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Late Upper Paleolithic-Initial Jomon transitions, southern Kyushu, Japan: Regional scale to macro processes a close look

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ABSTRACT

Neolithization processes are among the most significant changes that have occurred in human history. The timing, order, and appearance of new behavioral elements and causes of behavioral change have been widely investigated. In the Japanese Archipelago, transitions from the Upper Paleolithic to Jomon show the first appearances of Neolithic behavioral elements. Research has commonly yielded inter-regional perspectives comparing technological changes with climate and landscape changes. This paper provides intra-regional comparisons of different environmental variables with technological changes focusing on southern Kyushu, Japan. This paper compares data on climate fluctuations, sea level changes, volcanic eruptions and impacts, and biomes with data on the appearance of and changes in pottery technology and variability, supplemented with studies of stone tools and archaeological features. Results suggest that climatic fluctuations, sea level changes, and biome variability may have had significant impacts on behavioral changes and that volcanic eruptions should be evaluated on an intra-regional and site-based scale.

1. Introduction

The evaluation of the causes and timing of the advent of Neolithic behaviors and the nature of artifacts, features, and behaviors associated with the Neolithic, or "Neolithization Processes" have undoubtedly been among the major topics in world archaeology. Extensive research into changes, such as hunting and gathering to farming, that occurred during the Upper Paleolithic to Neolithic transitions has been conducted. This research overlaps with studies of "sedentarization processes," a concept that incorporates much of the same phenomena as Neolithization processes. Nevertheless, a consensus has not been reached on which behavioral and material elements constitute the Neolithic period or the changes that characterize Neolithization processes.

The earliest perspectives focused on the "Neolithic Revolution" in which extreme climate change occurred at the transition between the last Ice Age and the warm period (Childe, 1951(1936)). Childe argued that these changes triggered animal domestication in places such as West Asia and that agriculture with plant domesticates emerged nearly simultaneously with pottery, ground stone, and sedentary communities. The Neolithic Revolution was understood as a major shift from mobile, hunting and gathering lifeways to Neolithic lifeways (Iizuka, 2016: 1; Iizuka et al., 2016: 31).

After the 1960s, increasing number of researchers, following the lineages of processual archaeology, began to study change toward sedentism as comprised of processes. In their research regions, they investigated whether or not residentially mobile hunter-gatherers a) adopted agriculture and became sedentary, b) adopted logistical foraging, or c) continued mobile foraging lifeways, (e.g., Binford, 1968; Flannery, 1969, 1973; Price and Brown, 1985; Keeley, 1988; Aldenderfer, 1989; Kelly, 1995; Piperno and Pearsall, 1998; Habu, 2000; Iizuka et al., 2016: 31). Processualists examined artifacts, features, and behavioral and environmental changes and made inferences about mechanisms of occurrence of diverse trajectories toward sedentism. In recent years, our understanding of Neolithization processes and sedentarization processes have changed due to developments in scientific analytical techniques, including AMS dating and discoveries of sites in countries formerly without easy access. We now know, for example, that, in the Middle East, it took about/over 10,000 years with inter-regional variability for behavioral and material elements considered to be Neolithic to

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appear (Bar-Yosef, 1998; Zeder, 2009). Grinding stones were used by hunter-gatherers around 24,000 years ago, and it is likely that wild plants were tilled and tended for thousands of years before domestication. Animal domesticates appeared at the Pleistocene-Holocene boundary, about the same time as plant domesticates. Pottery making followed. There were varied tendencies toward increasing sedentism (Zeder, 2009). By contrast, cases from the Neotropics suggest a dramatic climatic change occurred at the Pleistocene-Holocene boundary that induced the adoption of cultivation. By 7000 to 8000 years ago, crops were produced from slash-and-burn farming (Piperno and Pearsall, 1998; Piperno, 2006, 2011). Grinding stones appeared with the use of cultivated plants (e.g., Piperno, 2011), but the timing of the adoption of pottery and inferred timing of sedentism varied (Oyuela-Caycedo and Bonzani, 2005; Iizuka, 2013). It is now clear that the evidence of Neolithic-like behaviors and materials emerged at different timings across space and there are variabilities within regions. Therefore, micro-regional scale case studies of the appearance of Neolithic behaviors need to be provided to better comprehend this phenomenon.

Materially, pottery has been considered among the major new technologies symbolizing the advent of Neolithic. New discoveries suggest that in the Russian Far East and Eastern Siberia, it was adopted by the Late Pleistocene mobile hunter-gatherers possibly to process nuts or fish for fat (Buvit and Terry, 2011); in Panama, it emerged much later than the advent of agriculture possibly for cooking (Iizuka, 2013); in the lowland Mexico, the first pottery was used mainly for display purposes and serving of special beverages or as a status symbol before it was used for cooking and storage (Clark and Gosser, 1995; Iizuka, 2016: 1). Varied pottery origins suggest that no single model can explain the behavioral context of the adoption of this technology.

This paper focuses on comparing paleoenvironmental changes with pottery and stone tool changes that occurred between the Upper Paleolithic and Initial Jomon of southern Kyushu, Japan. Micro-regional emphasis within the Japanese archipelago was conducted in order to contribute to the world-wide archaeological research theme of Neolithization processes. Our ultimate research goals are to investigate the causality of behavioral changes, providing thorough explanations. However, in the presented paper, we first assess the correlations between technological and environmental changes.

2. Timing of changes and intra-regional variability in southern Kyushu

In the Japanese Archipelago, the Incipient Jomon (ca. 15,000 to 13,000 ^{14}C B.P.) (Imamura, 1996; Habu, 2004; Kudo, 2012) has traditionally been considered the boundary between the Upper Paleolithic and Neolithic periods. From Hokkaido to Kyushu, many Incipient Jomon sites have been discovered and excavated. Extensive research has been done on pottery typology-based chronology (e.g., Otsuka, 1989; Amemiya, 1994; Murakami, 2008), changes in lithic production and technology (e.g., Inada, 1969; Sato, 1992), and the antiquity of the Incipient Jomon (Kobayashi et al., 2006; Taniguchi, 2011; Kudo, 2012; Iizuka et al., 2016: 31). The Neolithization processes, however, involve the appearance of new behavioral elements at different timings. Therefore, not only the Upper Paleolithic to Incipient Jomon transition but also the Incipient to Initial Jomon transition should provide a more complete picture.

Recently, research has compared behavioral changes inferred from stone tool technological changes and timings of paleoenvironmental changes during the Upper Paleolithic-Incipient Jomon transitions (e.g., Nakazawa et al, 2011; Sato et al., 2011 a, b; Ono and Izuho, 2012; Morisaki, 2015). Results suggest that there are great degrees of correspondence between changes in variability in lithic technology, the timing of the advent of pottery and storage pits, and the timing of changes in climate and ecology, between ca. 18,000 and 10,000 ^{14}C BP (Iizuka et al., 2016: 32). New technological elements emerged in the Japanese archipelago roughly simultaneously. So far, these studies have been able to illuminate macro processes at the inter-regional scale; however, more research is needed at the micro-regional scale. The Japanese archipelago, stretching north to south, has diverse environmental conditions. Temperature ranges differ. Climatic conditions are distinct on the Sea of Japan and Pacific Ocean sides due to cordilleras running in the center of the archipelago. Therefore, comparisons of paleoclimatic and technological changes at an intra-regional scale should be conducted.

During the Last Glacial Maximum (LGM: ca. 26,000-19,000 Cal BP) (Clark et al., 2009, 2012), the Japanese archipelago consisted of two landmasses: the Paleo-Sakhalin-Hokkaido-Kuril peninsula, connected to Eurasia, and Paleo-Honshu Island, composed of the modern day Honshu, Shikoku, and Kyushu islands (Japan Association for Quaternary Research, 1987; Matsui et al., 1998; Morisaki et al., 2015: 555). By the Marine Isotope Stage 1, Honshu, Shikoku, and Kyushu were separated (Oba, 1993; Oba et al., 1995; Sato et al., 2011a). However, the timing of island separations has not been commonly presented at micro-chronological and regional levels. Therefore, more precise data on the timing of sea level changes at a regional level compared with behavioral changes should provide new archaeological insights.

Southern Kyushu (e.g., Kagoshima City: 31.5966° N, 130.5571° E) is an excellent place to conduct regional studies of the Neolithization processes (Fig. 1). There, Neolithic-like stone tool technology and variability emerged earlier than in Honshu and northern Kyushu (Sato et al., 2011a). Southern Kyushu has the first indicators of increased sedentism, with pottery, grinding stones, pit houses and hamlets, trap pits, and storage structures, dated to the Incipient Jomon, starting around 14,000/13,500 Cal BP (Pearson, 2006; Sato et al., 2011a; Morisaki and Sato, 2014). The subsequent Initial Jomon occupation began around 12,800 Cal BP. It is characterized by increases in site occupations—with settlements classified as villages—and variability of features and artifacts, including an abundance of highly decorated ceramics (Pearson, 2006; Kurokawa, 2009). The earliest timings of the Neolithization can be tested here.

Geologically, this region also has heterogeneous characteristics making it an appropriate place for provenancing artifacts. The Tanegashima Island and the exterior rim of the Aira Caldera are mainly composed of Oligocene sandstone/mudstone. The Yakushima Island and the southern Osumi Peninsula are composed of Miocene granite. The area surrounding the Aira Caldera is covered with Pleistocene pyroclastic flow. The northwestern Satsuma Peninsula consists of Oligocene dacite/rhyolite (Machida et al., 2001) (Fig. 2, GeomapNavi, 2016). Southern Kyushu, furthermore, has had volcanic eruptions throughout the Quaternary. Intra-regional variability in human behavioral responses to volcanic events can potentially be understood using the well-dated tephra (Okuno, 2002; Machida and Arai, 2003).

Additionally, it has been inferred that vegetation remained unchanged from Marine Isotope Stage 3 to 1 in the southern tips of Kyushu, Shikoku, and central Honshu (Miyake, 2013; Takahara and Hayashi, 2015), likely due to the warm, Black Current, running south to north. There are also archaeological sites with *in-situ* paleoenvironmental reconstructions in the region that can elucidate *in-situ* conditions associated with technology and change and inter-site relations.

This region, therefore, is not only appropriate for examining the earliest timings of the Neolithization processes in the archipelago, but it would also potentially allow detailed behavioral

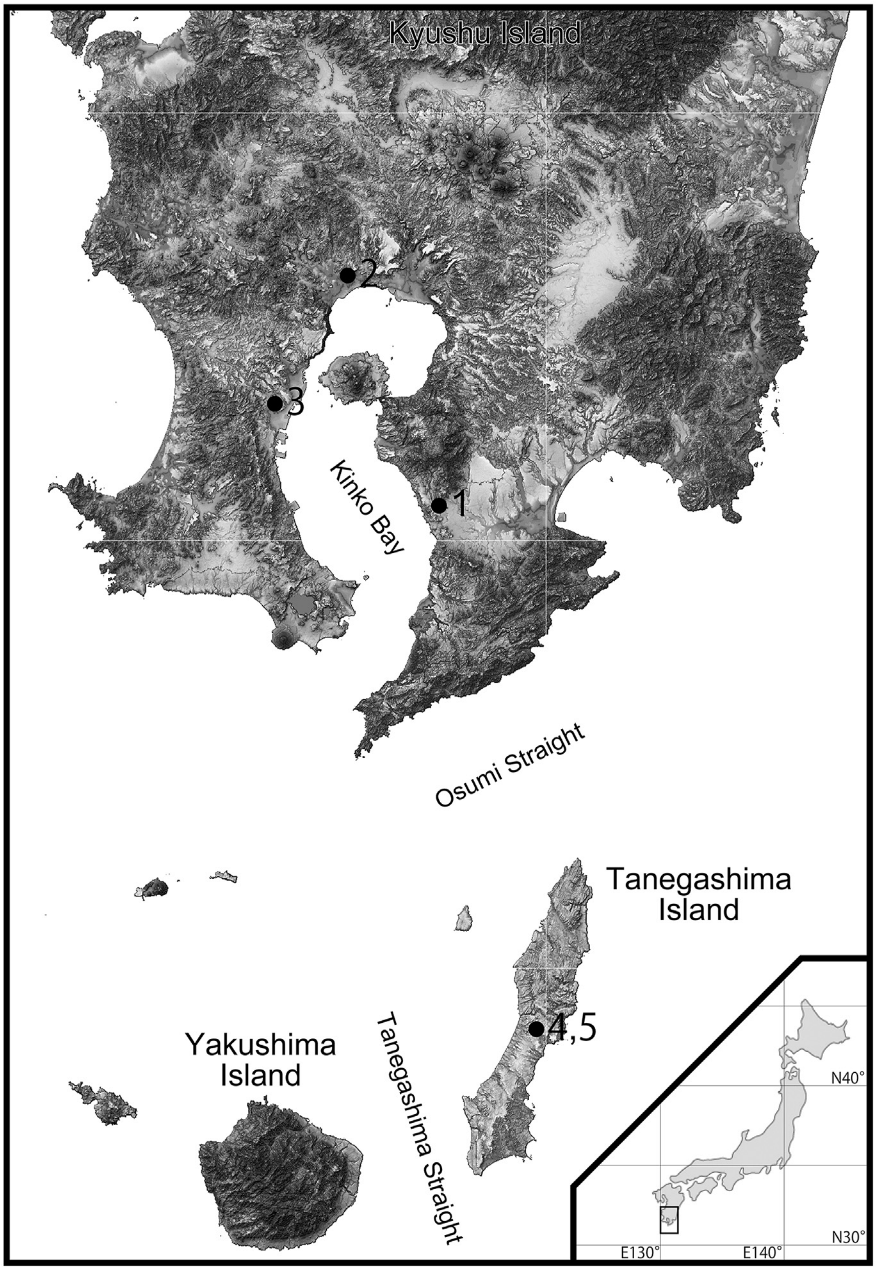

Fig. 1. Locations of sites mentioned in this paper. 1 is Nishimaruo, 2 is Kenshojo-Ato, 3 is Sojiyama, 4 is Sankakuyama I, and 5 is Okunonita. Shaded relief image derived from Super Chikei (2016).

reconstructions and research on the reasons behind changes.

3. Materials and methods

In this paper, we follow the human ecosystem approach (Butzer, 1982; Waters, 1992). Thus, the most important purpose of this paper is to investigate different environmental factors corresponding with technological and behavioral changes by focusing on the Late Upper Paleolithic-Incipient Jomon and the Incipient-Initial Jomon transitions. It is known that there are at least 105 Upper Paleolithic (Japanese Paleolithic Research Association, 2010), 53 Incipient Jomon, and 617 Initial Jomon sites (Kagoshima Center for Buried Cultural Property, 2014). Large scale excavations have been conducted at approximately 20 sites. For effective results, sites that have reliable excavation and stratigraphic contexts were chosen. We also selected sites that have literature containing data that meet the objective of our study. The following five archaeological sites were examined from varied geographical and geological areas of southern Kyushu: (1) the Nishimaruo site (Kagoshima Prefecture Board of Education, 1992) in the Osumi Peninsula, near the coast of the Kinko Bay, (2) the Kenshojo-Ato site (Aira City Board of Education, 2005) in the interior near the north-western coast of the Kinko Bay, (3) the Sojiyama site (Kagoshima City Board of Education, 1992), which is inland, close to the western coast of the Kinko Bay, (4) the Sankakuyama I (Kagoshima Center for Buried Cultural Property, 2006), and (5) the Okunonita (Kagoshima Prefecture Board of Education, 1995) sites in the central area of the Tanegashima Island (Fig. 1).

For paleoenvironmental data, five variables were obtained from existing literature. The first variable pertained to the timing of

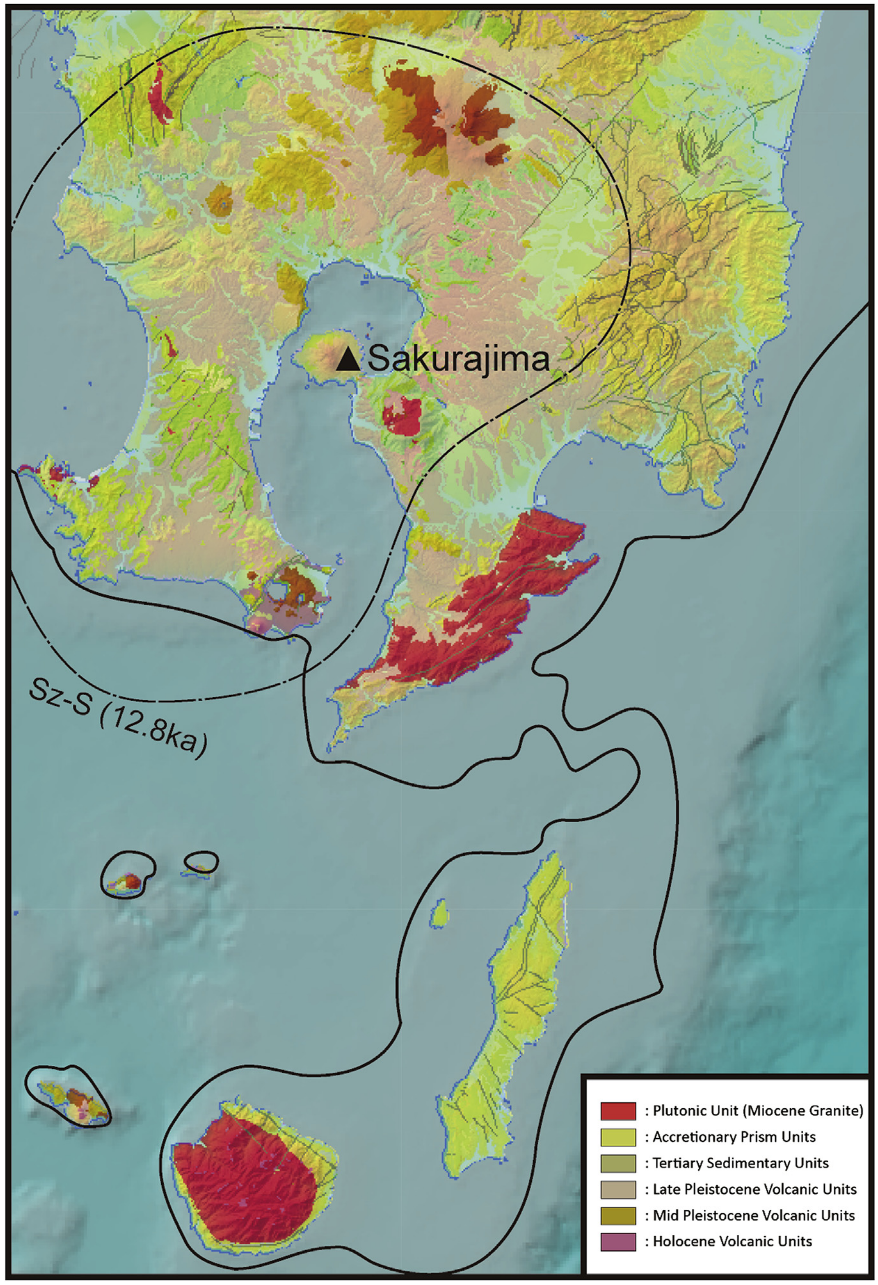

Fig. 2. Geological map of southern Kyushu, showing hypothesized coastlines during the late Pleistocene, and an isopack map of Sz-S having the distribution of tephra at >10 cm. The geological maps was created after GeomapNavi, the coastlines were made after Japan Association for Quaternary Research, and the isopack map was created after Okuno (2002).

paleoclimate and temperature changes. Data regarding this variable were obtained from Oldest Dryas and Bølling/Allerød, Bølling/Allerød and Younger Dryas, and Younger Dryas and Pre-Boreal transitions. The second variable was the timing and nature of sea level changes occurring between the terminal Pleistocene and Early Holocene. Inferred dates for increases in sea levels and the submergence of lands in southern Kyushu were provided. The third variable was the distribution and intensity of tephra. Presence and absence of tephra, name of tephra, and thickness of tephra at each studied site were recorded. The fourth was the differential biomes in southern Kyushu. Inferred biome differences within southern Kysuhu during the terminal Pleistocene were presented. Fifth variable was the *in-situ* paleoenvironmental data obtained from the Kenshojo-Ato site and the Sankakuyama I site. The timing of changes in the site environment was presented.

To investigate human behaviors, pottery data were examined and the study was supplemented with research on stone tools and features. Studies of pottery production processes (raw material procurement, production, technology, use, and discard) allow us to understand pottery production locations and circulation patterns and the possible reasons behind vessel transportation. Through these studies, we can identify the duration of occupation of producers at sites. Producers' technical choice related to frequency and distance of transportation can also be assessed. Stone tool-kit diversity research allows the understanding of a range of activities carried out at each site. Increased numbers of features indicate occupational intensification. Ceramic data were obtained through artifact analyses and from archaeological literature. Pottery artifact analyses were done with the identification of pottery inclusion variability, comparing thickness of sherds, and studying manufacturing techniques for inter-site comparisons. The inclusions were examined under a stereoscope; types and variability were identified and recorded. Provenance was inferred. Thickness was measured at the thickest areas of the body sherds. Manufacturing techniques were studied through visual analyses of the exterior and interior and all sides of sherds. Thickened and thinned areas of vessel walls, indentations and cracks on exterior and interior surfaces, and fracture pattern and voids on sherd profiles were examined. These visually observable variables served as the evidence to identify locations where clays were joined (see Vandiver, 1987, 1988). In turn, tracing joined areas helped us understand units, sizes, and forms of joined clays. Inferences of manufacturing techniques were supplemented with data obtained with xeroradiography (Iizuka and Izuho, 2015; Iizuka et al., 2016; following methods of Vandiver, 1987, 1988). Sherds selected for the artifact analyses were from three sites: Kenshojo-Ato (n = 30), Sojiyama (n = 29), and Sankakuyama I (n = 58). These samples were from the Incipient Jomon, and data were used for inter-site comparisons. Pottery technological change between the Incipient and Initial Jomon was assessed adopting data from site reports of the Okunonita (Kagoshima Prefecture Board of Education, 1995) and Kenshojo-Ato (Aira City Board of Education, 2005) sites. Vessel form variability and proportions of decorative sherds were compared. Reconstructed vessels and sherds that were classifiable into decorative and non-decorative sherds were counted. Sherds that were recorded as smoothed (or smoothed with a tool) and burnished were classified as plain sherds for the Initial Jomon data. Sherds in the Kenshojo-Ato report (Aira City Board of Education, 2005) were classified into decorative and non-decorative vessel types and sherd counts were provided based on the subcategories of those types. Although there were typology-based classifications that combine vessel forms and decorations in archaeological literature of southern Kyushu, for the presented study, vessel forms were broadly classified by possible functional types.

For stone tools, data from archaeological literature were adopted. Primary reductions and tool types and richness by site were provided. Archaeological features were also presented as supplementary information. Data from the Upper Paleolithic period of Nishimaruo, the Incipient and Initial Jomon of Kenshojo-Ato, Sankakuyama I, and Okunonita were obtained. The intra-regional differences between the north—Kenshojo-Ato—and the south—Sankakuyama I and Okunonita—during both the Incipient and Initial Jomon were also studied.

Finally, results were discussed, comparing the timing of climate change, sea level change, volcanic events and intensities, and intra-regional biome variability and change, with technological variability and changes.

4. Paleoenvironment and variables

4.1. Climatic fluctuations

Following the Last Glacial Maximum, climatic fluctuations occurred worldwide from about 19,000 Cal BP (Clark et al., 2012) to about 11,500 Cal BP, the end of the Late Glacial (LG) (Bradley, 1999). According to these records, there were transitions between the Oldest Dryas and Bølling/Allerød around 15,000 Cal BP; between the Bølling/Allerød and Younger Dryas around 12,900 Cal BP; and between the Younger Dryas and Pre-Boreal about 11,500 Cal BP. An abrupt warming occurred early in the Holocene, between 11,500 and 8800 Cal BP during the Pre-Boreal (Gedda et al., 1999 in Gedda, 2001) and between 8800 and 7800 Cal BP during the Boreal (Gedda and Proschwitz in Gedda, 2001; Karlsson, 2011). The local climatic fluctuations in southern Kyushu have been debated due to the lack of successful pollen and marine core records in this region. However, archaeologists have attempted archaeological studies incorporating broader, world-wide changes (Nakazawa et al., 2011; Morisaki and Sato, 2014). Their research suggests that human behavioral change tends to correspond with climate change. Therefore, we tentatively compare world-wide climatic data to the archaeological record.

4.2. Sea level changes

Due to lower sea levels, Kyushu Island merged with the mainland Honshu and Shikoku Islands during the Pleistocene (Japan Association for Quaternary Research, 1987). Similarly, the northeastern tip of Tanegashima Island was connected to the mainland Kyushu, and the eastern side of Yakushima Island to Tanegashima Island, during the Terminal Pleistocene; these islands were separated by the onset of the Holocene (Fig. 2). However, evidence from a recently published fine scale study (Moriwaki et al., 2015) suggests the possibility that southern Kyushu may have experienced sea level rises by the terminal Pleistocene and the separation of Tanegashima, Yakushima, and mainland Kyushu may have occurred earlier. An abrupt sea level rise occurred around 14,300 Cal BP to about 75 m below the current level; water entered the Kinko Bay of the Aira Caldera (Moriwaki et al., 2015: 165). By about 13,000 Cal BP, prior to the time of the fall of Satsuma Tephra (Sz-S), the sea transgressed to 40–50 m below the current level; the water partially entered the recess of the Kinko Bay. By 11,500 Cal BP, the sea level was 35 m below the current level; another abrupt sea level rise occurred and reached the current level by K-Ah (Moriwaki et al., 2015: 164–166). The two abrupt sea level rises were correlated with the timing of temperature warming (Moriwaki et al., 2015: 167): the first one occurred after the onset of the Bølling/Allerød and the second one, the beginning of the Pre-Boreal. The Osumi Strait between mainland Kyushu and Tanegashima has the depth of about 100–250 m below the present sea level and the Tanegashima Strait below 100 m. Although Moriwaki et al. (2015) study is focused on the Aira Caldera area of mainland Kyushu, the sea level rises may have created the Osumi and Tanegashima Straits by the beginning of the Incipient Jomon.

4.3. Tephra distribution and thickness

The Incipient and Initial Jomon are separated by the Satsuma Tephra (P14: Sz-S, 12,800 Cal BP, Okuno, 2002) (Fig. 2). The Initial Jomon is classified to have continued to 7300 Cal BP (Kuwahata, 2013) with the occupation ending below the tephra derived from an enormous eruption of the Kikai Caldera (K-Ah).

Thicknesses of the Satsuma Tephra layers differ greatly by regions and sites. Sz-S is 20 cm at Nishimaruo (Kagoshima Prefecture Board of Education, 1992), 17 cm at Kenshojo-Ato (Aira City Board of Education, 2005), 110 cm at Sojiyama (Kagoshima City Board of Education, 1992), 2 cm at Sankakuyama I (Kagoshima Center for Buried Cultural Property, 2006), and none found at Okunonita. At Sankakuyama I, however, the tephra are not distributed widely and are found as a discontinuous thin layer; an example of the thickness measurement comes from Zone F-7.

The most significantly impacted site was Sojiyama. Sojiyama was not re-occupied during the subsequent, Initial Jomon; this may be correlated with the impact of the fall of Sz-S. Tanegashima Island with Sankakuyama I and Okunonita received little impact from Sz-S. This indicates that technological and behavioral changes observed at sites on Tanegashima were not likely due to the impact of the eruption that caused the fall of Sz-S. From these patterns, it can be inferred that for a while after the fall of Sz-S tephra, there was micro regional biome variability and differential human responses observed in settlement patterns.

4.4. Inferred biomes

Recent studies suggest that warm-temperate species existed in southern Kyushu during LGM (Miyake and Momohara, 2015). Temperate coniferous and temperate deciduous broad-leaved mixed forests were broadly distributed in Kyushu; coniferous trees included northern types, Korean pine (*Pinus Koraiensis*), and spruce (*Picea torano syn. Picea polita*) (Miyake, 2013; Miyake and Momohara, 2015: 4). However, in southwestern Kyushu, temperate deciduous broad-leaved trees were likely to have been abundant. Warm-temperate evergreen and deciduous broad-leaved forests were inferred to have existed in the lowlands of the southern tip of the Kagoshima Prefecture, Tanegashima, and Yakushima, inferred from its present distribution and DNA haplogroup (Miyake, 2013; Miyake and Momohara, 2015). Kenshojo-Ato, at the northern tip of the Kinko Bay, and sites on Tanegashima can be used for comparison to examine possible human behavioral responses to biome differences.

4.5. Site-based paleo-environmental data

According to phytolith-based observation and data, paleoenvironmental differences between Kenshojo-Ato (Aira City Board of Education, 2005: 395–397) and Sankakuyama I (Kagoshima Center for Buried Cultural Property, 2006: 254, 284) are the following: At Kenshojo-Ato, only above the Sz-S, evergreen arbors emerged, and cold climate indicators such as *Sasa* sect. Crassinodi and *Sasa* sect. Sasa significantly reduced. This suggests that a drastic warming occurred after the fall of Sz-S. At Sankakuyama I, the significant reduction of *Sasa* veitchii (Carr.) Rehd, the cold-climate indicator, and the appearance of evergreen arbors occurred as early as layer 6 and continued as late as the upper part of layer 5, prior to the fall of Sz-S. These site-based trends, the early warming on Tanegashima, roughly correspond with the inferences from the biome differences in southern Kyushu that continued from LGM (Miyake, 2013; Miyake and Momohara, 2015).

5. Archaeological results

5.1. Pottery and variability

Slab techniques are observed in all sherds from Kenshojo-Ato, Sojiyama, and Sankakuyama I (Iizuka and Izuho, 2015; Iizuka et al., 2016) (Fig. 3, Table 2). Slab techniques are inferred because there are fragments of clays that are flattened in irregular or oval forms. These slabs are longer at least on one axis on the vessel surface compared to the thickness of the clay units visible on the vessel wall. These slabs appeared to be layered constructing the wall. The slab-based vessel walls tended to be supplemented with minor amounts of clay lumps, globs of clays with cubic or spherical dimensions having equal lengths on x, y, and z coordinates.

Kenshojo-Ato has paste consisting of pyroclastics-derived minerals and rock fragments of different densities in all of the analyzed sherds. Pyroclastic materials are available around the site. Sojiyama has mainly pyroclastic inclusion-based sherds; however, minor amounts of pyroclastics mixed with granite or ganodiorites are also present. Pyroclastic materials are locally available, but those with acidic coarse igneous rock fragments suggest transportation from elsewhere. Sankakuyama I has varied inclusion types: pyroclastics, possible alluvial mixed with pyroclastics, granite, possible alluvial, pyroclastics with granite, and possible alluvial and pyroclastics with granite. Pyroclastic materials are deposited on Tanegashima and alluvial materials are available nearby; therefore, they are local.

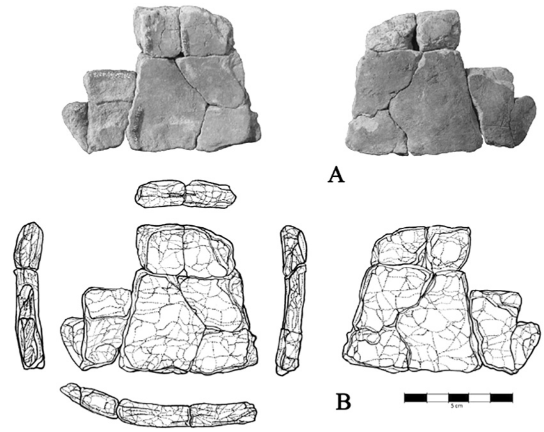

Fig. 3. Manufacturing technique of the Incipient Jomon pottery from the Sankakuyama I site. A: photo of an interior and an exterior of a reconstructed sherd (Sample 045) from the Incipient Jomon context of the Sankakuyama I site. This shows step fractures at the edge, at the right side of the interior, and the upper edges of the exterior. B: drawing of the same sherd. The solid lines in B are the outlines and ridge lines. The broken lines indicate the locations of possible clay joins. The vessel wall is constructed with a number of slabs supplemented with some lumps having between 5 and 9 layers. There are 5–7 layered slabs having the long axis measuring ≤15 mm, when visually observing the interior and exterior in the lower part of the sherd; however, these slabs may compose larger slabs of 5–7 layers with the long axis measuring ≤30 mm. In the upper half of the sherds, there are also slabs having the long axis measuring ≤15 mm. There is a maximum of 9 layers. The edges at the bottom and the top have step fractures (Iizuka et al., 2016).

Granitic materials are not available locally. Although petrographic and geochemical studies are required for further understanding, stereoscopic analyses suggest that in pottery from Sojiyama and Sankakuyama I, there are, at least, non-local granitic or granodioritic inclusions in pottery. There are granitic intrusive units within 20 km distance from Sojiyama in the Satsuma Peninsula. The granitic intrusive units are found on Yakushima Island and Osumi Peninsula across the Osumi Strait (Fig. 2, Table 1).

Thickness comparisons suggest that Kenshojo-Ato and Sojiyama have sherds with similar thickness and that they are thicker than sherds from Sankakuyama I.

At Okunonita, vessels take the form of deep and shallow bowls in the context of Incipient Jomon. In the Initial Jomon, by contrast, only deep bowls are present. At Kenshojo-Ato, there were two types, a somewhat open mouthed deep bowl and a cylinder, from the Incipient Jomon, and three types, cylinders, deep bowls, and jars from the Initial Jomon (Fig. 4).

At Okunonita, 26.8% of reconstructed vessels and sherds (Kagoshima Prefecture Board of Education, 1995) derived from the Incipient Jomon are decorative. For the Initial Jomon, 78.6% are decorative. At Kenshojo-Ato, 0.6% of pottery from the Incipient Jomon (all from layer IX) is decorated. All of these decorated sherds are Pottery Type I. For the Initial Jomon (Research Zone I), 98.6% are derived from decorative wares (Table 1).

Variability in vessel forms decrease between the Incipient and Initial Jomon at Okunonita. At Kenshojo-Ato, although the microvariability of vessel forms increases between the Incipient and Initial Jomon, drastic changes in vessel form variability are not observed between those periods. At Kenshojo-Ato, cylindrical vessels are present from the Incipient Jomon to the Initial Jomon; however, they are not found at Okunonita during either of the periods. Additionally, at Okunonita, proportions of decorative sherds increase between the Incipient and Initial Jomon by nearly three times. At Kenshojo-Ato, all sherds come from decorative ware vessels in the Initial Jomon, compared to almost none in the Incipient Jomon.

Table 1
Ceramic technology by site.

No.	Site	Inclusion types and samples (n)	Body sherd average thickness (mm)	Manufacturing techniques	Vessel forms	Decorative vessels and/or sherds (%)
2	Kenshojo-Ato (Icp-J)	Pyroclastic (n = 30), [total analyzed n = 30]	11.54 (n = 21)	Slabs or slabs combined with lumps (n = 30) [total analyzed n = 29]	Somewhat open mouthed deep bowl, cylinder	0.6 (n = 3) [total analyzed n = 491]
	Kenshojo-Ato (Int-J)	N/A	N/A	N/A	Cylinder, deep bowls, jars	98.6 (n = 9872) [total analyzed n = 10,012]
3	Sojiyama (Icp-J)	Pyroclastic (n = 26 of total n = 29), granite or granodiorite (n = 3 of total n = 29), [total analyzed n = 29]	11.52 (n = 24)	Slabs or slabs combined with lumps (n = 29) [total analyzed n = 29]	–	–
4	Sankakuyama (Icp-J)	Pyroclastic (n = 22), possible alluvial + pyroclastic (n = 25), granite (n = 2), posible alluvial (n = 2), pyroclastic + granite (n = 1), posible alluvial + pyroclastic + granite (n = 2), [total analyzed n = 58]	8.25 (n = 24)	Slabs or slabs combined with lumps (n = 58) [total analyzed n = 58]	–	–
5	Okunonita (Icp-J)	N/A	N/A	N/A	Deep bowls, shallow bowls	26.8 (n = 348) [total analyzed n = 1278]
	Okunonita (Int-J)	N/A	N/A	N/A	Deep bowls	78.6 (n = 38) [total analyzed n = 49]

*Icp-J: Incipient Jomon, Int-J: Initial Jomon.

5.2. Lithic compositions and features at sites

Table 2 shows changes over time in the lithic compositions and features at studied sites. In the Late Upper Paleolithic, primary reduction techniques are mainly microblade and flake-based. On the contrary, later Jomon periods are strictly flake-based with the exception of some microblade-like tiny elongated flakes found at Kenshojo-Ato. Tool-richness, both in chipped stone tools and pebble tools is higher in the Incipient and Initial Jomon than in the Late Upper Paleolithic, suggesting that the range of activities carried out at Jomon sites were greater than in the Late Upper Paleolithic. Appearance of large pebble tools, for example, grinding stones and stone plates, first appeared in the Incipient Jomon. It is apparent that the largest stone tool compositional change occurred between the Late Upper Paleolithic and the Incipient Jomon. New features, such as pits and pit-dwellings, were added in the Incipient Jomon. No significant change in the composition of feature is observed from the Incipient Jomon to the Initial Jomon. In sum, range of activities and occupational duration, as proxies of sedentism are greater in the Incipient Jomon and the Initial Jomon than in the Late Upper Paleolithic.

6. Discussion

From pottery visual analyses and comparisons of the Incipient Jomon of Kenshojo-Ato, Sojiyama, and Sankakuyama I, the following can be inferred. The slab techniques used in vessel manufacture could be due to the producers prioritizing the ease of manufacture (Schiffer and Skibo, 1987) or they could indicate that producers belonged to the same linguistic group (Reina and HIll, 1978; Arnold, 1989; Gosselain, 1998). Sankakuyama I's thin vessel walls indicate that vessels may have been produced for the performance characteristic of transportability (Rice, 1987). Although ceramics have signatures mainly of local production at each site, at Sojiyama and Sankakuyama I, there are vessels with signatures of non-local materials. Producers at Sankakuyama I, in particular, may have prioritized the performance characteristic of transportability due to Sankakuyama I's location on Tanegashima where oceanic transgression may have caused an abrupt separation from Yakushima and mainland Kyushu by the onset of the Incipient Jomon, possibly requiring sea navigation to communicate with other islands. Producers at all sites may have preferred ease of manufacture, but at Sanakakuyama I, ease of transportation may also have been

Table 2
Lithic compositions and features at study sites.

Time period	Site	Primary reduction	Chipped stone tools richness	Pebble tools richness	Features
LUP	Nishimaruo, Layer VIIb	Microblade, Flake-based	2 (endscrapers, utilized flakes)	3 (edge-ground axes, choppers, grinding stones)	FCRs
Icp-J	Sankakuyama	Flake-based	6 (arrow-heads, drills, points, endscrapers, sidescrapers, wedges)	5 (edge-ground axes, hammer stones, choppers, grinding stones, stone plates)	Pit-dwellings, FCRs
	Kenshojo-Ato	Flake-based, Microblade?	5 (arrow-heads, points, endscrapers, sidescrapers, wedges)	4 (edge-ground axes, choppers, grinding stones, stone plates)	Pit-dwellings, Hearths, FCRs
	Okunonita	Flake-based	3 (arrow-heads, sidescrapers, wedges)	4 (edge-ground axes, hammer stones, grinding stones, stone plates)	FCRs
Int-J	Sankakuyama	Flake-based	5 (arrow-heads, sidescrapers, wedges, perforators, a body ornament)	4 (ground axes, hammer stones, grinding stones, stone plates)	Pit, FCRs
	Kenshojo-Ato	Flake-based	4 (arrow-heads, points, sidescrapers, wedges)	3 (ground axes, grinding stones, stone plates)	Pit-dwelling, Hearths, FCRs
	Okunonita	None	3 (arrow-heads, scrapers, wedges)	3 (hammer stones, grinding stones, stone plates)	FCRs

FCR: Fire Cracked Rock.

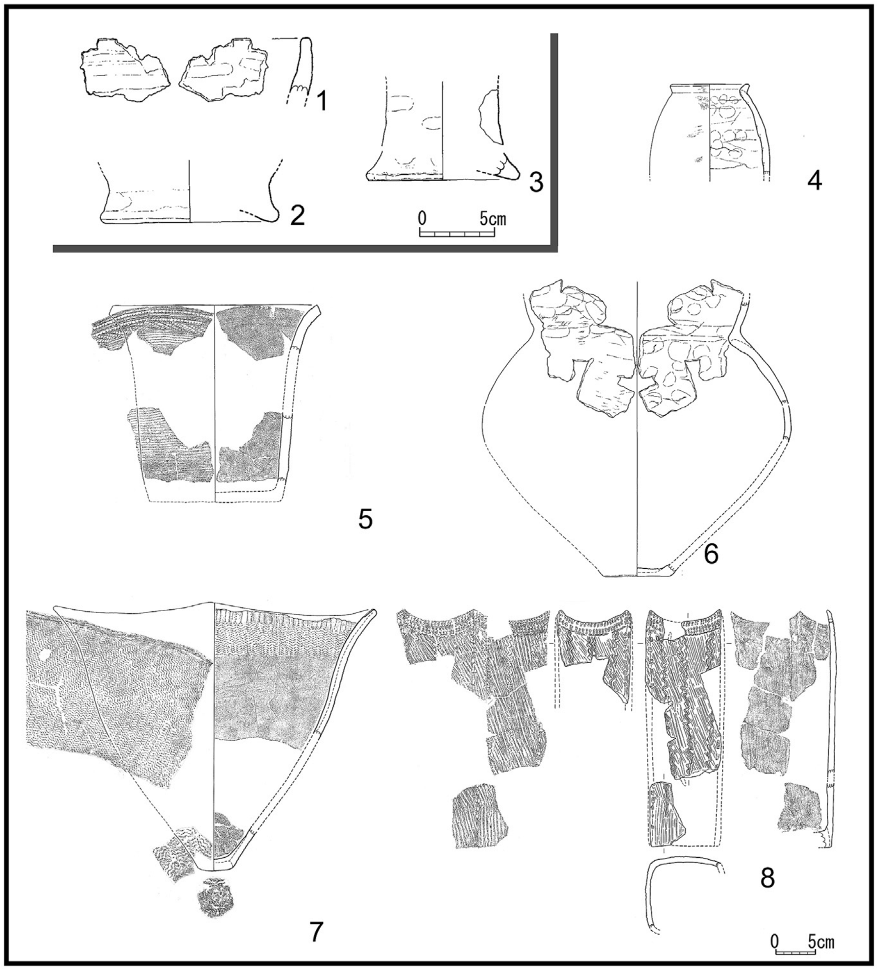

Fig. 4. Vessel forms of the Incipient and Initial Jomon from the Kenshojo-Ato site. 1 to 3: the Incipient Jomon, 4 to 8:the Initial Jomon.

important for resource and/or social exchange with related people on other island(s).

When the Incipient and Initial Jomon periods are compared, Kenshojo-Ato shows more change in the importance of pottery's suitability for display (e.g., Schiffer, 1992, 2011). At Okunonita, potters produced vessels to have symbolic performance characteristics (e.g., for public use or display purposes) during the Incipient Jomon. This tendency was significantly enhanced there during the Initial Jomon. At Kenshojo-Ato, on the contrary, symbolic performance characteristics were minimum priority during the Incipient Jomon; however, during the Initial Jomon, the importance of symbolic performance in Kenshojo-Ato may have surpassed that of Okunonita. Observing the overall vessel forms related to basic uses, between the two periods at Okunonita and Kenshojo-Ato, no drastic change was found at either site. This indicates that although symbolic performance characteristics were enhanced at the Initial Jomon, basic vessel use related to vessel form may not have differed between the two periods at either site.

6.1. Temperature changes

The Incipient Jomon period of southern Kyushu started around 14,000/13,500 Cal BP. This beginning does not seem to coincide with the timing of the Oldest Dryas and Bølling/Allerød transitions occurring around 15,000 Cal BP. However, the Bølling/Allerød and Younger Dryas transition, which occurred around 12,900 Cal BP, is the approximate timing of the beginning of the Initial Jomon period. Hence, temperature changes at the onset of the Younger Dryas roughly correspond with archaeological changes from the Incipient to Initial Jomon.

6.2. Sea level changes

In southern Kyushu, abrupt sea level changes occurring by about 14,300 Cal BP—after the onset of the Bølling/Allerød—roughly overlap with the beginning of the Incipient Jomon Period, about 14,000/13,500 Cal BP in southern Kyushu. It is likely that the disconnection of mainland Kyushu and Tanegashima and the entrance of water into the Kinko Bay occurred (Moriwaki et al., 2015). The adoption of ceramics and possible increase in sedentism and in stone tool-kit diversity correlate with the abrupt changes in the landscape. During this time, humans must have been forced to change subsistence strategies, non-subsistence resource uses, habitational and non-habitational site locations, paths, and means of inter-group communications. For communications to occur between Tanegashima and mainland Kyushu, water-craft navigation must have been required by the Incipient Jomon.

An abrupt sea transgression occurring prior to the fall of Sz-S caused the water to partially enter the recess of the Kinko Bay and the process continued to about 11,500 Cal BP (Moriwaki et al., 2015). Sites surrounding the recess of the bay, therefore, must have experienced a drastic environmental change. Kenshojo-Ato is one of them. Ceramics from Kenshojo-Ato show significant increase in the proportion of decorative wares, suggesting changes in how producers weighed the symbolic performance characteristics of vessels at the transition to the Initial Jomon. This change may be correlated with the altering environmental conditions. At Kenshojo-Ato, stone tool-kit diversity decreased between the Incipient Jomon and Initial Jomon, which indicates behavioral changes at this site. However, sea level changes affecting change in variability of the major stone tool categories were not found at the onset of either Incipient or Initial Jomon. The sea level changes that occurred at Kenshojo-Ato around the transition to the Initial Jomon may correspond to behavioral changes. Sea level changes, therefore, seem to correspond with technological changes, especially in ceramics, at the Upper Paleolithic and Incipient and the Incipient and Initial Jomon transitions.

6.3. Volcanic events

Except at the Sojiyama site, the timing of the ending of the Incipient Jomon and the onset of the Initial Jomon at studied sites did not show significant correlations with the intensity of volcanic impacts. This is particularly the case at Sankakuyama I and Okunonita on Tanegashima Island where Sz-S had only a minor effect; there is no indication of correspondence between Sz-S and the end of the Incipient Jomon occupation or between Sz-S and ceramic technological change occurring at the Initial Jomon.

6.4. Biome differences

The inferred biome differences in southern Kyushu with warm temperate evergreen and deciduous broad-leaved forest existed by the LGM in the southern tip of mainland Kyushu, Tanegashima, and Yakushima. The reconstructed site-based timing of warming between the northern site, Kenshojo-Ato, and the southern site, Sankakuyama I, roughly corresponds with this pattern. Therefore, biome and site-based paleoenvironmental variability and changes are discussed together to compare them with the timing of technological change.

When ceramic technology was adopted, it was regardless of biome differences. However, Kenshojo-Ato has very little indication of prioritized vessel performance characteristic for display purposes (e.g., Schiffer, 2011). We infer this because vessel surface decorations, one of the major indicators of displayability, are nearly absent. When the warming trend and vegetational changes occurred after the Initial Jomon, there was a drastic prioritization of this performance at Kenshojo-Ato.

Additionally, during the Incipient Jomon, stone tool-kit diversity was higher at Sankakuyama I compared to Kenshojo-Ato. This probably indicates that resource variability due to higher diversity in the biome existed on Tanegashima. When data from the Initial Jomon period in Sankakuyama I and Kenshojo-Ato are compared, stone-tool diversity is similar, but whereas Sankakuyama I shows no change in occupational density, at Kenshojo-Ato, there is an enormous increase.

The early, warm conditions in the southern fringes of southern Kyushu may have affected the early symbolic significance of vessels and stone-tool diversity at sites on Tanegashima Island. The importance of symbolic performance of vessels only increased with the appearance of warming conditions at Kenshojo-Ato. Kenshojo-Ato became a preferred location for occupation after the onset of the Initial Jomon. This may indicate a shift of favorable resource environment to the northern part of southern Kyushu at the onset of the Initial Jomon.

7. Conclusions

In conclusion, this study suggests that correlations between climate change and region-wide technological changes occurring at the transition from Bølling/Allerød and Younger Dryas, around 12,900 Cal BP, seem to be strong. Additionally, sea transgressions disconnecting the mainland and Tanegashima, and the creation of the Kinko Bay during the Bølling/Allerød may relate to human decisions in adopting ceramic technology, more sedentary lifestyle, and new behaviors that require additional varieties of stone tools. Water entering the recess of the Kinko Bay prior to the fall of Sz-S may correlate with significant changes in symbolic performance characteristics of ceramics at the Kenshojo-Ato site. The volcanic eruption that caused the fall of Sz-S tephra had area-based impacts but neither the fall of tephra nor the effects of volcanic activity explain the causes of the region-wide technological changes. With regards to biome differences, evergreen arbors appeared in Tanegashima earlier than in the northern part of southern Kyushu. The warming and vegetational changes that occurred after Sz-S in the northern part of southern Kysuhu (e.g., Kenshojo-Ato) may correspond with changes in prioritized performance characteristics of ceramics and increased occupational density of the northern part. Vessel suitability for display was present to a significant degree at Okunonita during the Incipient Jomon and was drastically increased at Kenshojo-Ato with the onset of the Initial Jomon.

Overall, this study suggests that climate change in Bølling/Allerød-Younger Dryas, sea level changes during the Bølling/Allerød and prior to the Younger Dryas, and biome variability and change across the northern and southern parts of southern Kyushu showed correspondence with technological change, especially with ceramics, the main subject of this study. These paleoenvironmental variables have potential for further investigation of their impacts on human behavioral changes. However, the Sz-S volcanic event and its impacts need to be assessed on a site by site basis.

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References

Aira City Board of Education, 2005. Kenshojo-ato. Aira City Board of Education, Aira (in Japanese).
Aldenderfer, M., 1989. The Archaic period in south-central Andes, 3 (2), 117–158.
Amemiya, M., 1994. Minamikyushu Jomonjidai sosoki doki hennen - futome no ryutaimondoki kara entokikagaramonkei doki heno hensen (The chronology of the Incipient Jomon: from thick ryutaimon pottery to entokikagaramonkei pottery). News Letter of Jomon Study in South Kyushu, 8, pp. 1–12 (in Japanese).
Arnold, D., 1989. Patterns of learning, residence and descent among potters in Ticul, Yucatan, Mexico. In: Shennan, S. (Ed.), Archaeological Approaches to Cultural Identity. Unwin Hyman, London, pp. 174–184.
Bar-Yosef, O., 1998. The Natufian culture in the Levant, threshold to the origins of agriculture. Evol. Anthropol. 6 (5), 159–177.
Binford, L., 1968. Post-pleistocene adaptations. In: Binford, S., Binford, L. (Eds.), New Perspectives in Archaeology. Aldine, Chicago, pp. 313–341.
Bradley, R., 1999. Paleoclimatology: Reconstructing Climates of the Quaternary.

Academic Press, San Diego.
Butzer, K.W., 1982. Archaeology as Human Ecology: Method and Theory for a Contextual Approach. Cambridge University Press, New York.
Buvit, I., Terry, K., 2011. The twilight of Paleolithic Siberia: humans and their environments east of lake Baikal at the late-glacial/Holocene transition. Quat. Int. 242 (2), 379–400.
Childe, G., 1951 (1936). Man Makes Himself. A Mentor Book, New York.
Clark, J., Gosser, D., 1995. Reinventing mesoamerica's first pottery. In: Barnett, W., Hoopes, J. (Eds.), The Emergence of Pottery: Technology and Innovation in Ancient Societies. Smithsonian Institution Press, Washington, pp. 209–222.
Clark, P., Dyke, A., Shakun, J., Carlson, A., Clark, J., Wohlfarth, B., Mitrovica, J., Hostetler, S., McCabe, A., 2009. The last glacial maximum. Science 325 (5941), 710–714.
Clark, P., Shakun, J., Baker, P., Bartlein, P., Brewer, S., Brook, E., Carlson, A., Cheng, H., Kaufman, D., Liu, Z., Marchitto, T., Mix, A., Morrill, C., Otto-Bliesner, B., Pahnke, K., Russell, J., Whitlock, C., Adkins, J., Blois, J., Clark, J., Colman, S., Curry, W., Flower, B., He, F., Johnson, T., Lynch-Stieglitz, J., Markgraf, V., McManus, Mitrovica, J., Moreno, P., Williams, J., 2012. Global climate evolution during the last deglaciation. Proc. Natl. Acad. Sci. 109 (19), E1134–E1142.
Flannery, K., 1969. Origins and ecological effects of early domestication in Iran and the near east. In: Ucko, P.J., Dimbleby, G.W. (Eds.), The Domestication and Exploitation of Plants and Animals. Duckworth, London, pp. 73–100.
Flannery, K., 1973. The origins of agriculture. Curr. Anthropol. 2, 271–310.
Gedda, B., 2001. Environmental and Climatic Aspects of the Early to Mid Holocene Calcareous Tufa and Land Mollusk Fauna in Southern Sweden. Doctoral dissertation. Department of Quaternary Geology, Lung University, Sweden.
Gedda, B., Lemdahl, G., Gaillard, M.J., 1999. Late glacial and early Holocene environments inferred from a tufa deposit at Fyledalen, S. Sweden. GFF 121, 33–41.
GeomapNavi, 2016. Geological Survey of Japan, AIST, https://gbank.gsj.jp/geonavi/?lang.en, (Accessed 31 May 2016).
Gosselain, O., 1998. Social and technical identity in a clay crystal ball. In: Stark, M. (Ed.), The Archaeology of Social Boundaries. Smithsonian Institution Press, Washington, pp. 78–106.
Habu, J., 2000. Residential mobility of the Jomon people (1) (2). Cultura Antiqua 52, 95–103, 214–225 (in Japanese).
Habu, J., 2004. Ancient Jomon of Japan. Cambridge University Press, New York.
Iizuka, F., 2013. Early Pottery in the Tropics of Panama (Ca. 4500-3200 BP): Production Processes, Circulation, and Diagenesis. Ph.D. dissertation. School of Anthropology, University of Arizona, Tucson.
Iizuka, F., 2016. The emergence of pottery in Panama (ca. 4500–3200 ^{14}C BP) and its relations to use and degrees of sedentism (summary of oral presentation: http://jssaa.rwx.jp/kondankai_east006_shouroku.pdf). In: Sixth Round-table Conference of Eastern Japan, Japan Society for Studies of Ancient America. Tokyo, Japan, pp. 1–9 (in Japanese).
Iizuka, F., Izuho, M., 2015. Comparing paleoenvironmental changes and technological changes from the Late Upper Paleolithic to Initial Jomon (ca. 19,000-7,300 cal BP) of southern Kyushu, Japan. In: Poster Presented at the International Union for Quaternary Research XIX, Nagoya.
Iizuka, F., Izuho, M., Vandiver, P., Okubo, K., 2016. Manufacturing Techniques and Variability: Incipient Jomon Pottery from the Sankakuyama I Site, Kagoshima, Japan. From Jomon no Mori, Bulletin of Kagoshima Prefectural Archaeological Center 9, pp. 31–50 (in Japanese, with English Abstract).
Imamura, K., 1996. Prehistoric Japan: New Perspective on Insular East Asia. UCL Press, London.
Inada, T., 1969. Sentokibunka no shutsugen to kyusekkiteki sekki seisaku no kaitai (The emergence of Sentoki culture and decipherment of Paleolithic-like stone tool production). Kokogakukenkyu 15 (3), 3–18 (in Japanese).
Japan Association for Quaternary Research, 1987. The Quaternary Map of Japan. University of Tokyo, Tokyo.
Japanese Paleolithic Research Association, 2010. Paleolithic Period Sites of the Japanese Archipelago. Meiji University Museum, Tokyo (in Japanese).
Kagoshima Center for Buried Cultural Property, 2006. Sankakuyama I. Kagoshima Center for Buried Cultural Property, Kirishima (in Japanese).
Kagoshima Center for Buried Cultural Property, 2014. Buried Cultural Property Information Database. http://www.jomon-no-mori.jp/kmai_public/ (accessed September 28, 2014) (in Japanese).
Kagoshima City Board of Education, 1992. Sojiyama. Center for Buried Cultural Property, Kagoshima (in Japanese).
Kagoshima Prefecture Board of Education, 1992. Nishimaruo Site. Kagoshima City Board of Education, Kagoshima (in Japanese).
Kagoshima Prefecture Board of Education, 1995. Okunonita Site and Okuaraishi Site. Nishinoomote City Board of Education, Nishinoomote (in Japanese).
Karlsson, S., 2011. Chapter 11, Vegetational Developmment in the Provinces of Södermanland and Uppland, Eastern Sweden. The Swedish National Heritage Board, Stockholm.
Keeley, L., 1988. Hunter-gatherer economic complexity and “population pressure:” a cross-cultural analysis. J. Anthropol. Archaeol. 7, 373–411.
Kelly, R., 1995. The Foraging Spectrum, Diversity in Hunter-Gatherer Lifeways. Smithsonian Institution Press, Washington and London.
Kobayashi, K., Harunari, H., Onbe, S., Watanuki, S., Anezaki, T., Hashimoto, M., Ushino, T., Okazaki, K., 2006. Special issue: the beginning of pottery. Rekihaku 139, 1–25 (in Japanese).
Kudo, Y., 2012. Environment and Culture History of the Upper Paleolithic and the Jomon Period: High-precision Radiocarbon Dating and Archaeology. Shinsensha, Tokyo (in Japanese).
Kurokawa, T., 2009. On cultural pioneering in the first part of Initial Jomon period, southern Kyushu, Japan. Quat. Res. 41 (4), 331–344.
Kuwahata, M., 2013. The relationship between the years of the Kikai-Akahoya tephra and the chronological sequence of Jomon pottery in Kyushu. Quat. Res. 52 (4), 111–125 (in Japanese with English abstract).
Machida, H., Arai, F., 2003. Atlas of Tephra in and Around Japan. University of Tokyo, Press (in Japanese).
Machida, H., Ota, Y., Kawana, T., Moriwaki, H., Nagaoka, S. (Eds.), 2001. Nihon no Chikei 7: Kyushu Nansei Shoto (Regional Geomorphology of the Japanese Islands, vol. 7, Geomorphology of Kyushu and the Ryukyus). University of Tokyo Press, Tokyo (in Japanese).
Matsui, H., Tada, R., Oba, T., 1998. Low-salinity isolation event in the Japan sea in response to eustatic sea-level drop during LGM: reconstruction based on salinity-balance model. Quat. Res. 37, 221–233 (in Japanese).
Miyake, N., 2013. Distribution patterns of forest vegetation during the last glacial maximum in the southwestern Japan, based on fossil pollen records. In: The 28th Annual Meeting of the Japanese Association of Historical Botany, pp. 15–19 (in Japanese).
Miyake, N., Momohara, A., 2015. Vegetation Patterns on Shikoku and Kyushu Islands during the Last Glacial Maximum, 4. MRC2015 Koenyokoushu (in Japanese).
Morisaki, K., 2015. Settlement patterns of prehistoric hunter-gatherers in the Kyshu region during the terminal Pleistocene. Quat. Res. 54 (5), 257–270 (in Japanese with English abstract).
Morisaki, K., Sato, H., 2014. Lithic technological and human behavioral diversity before and during the late glacial: a Japanese case study. Quat. Int. 347, 200–210.
Morisaki, K., Izuho, M., Terry, K., Sato, H., 2015. Lithics and climate: technological responses to landscape change in upper Paleolithic Neolithic northern Japan. Antiquity 89 (345), 554–572.
Moriwaki, H., Matsushima, Y., Sugihara, S., Ohira, A., Oki, K., Masubuchi, K., Tsurumaki, K., 2015. Sea-level and paleoenvironmentala changes of Kokubu plain on the northern coast of Kagoshima By, south Japan, since 15,000 years ago. Quat. Res. 54 (1), 149–171 (in Japanese).
Murakami, N., 2008. The chronology of Initial Jomon pottery in the western Japanese archipelago especially focused on the south Kyushu region. J. Jpn. Archaeol. Assoc. 24, 1–20 (in Japanese).
Nakazawa, Y., Iwase, A., Akai, F., Izuho, M., 2011. Human responses to the younger dryas in Japan. Quat. Int. 242, 416–433.
Oba, T., 1993. Saishu hyoki iko no nihon retto shuhen ni okeru kairyu hensen. (The oceanic current change around Japan Sea in the Last Glacial Maximum). Gakujutsu Geppou. (Japanese Scientific Monthly) 46 (10), 934–938 (in Japanese).
Oba, T., Murayama, M., Matsumoto, E., Nakamura, T., 1995. AMS-^{14}C ages of Japan sea cores from the oki ridge. Quat. Res. 34 (4), 289–296 (in Japanese).
Okuno, M., 2002. Chronology of tephra layers in southern Kyushu, SW Japan, for the last 30,000 years. Quat. Res. 41 (4), 225–236 (in Japanese with English abstract).
Ono, A., Izuho, M., 2012. Environmental Changes and Human Occupation in North and East Asia during OIS 3 and OIS 2. British Archaeological Report International Series, 2352. Archaeopress, Oxford.
Otsuka, T., 1989. Sosoki no doki (Incipient Jomon pottery). In: Kobayashi, T. (Ed.), Jomon Doki Taikan 1: Sosoki, Soki, Zenki (A Grand Survey of Jomon Pottery 1: Incipient, Initial, and Early Jomon). Shogakukan, Tokyo, pp. 251–256 (in Japanese).
Oyuela-Caycedo, A., Bonzani, R.M., 2005. San Jacinto I: A Historical Ecological Approach to an Archaic Site in Colombia. The University of Alabama Press, Tuscaloosa.
Pearson, R., 2006. Jomon hot spot: increasing sedentism in south-western Japan in the incipient Jomon (14,000-9250 cal. BC) and earliest Jomon (9250-5300 cal. BC) periods. World Archaeol. 38 (2), 258–329.
Piperno, D., 2006. Quaternary environmental history and agricultural impact on vegetation in central America. Ann. Mo. Bot. Gard. 93, 274–296.
Piperno, D., 2011. The origins of plant cultivation and domestication in the new world tropics. Curr. Anthropol. 52 (S4), 453–470.
Piperno, D., Pearsall, D., 1998. The Origins of Agriculture in the Lowland Neotropics. Academic Press, San Diego.
Price, T.D., Brown, J.A., 1985. Aspects of hunter-gatherer complexity. In: Price, D., Brown, J. (Eds.), Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity. Academic Press, New York, pp. 3–20.
Reina, R.E., Hill II, R., 1978. The Traditional Pottery of Guatemala. University of Texas Press, Austin.
Rice, P., 1987. Pottery Analysis: A Source Book. The University of Chicago Press, Chicago.
Sato, H., 1992. Hoppokei sakuhenkei saisekki sekkigun to teijuka kasetsu: kantochiho wo chushin ni (Northern spall detached microblade industry and hypothesis of sedentism: Around the Kanto region). Bull. Grad. Stud., Hosei University 29, 55–83 (in Japanese).
Sato, H., Izuho, M., Morisaki, K., 2011a. Human cultures and environmental changes in the Pleistocene/Holocene transition in the Japanese Archipelago. Quat. Int. 237, 93–120.
Sato, H., Yamada, S., Izuho, M., 2011b. Hunting during Paleolithic periods: history of fields and plains. In: Yumoto, T. (Ed.), Series, Japanese Archipelago Created by Humans and Nature, Volume 2. Bunichi Sogo Shuppan, Tokyo, pp. 51–71 (in Japanese).
Schiffer, M.B., 1992. Technological Perspectives on Behavioral Change. The

University of Arizona Press, Tucson.
Schiffer, M.B., 2011. Studying Technological Change: a Behavioral Approach. The University of Utah Press, Salt Lake.
Schiffer, M., Skibo, J., 1987. Theory and experiment in the study of technological change. Curr. Anthropol. 28 (5), 595–622.
Super Chikei, 2016. http://www.kashmir3d.com/ (Accessed 30 May 2016).
Takahara, H., Hayashi, R., 2015. Paleovegetation during Marine Isotope Stage 3 in East Asia. In: Kaifu, Y., Izuho, M., Goebel, T., Sato, H., Ono, A. (Eds.), Emergence and Diversity of Modern Human Behavior in Paleolithic Asia. Texas A&M University Press, College Station, pp. 314–324.
Taniguchi, Y., 2011. Reconstructing Jomon Cultural Origin Theory. Doseisha, Tokyo (in Japanese).
Vandiver, P., 1987. Sequential slab construction: a conservative southwest Asiatic ceramic tradition, ca. 7000-3000 B.C. Paléoriet Année 13 (2), 9–35.
Vandiver, P., 1988. The implications of variation in ceramic technology: the forming of Neolithic storage vessels in China and the Near East. Archaeomaterials 2, 139–174.
Waters, M., 1992. Principles of Geoarchaeology: a North American Perspective. University of Arizona Press, Tucson.
Zeder, M., 2009. The Neolithic macro-(R)evolution: macroevolutionary theory and the study of culture change. J. Archaeol. Res. 17, 1–63.