range
Chains of high mountains in Hokkaido

Figure2

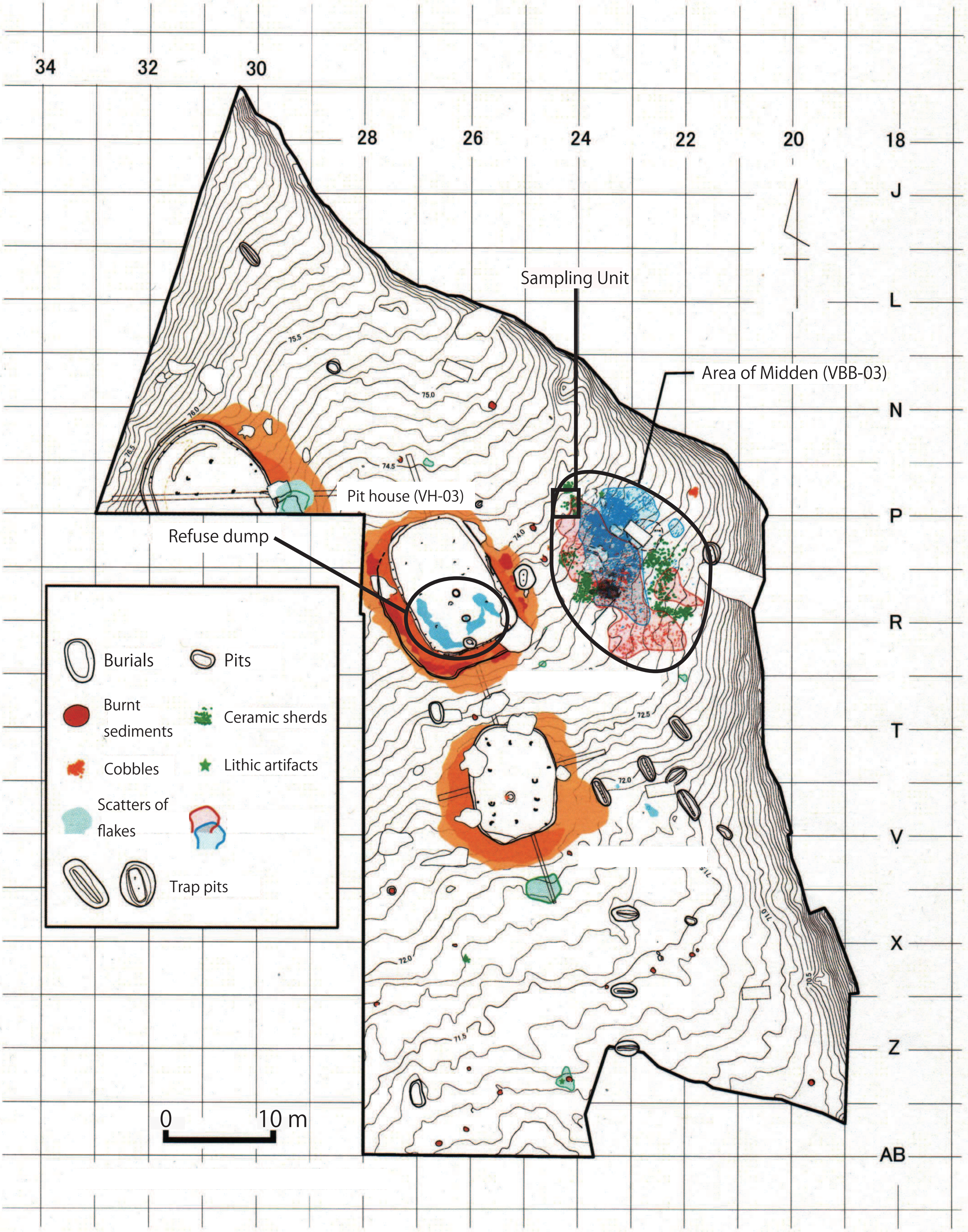
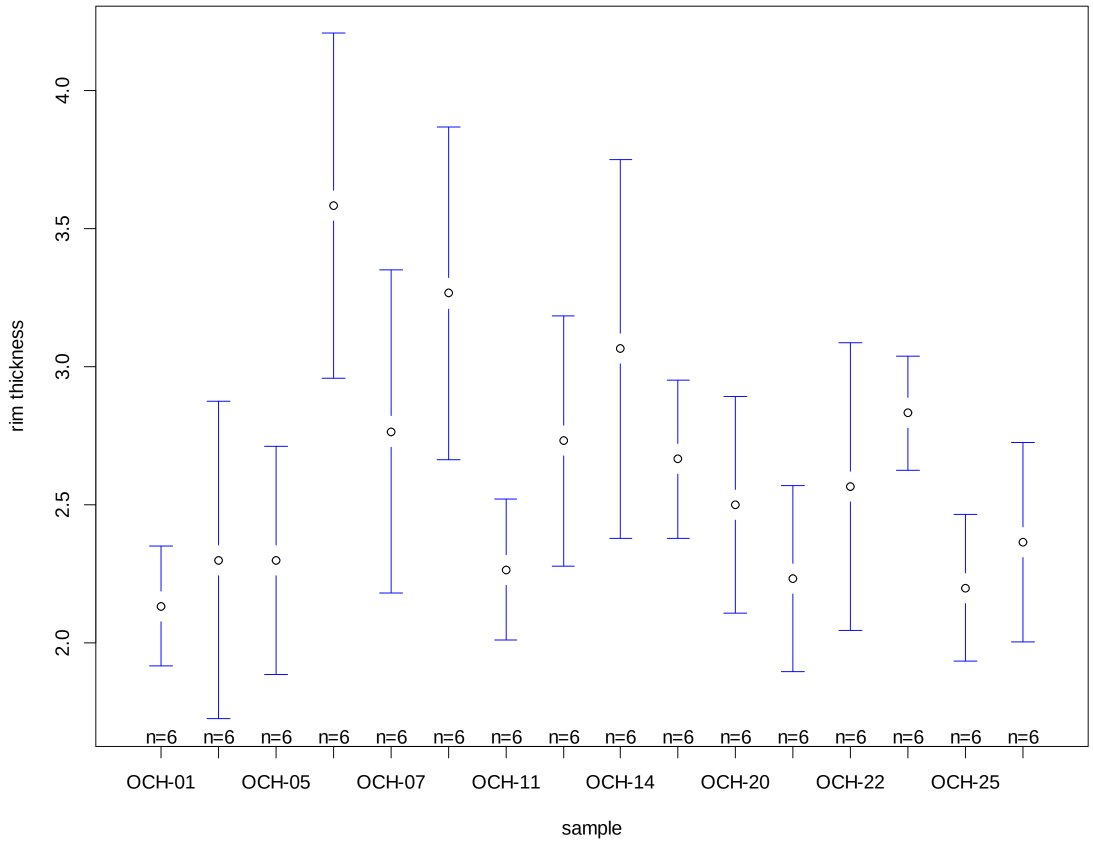

34
32
30
28
26
24
22
20
18
J
L
N
P
R
T
V
X
Z
AB
Sampling Unit
Area of Midden (VBB-03)
Pit house (VH-03)
Refuse dump
75.5
75.0
76.0
76.5
74.5
74.0
72.5
72.0
71.5
71.0
70.5
Burials
Pits
Burnt sediments
Ceramic sherds
Cobbles
Lithic artifacts
Scatters of flakes
Trap pits
0
10 m

Figure3


rim thickness
4.0
3.5
3.0
2.5
2.0
n=6
n=6
n=6
n=6
n=6
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n=6
n=6
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n=6
n=6
OCH-01
OCH-05
OCH-07
OCH-11
OCH-14
OCH-20
OCH-22
OCH-25
sample

Table1

Dorsaml surface							Ventral surface					
1	2	3	mean	s.d.	CV	corrected CV	4	5	6	mean	s.d.	CV
2.40	2.00	2.00	2.13	0.19	8.84	9.58	2.40	2.00	2.00	2.13	0.19	8.91
2.00	1.80	3.00	2.27	0.52	23.16	25.09	2.00	3.00	2.00	2.33	0.47	20.14
2.40	4.00	3.20	3.20	0.65	20.41	22.11	NA	NA	NA	NA	NA	NA
2.60	2.40	3.00	2.67	0.25	9.35	10.13	4.00	3.00	4.00	3.67	0.47	12.82
2.40	2.00	2.00	2.13	0.19	8.84	9.58	2.40	3.00	2.00	2.47	0.41	16.62
3.90	3.20	3.00	3.37	0.39	11.46	12.42	3.00	4.00	4.40	3.80	0.59	15.53
2.00	3.60	2.40	2.67	0.68	25.50	27.62	3.00	3.00	2.60	2.87	0.19	6.63
2.40	3.60	3.00	3.00	0.49	16.33	17.69	3.60	4.00	3.00	3.53	0.41	11.60
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.60	2.00	2.40	2.33	0.25	10.69	11.58	3.00	3.00	2.60	2.87	0.19	6.63
2.40	2.00	2.60	2.33	0.25	10.69	11.58	2.00	2.20	2.40	2.20	0.16	7.27
3.00	2.00	3.00	2.67	0.47	17.68	19.15	3.00	3.00	2.40	2.80	0.28	10.00
3.00	3.20	3.00	3.07	0.09	3.07	3.33	2.20	2.00	3.00	2.40	0.43	17.92
3.60	3.00	2.20	2.93	0.57	19.55	21.18	4.00	2.60	3.00	3.20	0.59	18.44
2.00	2.40	3.60	2.67	0.68	25.50	27.62	NA	NA	NA	NA	NA	NA
2.00	3.00	2.40	2.47	0.41	16.66	18.05	3.00	3.60	3.60	3.40	0.28	8.24
3.20	4.00	4.00	3.73	0.38	10.10	10.94	2.00	3.00	2.00	2.33	0.47	20.14
2.60	2.40	3.00	2.67	0.25	9.35	10.13	3.00	2.40	2.60	2.67	0.25	9.38
2.00	3.20	2.40	2.53	0.50	19.69	21.33	NA	NA	NA	NA	NA	NA
2.40	3.20	2.40	2.67	0.38	14.14	15.32	2.60	2.20	2.20	2.33	0.19	8.14
2.40	2.80	2.20	2.47	0.25	10.11	10.96	2.00	2.00	2.00	2.00	0	0.00
3.00	2.40	2.00	2.47	0.41	16.66	18.05	2.00	3.00	3.00	2.67	0.47	17.63
NA	NA	NA	NA	NA	NA	NA	3.20	3.00	3.00	3.07	0.09	2.93
3.00	2.60	3.00	2.87	0.19	6.58	7.13	3.00	2.80	2.60	2.80	0.16	5.71
2.00	2.00	2.20	2.07	0.09	4.56	4.94	2.00	2.40	2.60	2.33	0.25	10.71
2.00	2.00	2.20	2.07	0.09	4.56	4.94	2.60	2.60	2.80	2.67	0.09	3.38
3.20	3.00	3.00	3.07	0.09	3.07	3.33	NA	NA	NA	NA	NA	NA

Captions

Figure 1. The location of Hokkaido in northern Pacific and research area of central Hokkaido.

Figure 2. The locations of midden and pit houses on the early Jomon occupation level of the Ocharasenai (OCH), Hokkaido. Map only shows excavation area of 2010. Contours are on the surface of Layer III. Map courtesy of the Atsuma Board of Education.

Figure 3. Whisker plot representing variation in rim thicknesses within and among the specimens from OCH (n = 16).