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Lithic raw material exploitation and circulation in Préhistory. A comparative perspective in diverse palaeoenvironments
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2.6. Upper Palaeolithic obsidian use in central Japan: the origins of obsidian source exploitation

Résumé

Cet article fait une mise au point sur la découverte des sources d'obsidienne et leur exploitation au centre du Japon durant la première moitié du Paléolithique supérieur récent (ca 38 000 – 35 000 cal B.P.). Car il n'existe pas de preuve fiable remontant avant 40 000 ans cal B.P. au centre du Japon et donc nous allons essayer de les rechercher grâce à l'étude des relations entre l'apparition de l'exploitation lointaine de l'obsidienne et les stratégies mobiles des populations de l'EUP. Cette étude permet de fournir des informations significatives sur l'adaptation de l'homme moderne dans des paysages peu familiers. Nous allons examiner les changements, dans l'utilisation de l'obsidienne, du modèle de distribution de l'obsidienne basé sur l'analyse de sa provenance, et des stratégies de mobilité des chasseurs-cueilleurs à partir de la phase élémentaire et jusqu'à la phase développée durant l'EUP. Bien qu'il n'y ait qu'un faible pourcentage de produits d'obsidienne dans l'ensemble lithique, nous pouvons identifier toutes les sources d'obsidienne: le centre du Japon et l'îlot de Kose-Onbase, dans l'Océan Pacifique. La phase développée se caractérise par une augmentation de l'utilisation d'obsidienne et l'apparition d'une implantation circulaire. En particulier la population de l'EUP du lac Nojiri a montré une activité importante. Les modèles de distribution d'obsidienne durant cette période se caractérisent par une circulation sur de longues distances dépassant leurs aires résidentielles. La région montagneuse centrale du Japon a joué un rôle important comme axe de ces déplacements. Il semble que les chasseurs cueilleurs pouvaient considérer cette région comme une place centrale de ces mouvements sur de longues distances et l'homme préhistorique avait chassé les grands herbivores qui avaient finalement disparu pendant le maximum de la dernière glaciation dans l'ensemble des sites du lac Nojiri. L'EUP développé succédait à la phase initiale d'exploitation et de migration dans les îles japonaises.

Abstract

This paper focuses on the discovery of obsidian sources and the establishment of obsidian use in central Japan in the early part of the Early Upper Palaeolithic (eEUP: ca. 38,000-35,000 cal BP). Because there is no reliable archaeological and palaeoanthropological evidence dating back to before 40,000 cal BP in central Japan, elucidating the relationship between the first establishment of obsidian procurement system and the mobility strategies of the eEUP populations would provide significant information with regard to modern human adaptations to unfamiliar landscapes. Temporal changes in obsidian use from the initial eEUP to the developed eEUP, obsidian distribution patterns based on provenance analysis, and the mobility strategies of eEUP hunter-gatherers are examined. Although the initial eEUP is characterized by an extremely low degree of obsidian use in lithic assemblages, all obsidian sources in central Japan and the Kozu-Onbase Islet on the Pacific Ocean that have been discovered, indicate that an initial exploration of the natural resource environment took place. The developed eEUP is characterized by an increase in obsidian use and the appearance of circular settlements. In particular, the Lake Nojiri site group shows intensive land use by the developed eEUP population. The obsidian distribution pattern in the eEUP indicates an overarching distribution of Central Highlands obsidian throughout central Japan, regardless of the distance from residential areas. The Central Highlands played a role as the focal point that linked the procurement routes extending from residential areas. The hunter-gatherers of the eEUP used the Central Highlands as a hub for far-reaching mobile routes and they aggregated at the Lake Nojiri site group to hunt the large herbivores that would become extinct during the Last Glacial Maximum. The developed eEUP represents a settling-in phase following the initial exploration of and migration into the Japanese Islands.

Keywords: Obsidian use, Early Upper Palaeolithic, Japanese Islands

1 – Introduction

Preceding chronological studies have constructed a basic chronostratigraphic framework for the Upper Palaeolithic industries of central Japan using the wide-ranging distribution of the Pleistocene deposits (e.g., the Kanto loam, which are aeolian sediments originating from the detritus of Quaternary volcanos), tephrochronology, and radiocarbon dating (Tamura 2006; Takao 2006; Suto 2006; Kosuge and Nishii 2010; Suwama *et al.,* 2010; Nakamura and Sato 2010; Kudo 2012). The Upper Palaeolithic sequence is divided into the Early and the Late Upper Palaeolithic by the Aira-Tn volcanic ash that formed one of the key tephra beds dated to ca. 28,000-29,000 cal BP and which fell in a wide area across the Japanese Islands of Honshu, Shikoku, and Kyushu (Machida and Arai 2003: 64-70). The Early Upper Palaeolithic (EUP) is assigned to the period spanning from ca. 38,000 to ca. 30,000 cal BP, and the Late

Upper Palaeolithic (LUP) is assigned to the period spanning from ca. 30,000 to ca. 16,000 cal BP (Kudo 2012: Fig. 6-12). The earliest pottery emerged in ca. 16,000 cal BP, indicating the beginning of the Jomon Period (Kudo 2012).

The establishment of a lithic technology represented by knife-shaped tools and a particular blade technique divides the EUP into the early (eEUP) and late (lEUP) (Sato 1992; Ono *et al.,* 2002). The eEUP industries are characterized by trapezoids and edge-ground stone axes (Tsutsumi 2012). Radiocarbon dating assigns the eEUP to the period spanning from ca. 38,000 to ca. 34,500 cal BP (Miyoshi 2011). Figure 1 shows stratigraphic changes in the eEUP industries and the sequence of the loam sediments in the Ashitaka region of the Shizuoka Prefecture in central Japan.

The eEUP is divided into the initial eEUP and the developed eEUP by stratigraphic changes in the lithic industries, such as the appearance of a prototype blade technique, the emergence of circular settlements, an increase in obsidian use, and an increase in the number of trapezoids (Suwama *et al.,* 2010). The heavy-duty core tools dominate the lithic tool-kit of the initial eEUP, although by the developed eEUP they seem to have disappeared. The edge-ground stone axes continued to exist from the initial eEUP to the developed eEUP with some changes in their morphology, and then disappeared from the lithic assemblages in the lEUP (Tsutsumi 2012). Apart from the disappearance of edge-ground stone axes, changes in the lithic industries from the eEUP to the lEUP are represented by an increase in the number of knife-shaped tools, burins and scrapers, the establishment of a particular blade technique, a decrease in the number of trapezoids with some changes in lithic technology, an increase in obsidian use in the later part of the lEUP, and the disappearance of the circular settlements (Sato 1992).

This paper examines obsidian procurement and consumption in the lithic industries of the eEUP that are distributed throughout central Japan (Fig. 2). The eEUP industries represent the first traces of human habitation in the Japanese Islands. There are two main research objectives in this study of obsidian use in the eEUP: firstly, to clarify the timeline of the discovery of obsidian sources as well as any changes in obsidian use through time; and secondly, to understand the basic structure of the mobility strategy adopted by the eEUP population on a macroscale. These examinations lead us to evaluate the essence of adaptive behavior when modern humans first settled in an unfamiliar land, i.e., the Japanese Islands. Focusing the research on obsidian use is useful for the following reasons. Firstly, the obsidian sources in central Japan are located at relatively farther distances from main Upper Palaeolithic residential areas than the sources of other lithic raw materials (Fig. 2; Tabl. 1). Secondly, a large amount of obsidian provenance data obtained through chemical analysis has accumulated since the 1970s and is currently available in the form of a database.

Although a distinctive increase in obsidian use, along with the chronostratigraphic sequence from the eEUP to the lEUP, has already been researched (Tamura *et al.,*

Table 1 – Supposed distance between obsidian source areas and residential areas in central Japan

Regions \ Sources	Central Highlands (Kirigamine area)	Mt.Takahara	Hakone	Amagi	Kozu-Onbase
Northern Kanto	~100km (western area) (via Tone and Shinano Rivers)	~80km (eastern area) (via Kinu River)			
Eastern Kanto	~220km (via Kinu, Watarase, Tone, and Shinano Rivers)	~145km (via Kinu River)			~100km (LGM) (to the south tip of Boso Peninsula via Izu Islands)
Western Kanto	~160km (via Tama and Shinano Rives) ~180km (via Ara and Shinano Rivers)		~80km (in a straight line)	~100km (in a straight line)	
Ashitaka	~155km (via Fuji River)		~20km (in a straight line)	~35km (in a straight line)	~40km (LGM) (to the south tip of Izu Peninsula)
Lake Nojiri	~100km (via Shinano River)				

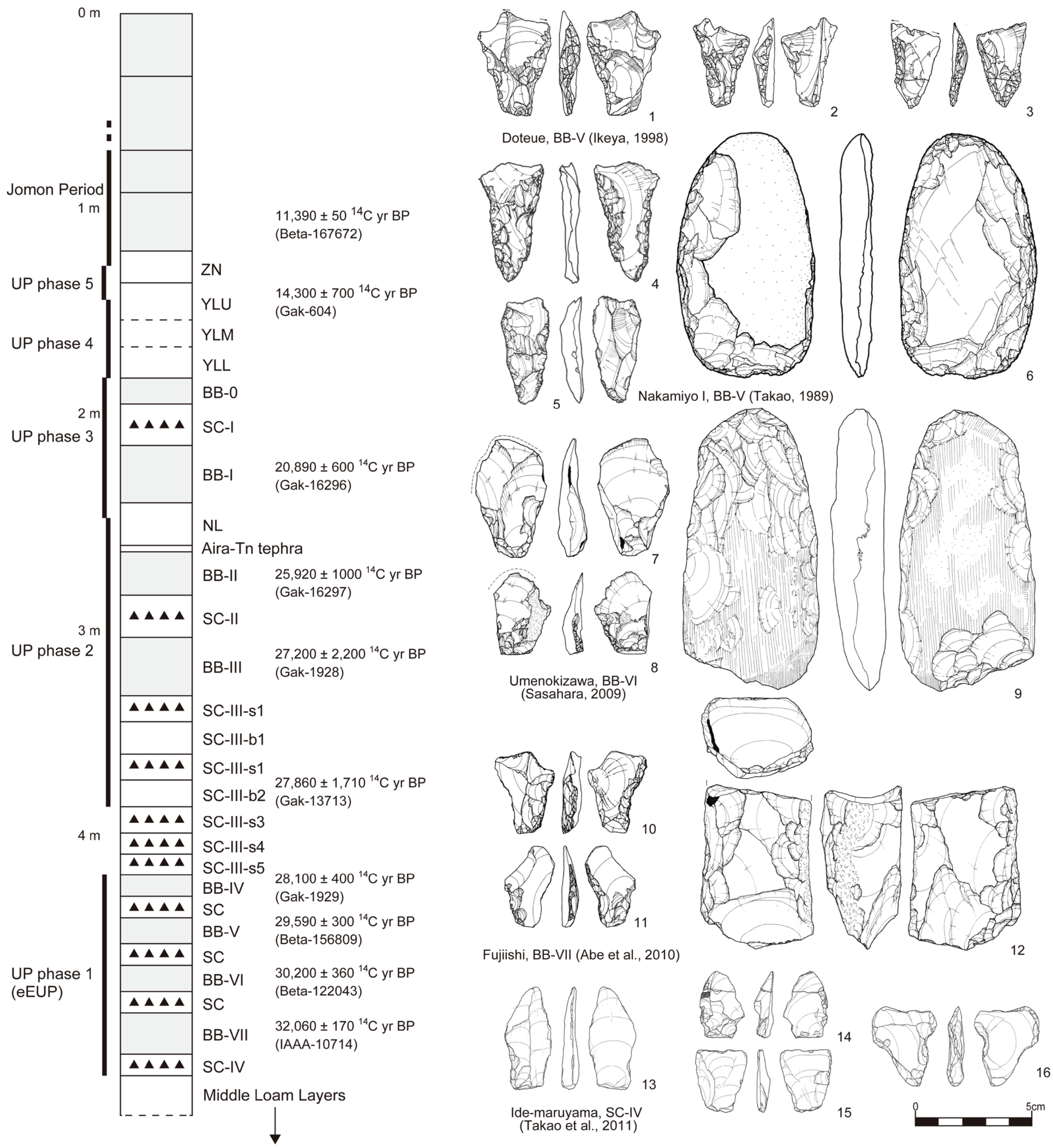
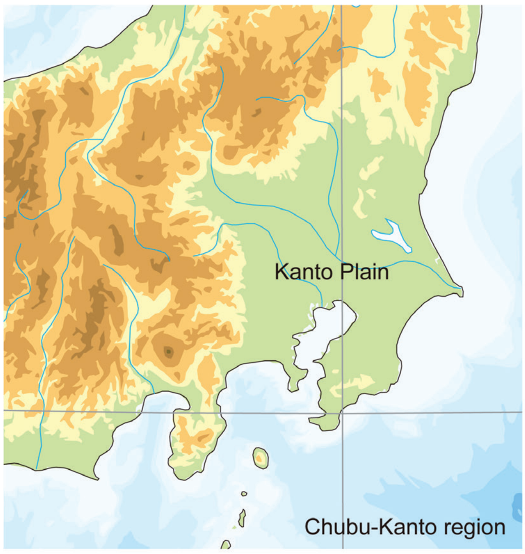


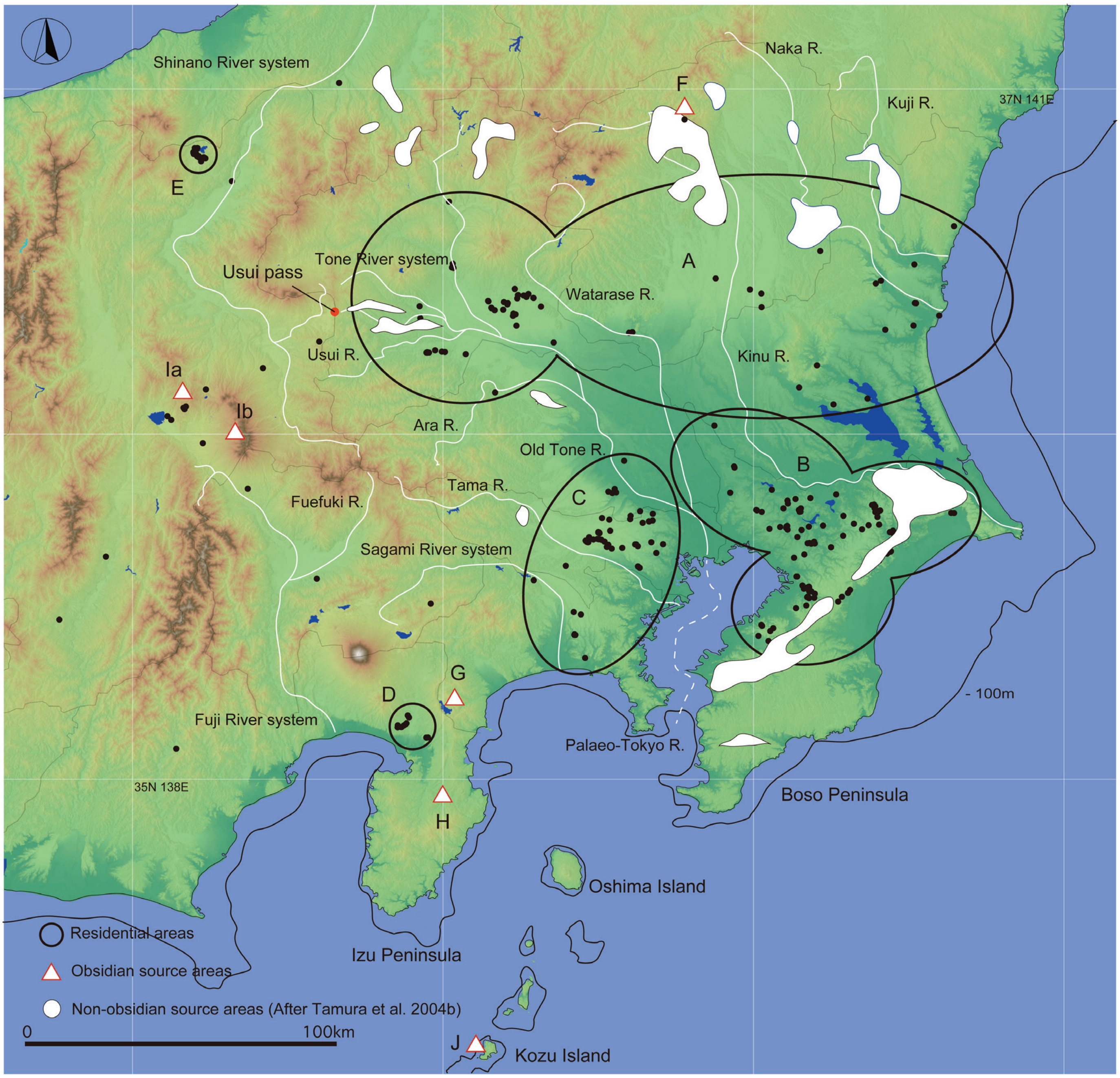
Figure 1 – Schematic stratigraphy of the Upper Loam Layers of the Ashitaka Loam (modified from Takao 2006) and the eEUP industries in the Ashitaka region. 1-5, 7, 8, 10, 11, 15, 16: trapezoids; 13, 14: small points with retouched base; 6, 9: edge-ground stone axes; 12: stone ax. ZN: transitional layer; YL: Yasumiba loam; NL: Nise loam; BB: black band; SC: scoria layer

1987: 126-137; Kanayama 1990; Yamaoka 2004a, 2004b, 2006), a comparative analysis of obsidian use between the initial eEUP and the developed eEUP has not yet been undertaken. It is estimated that a comparative analysis from the latter perspective will elucidate the dynamics between the discovery of distant obsidian sources and the integration of obsidian into regional stone tool production. Moreover, examining the origin and establishment of obsidian use in the eEUP from a socio-economic perspective will contribute to an understanding of the essence of the mobility strategies adopted in the eEUP. Regarding the socio-economic aspects of the eEUP industries, this paper examines the relations between the diversity of the circular settlements and human activities in the developed eEUP.

For the purposes of this study I have distinguished five residential areas or regional site clusters in central Japan on the basis of the distribution of eEUP industries in order to show more clearly the obsidian distribution patterns and changes in obsidian use from a regional perspective. As Figure 2 shows, these five residential areas are northern Kanto, eastern Kanto, western Kanto, the Ashitaka region, and the Lake


Hokkaido
JAPAN SEA
(NIHON KAI)
Honshu
JAPAN
Tokyo
Research area
NORTH PACIFIC OCEAN
(KITATAIHEI YO)
Kyushu
Japanese Islands


Kanto Plain
Chubu-Kanto region


Shinano River system
Naka R.
F
Kuji R.
37N 141E
E
A
Tone River system
Usui pass
Watarase R.
Usui R.
Kinu R.
Ia
Ib
Ara R.
Old Tone R.
B
Tama R.
Fuefuki R.
C
Sagami River system
G
D
- 100m
Fuji River system
Palaeo-Tokyo R.
35N 138E
Boso Peninsula
H
Oshima Island
Residential areas
Obsidian source areas
Non-obsidian source areas (After Tamura et al. 2004b)
Izu Peninsula
0
100km
J
Kozu Island

Nojiri site group. The Kanto Plain, which includes three residential areas, is the largest plain in the Japanese Islands, with an area of 17,000 square kilometers. The Ashitaka region is located in the Shizuoka Prefecture. The Lake Nojiri site group is located in the northern part of the Nagano Prefecture, where Upper Palaeolithic sites are densely distributed in a narrow area around Lake Nojiri.

2 – Background

A – Obsidian source areas in central Japan

Tamura *et al.,* (2003; 2004a; 2004b) and Tamura and Kunitake (2006) have shown that the sources (rocky areas) of lithic raw materials including obsidian used by the Upper Palaeolithic populations are arranged concentrically around the Kanto Plain (Fig. 2). According to this view, the obsidian sources are located in the farthest concentric circle from the Kanto Plain. Regarding the locations of obsidian source areas, there are five representative areas, that is, the Mt. Takahara source area (Tochigi Prefecture) is arranged to the north, the Central Highlands source area (Nagano Prefecture) to the west, the Hakone source area (Kanagawa and Shizuoka Prefectures), and the Amagi source area (Shizuoka Prefecture) to the southwest of the Kanto Plain. The concentric circle containing the obsidian source distribution extends from the mainland of Honshu and reaches the Kozu-Onbase Islet (Tokyo Metropolis) on the Pacific Ocean. Since the 1970s, chemical analysts have made databases of geological obsidian collected from various sources in central Japan and have accumulated obsidian provenance data. Although the Neutron Activation Analysis (NAA) was initially used for sourcing obsidian artifacts, Energy Dispersive X-Ray Fluorescence Spectrometry (EDXRF) became a mainstream analytical method (e.g., Suzuki 1969; 1970; 1971; Warashina *et al.,* 1984; Tamura *et al.,* 1987; Mochizuki *et al.,* 1994; Sugihara and Kobayashi 2004). The analysis usually classifies the obsidian artifacts derived from a certain source area into several subdivided groups on the basis of geochemical composition. In the Central Highlands, for example, Sugihara (2011) classified geological obsidian sampled from 23 outcrops or collection zones into six geochemical groups: Nishi-Kirigamine, Wada-toge, Takayama, Omegura, Mugikusa-toge/Tsumetayama, and Yokodake; and compiled these geochemical groups into two geographical areas: Kirigamine and Kita-Yatsugatake. However, all of the provenance data used in this paper are assigned to the above-mentioned representative five source areas in central Japan, and not to the subdivided geochemical groups in each source area, because the nomenclature of the source categories employed and the details for discrimination of the geochemical groups vary among analysts.

B – River systems as stone procurement routes

Each of the five residential areas in central Japan has its own character in terms of variety and combination of lithic raw material use. Accessibility to lithic sources is a primary reason that determines the representative combination of the lithic raw materials for regional stone tool production (Tamura *et al.,* 1987: 123-126; Shibata 1994). The author believes that accessibility from a certain residential area to lithic sources depended on large river systems that are geographically related to lithic source distribution including obsidian sources (Fig. 2). Moreover, the distribution of the eEUP sites in central Japan from a regional perspective clearly shows a close relationship with the large river systems, the basins of which extend for more than 100 km. Non-obsidian sources that Tamura *et al.,* (2004b) illustrated are located around the upper reaches of these river systems. Even the eEUP sites located farther from the main residential areas, are situated in places where the large river systems can connect them with the main residential areas. Accordingly, it is very likely that these large river systems played a significant role in the Late Pleistocene as prehistoric routes or paths for lithic raw material procurement.

When we discuss the exploitation of obsidian sources in central Japan, there is no need to assume a mobility strategy that was focused on only the long-distance transportation of obsidian. Although obsidian artifacts in the Kanto Plain tend to be recognized as

Figure 2 – Research area, distribution of the eEUP industries, and locations of lithic raw material sources in central Japan. Black dots: eEUP industries; A: northern Kanto region; B: eastern Kanto region; C: western Kanto region; D: Ashitaka region; E: Lake Nojiri site group; F: Mt. Takahara; G: Hakone; H: Amagi; Ia (Kirigamine) and Ib (Kita-Yatsugatake): Central Highlands; J: Kozu-Onbase. The site distribution is based on the work of the Japanese Palaeolithic Research Association (2010)

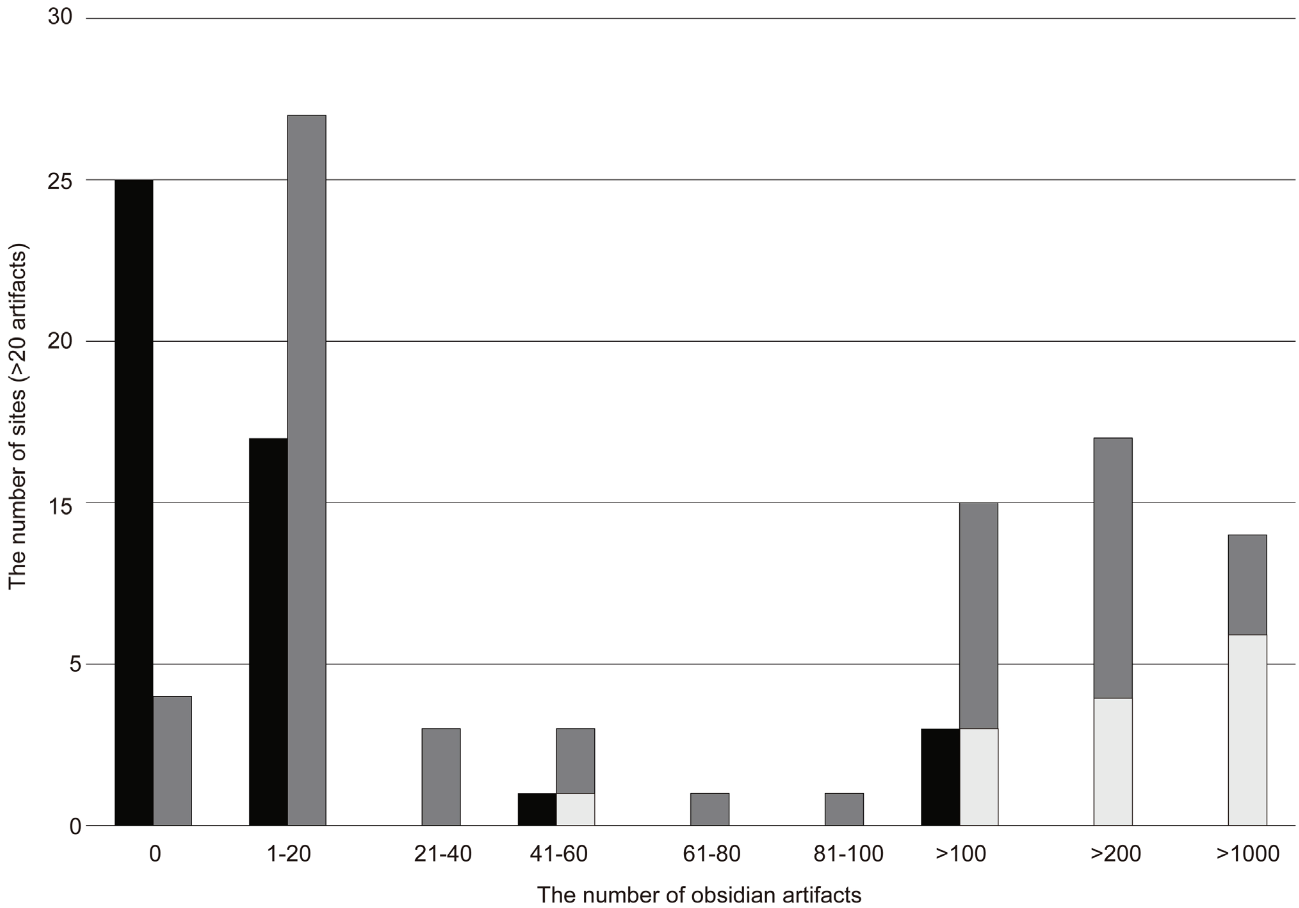


Figure 3 – Quantitative frequency of obsidian artifacts in the eEUP industries (source: appendix tables 1 and 2). Black: the initial eEUP industries (N = 35 sites); dark grey: the developed eEUP industries except for the Lake Nojiri site group (N = 50 sites); light grey: the developed eEUP industries from the Lake Nojiri site group (N = 14 sites)

a representative of non-local lithic raw materials, categorizing the lithic raw materials that were used in the Kanto Plain according to the dichotomy of local and non-local is meaningless, because all sources are distributed outside the Upper Palaeolithic residential areas (Tamura and Kunitake 2006). When we consider that large river systems played a significant role for lithic raw material procurement, obsidian sources can be accessed by the short extra trips of the prehistoric hunter-gatherers across multiple river systems from non-obsidian sources around the Kanto Plain, or, in any other case, a part of the sources of non-obsidian geographically overlaps with obsidian sources (e.g., Mt. Takahara obsidian source area). The main issue to be examined is to what degree and how obsidian were integrated with non-obsidian procurement in the hunter-gatherer mobility strategies.

3 – Data and analysis

A – Changes in obsidian use in the eEUP industries

To understand the origin of obsidian source exploitation, obsidian use is compared between the initial eEUP and the developed eEUP industries (Appendix Tables 1 and 2). The individual obsidian assemblages obtained from 35 sites having more than 20 lithic artifacts in the initial eEUP and from 64 sites in the developed eEUP are classified into nine groups according to the quantity of obsidian artifacts. They are grouped as follows, by number of pieces: 0, 1-20, 21-40, 41-60, 61-80, 81-100, >100, >200, and >1,000. Figure 3 shows the quantitative frequency of obsidian artifacts in the individual sites. The initial eEUP industries show a high frequency of appearance in the groups with 0 and 1-20 pieces. Only three sites appear in the group with >100 pieces and they are independently distributed in eastern Kanto, western Kanto, and the Ashitaka region, whereas sites appearing in the groups with between 21-40 and 81-100 pieces in the initial eEUP are very rare (one site).

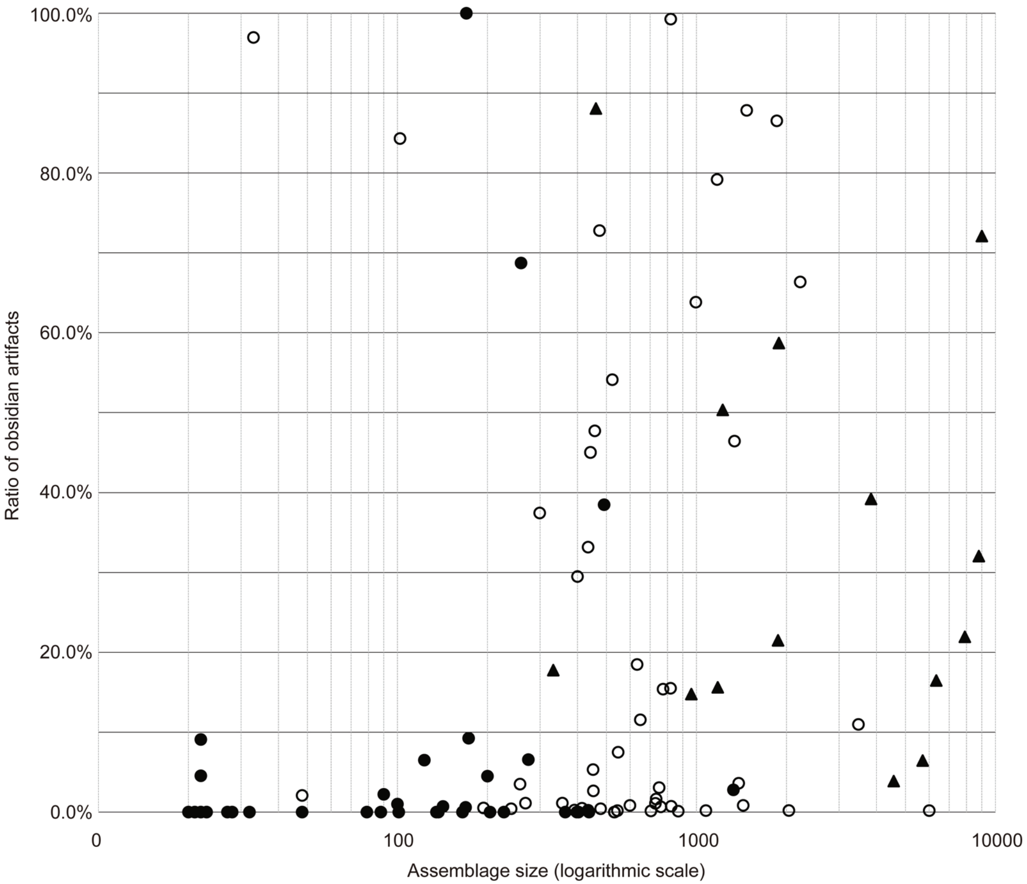
A regional absence of site distribution is observed in the initial eEUP industries (Appendix Table 1). Whereas a few small lithic assemblages have been found in

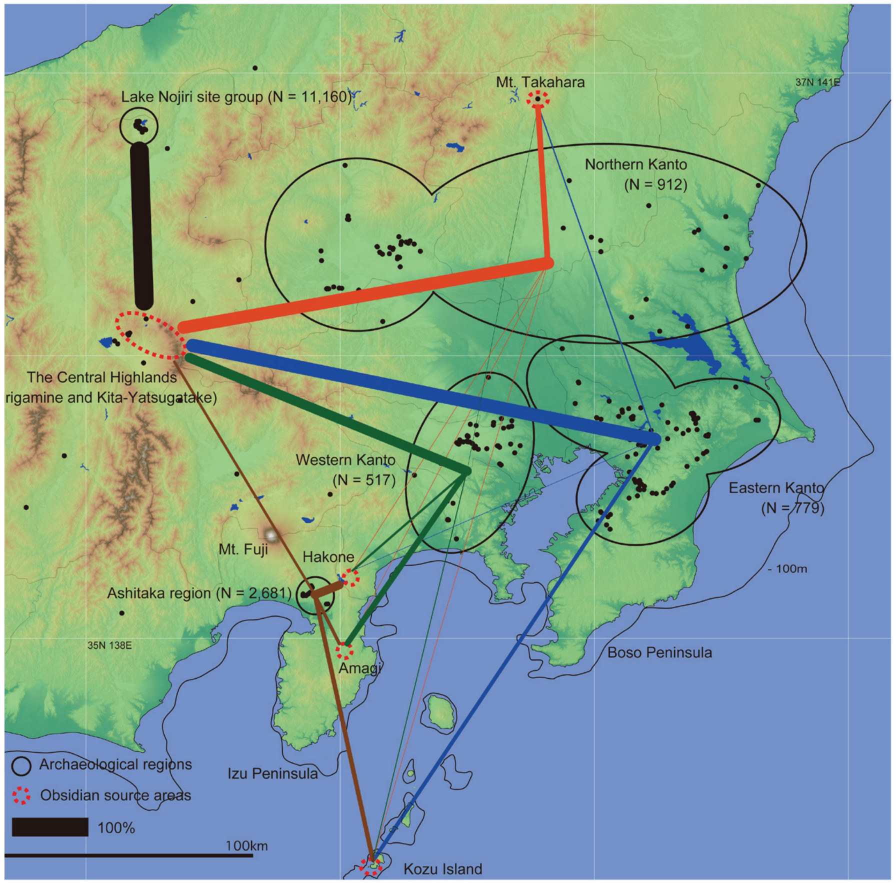
	Central Highlands		Mt.Takahara		Hakone		Amagi		Kozu-Onbase		Obsidian total (analysis)	Obsidian total (assemblage)	analysis/assemblage	Num. of sites
Northern Kanto	617	67.7%	280	30.7%	2	0.2%	2	0.2%	11	1.2%	912	Not available	-	14
Eastern Kanto	556	71.4%	57	7.3%	1	0.1%	0	0.0%	165	21.2%	779	2,630	29.6%	9
Western Kanto	271	52.4%	11	2.1%	60	11.6%	149	28.8%	26	5.0%	517	Not available	-	14
Ashitaka	385	14.4%	0	0.0%	1,203	44.9%	464	17.3%	629	23.5%	2,681	4,047	66.2%	15
Total	1,829	37.4%	348	7.1%	1,266	25.9%	615	12.6%	831	17.0%	4,889	-	-	52
Lake Nojiri	11,160	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	11,160	17,056	65.4%	15
Total	12,989	80.9%	348	2.2%	1,266	7.9%	615	3.8%	831	5.2%	16,049	-	-	67

Table 2 (Above) – Regional variability in obsidian procurement of the eEUP (source: appendix table 3)

Figure 4 (Below, left) – Correlation diagram between lithic assemblage size and ratio of obsidian artifacts (source: appendix tables 1 and 2). Black dots: the initial eEUP industries; circles: the developed eEUP industries except for the Lake Nojiri site group; triangles: the developed eEUP industries from the Lake Nojiri site group

Figure 5 (Below, ritght) – Obsidian distribution patterns in the eEUP in central Japan. The bars extending from each archaeological region show the ratio of obsidian artifacts classified into five source areas by provenance analysis (XRF, NAA). Black dots: the eEUP industries





the eastern part of the northern Kanto region, no initial eEUP industry has been discovered in the Lake Nojiri site group and the western part of northern Kanto. The geographical distribution of the developed eEUP industries extended all over the residential areas of central Japan, including the northern Kanto region and the Lake Nojiri site groups, where traces of human habitation were previously absent (Appendix Table 2).

During the developed eEUP (Fig. 3), there is a clear decrease in the frequency of zero pieces appearing, while a high frequency of appearance in the groups with 1-20 pieces is observable. A particular difference from the initial eEUP is that the sites appearing in the groups with >200 and >1,000 pieces consistently exist throughout the period. Although at a low frequency, the groups with between 21-40 and 81-100 pieces newly appeared in the developed eEUP industries. Figure 3 also shows the frequency of appearance that is limited to the eEUP industries in the Lake Nojiri site group. Thirteen out of 14 sites in the Lake Nojiri site group appear in the groups with >100, >200 and >1,000 pieces, clearly indicating that a larger quantity of obsidian was consumed in the individual sites in comparison with the other residential areas.

Figure 4 is a correlation diagram showing the proportion of obsidian artifacts to the total number of lithic assemblages. Overall, the diagram shows that the assemblage sizes of the initial eEUP industries appear to be smaller than those of the developed eEUP industries. Almost all of the initial eEUP industries yielding obsidian artifacts are shown to be less than 10% in proportion to the total number of lithic artifacts. In the developed eEUP industries, relatively larger assemblage sizes than those of the initial eEUP industries are dominant. In particular, this is notable for the lithic industries of the Lake Nojiri site group. The diagram also shows that the distribution of the obsidian artifact proportion to the total number of lithic assemblages in the developed eEUP industries is represented by a scattered pattern ranging from between 0% to 100% regardless of assemblage size. As Figure 4 shows, in the developed eEUP industries of the Lake Nojiri site group that consumed a relatively large amount of obsidian in central Japan, the distribution of the obsidian artifact proportion to the total number of lithic assemblages shows a scattered pattern similar to those of other residential areas.

Because there are basically no essential differences in the size or depth of excavation areas between the initial and the developed eEUP industries, an increase in obsidian use and the enlargement of the lithic assemblage size are evaluated as temporal changes in the chronological sequence of the eEUP. The pattern of obsidian use in the initial eEUP is summarized as follows: 1) The pattern of quantitative frequency is polarized at a few sites that yielded more than 100 pieces of obsidian artifacts and the majority of sites that yielded 0 or 1-20 pieces, and 2) the proportion of obsidian artifacts to the total number of lithic assemblages is concentrated at less than 10%, reflecting that stone tool manufacturing generally depends on a high percentage of non-obsidian exploitation.

The main patterns of obsidian use in the developed eEUP are the following: 1) The sites lacking obsidian artifacts appear to have decreased in number, and sites in which obsidian reduction was undertaken, at which 1-20 pieces were found, increased; 2) the sites that appear in the groups with >100, >200, and >1,000 pieces were consistently formed during the period; 3) the sites that appear in the groups with between 21-40 and 81-100 pieces were a new addition to this consumption pattern; 4) the proportion of obsidian artifacts to the total number of lithic assemblages varies widely, regardless of assemblage size, reflecting that there were diverse circumstances for obsidian use among the developed eEUP industries; and 5) the Lake Nojiri site group, which was established for the first time during the developed eEUP, is the place where obsidian use was relatively higher among the residential areas in central Japan. Nevertheless, the proportion of obsidian artifacts to the total number of lithic assemblages also varies widely among the sites, similarly to the other residential areas. Accordingly, the formation of large assemblages in comparison with the other residential areas is the main cause for the large quantity of obsidian use in the individual sites of the Lake Nojiri site group.

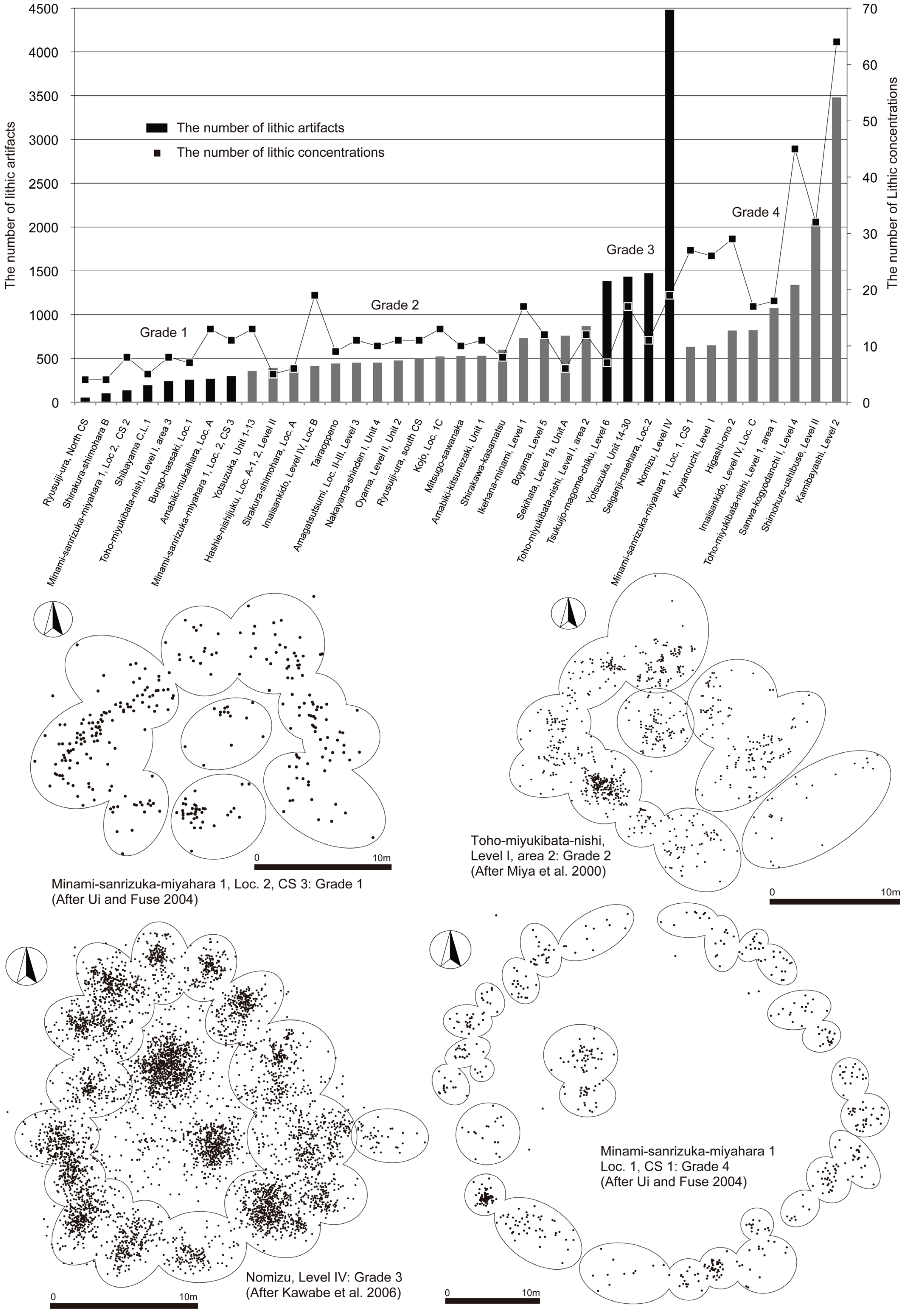
B – Obsidian distribution patterns in the eEUP

Serizawa *et al.,* (2011) have compiled obsidian provenance data accumulated since the 1970s, from the lithic industries of the Upper Palaeolithic, Jomon, and Yayoi periods in the Kanto Plain. The data demonstrated that the total number of obsidian artifacts identified with a source from all of the Upper Palaeolithic industries in the Kanto Plain reaches 38,235 pieces. Appendix Table 3 is a list of provenance data collected from the eEUP industries in the Kanto Plain, the Ashitaka region, and the Lake Nojiri site group. Table 2 shows the total values of the provenance data separated into five source areas within each residential area with the number of pieces and its proportion to the total. Since the initial eEUP has had few samples applied to provenance analysis, all of the provenance data obtained from the initial eEUP and the developed eEUP have been compiled together in Table 2 and Figure 5.

There are three distinctive patterns for obsidian artifacts distribution in the eEUP. Distance of obsidian sources from the perspective of residential areas causes biased distributions of obsidian artifacts derived from the source areas of Mt. Takahara, Hakone, Amagi, and the Kozu-Onbase Islet (Tabl. 1 & 2; Fig. 5). The obsidian artifacts made from Mt. Takahara obsidian are primarily distributed throughout northern Kanto (~80 km, 30.7% of the total number of analyzed pieces in that region; the same applies below) and eastern Kanto (~145 km, 7.3%), whereas a small number of them have been found in western Kanto (2.1%). Mt. Takahara obsidian has not been found in the Ashitaka region and the Lake Nojiri site group. The obsidian artifacts made from Hakone obsidian are primarily distributed in the Ashitaka region (~20 km, 44.9%) and have also been found in western Kanto to a certain degree (~80 km, 11.6%), whereas they are very rare in northern Kanto (0.2%) and eastern Kanto (0.1%). No Hakone obsidian has been identified in the Lake Nojiri site group. The obsidian artifacts made from Amagi obsidian are primarily distributed in western Kanto (~100 km, 28.8%) and the Ashitaka region (~35 km, 17.3%), but they are very rare in northern Kanto (0.2%). Amagi obsidian is not distributed throughout eastern Kanto and the Lake Nojiri site group. The obsidian artifacts made from Kozu-Onbase obsidian are primarily distributed in the Ashitaka region (~40 km by sea, 23.5%) and eastern Kanto (~100 km by sea, 21.2%). A small number of them have been identified in western Kanto (5.0%) and northern Kanto (1.2%), whereas no Kozu-Onbase obsidian has been identified in the Lake Nojiri site group.

Contrary to the obsidian distribution pattern indicating the above-mentioned regional biases, the obsidian artifacts made from Central Highlands obsidian are characterized by their overarching distribution all over central Japan (Tabl. 1 & 2; Fig. 5). In particular, they account for the highest percentage of the source composition in all residential areas including northern Kanto (~100 km, 67.7%), eastern Kanto (~220 km, 71.4%), western Kanto (~160-180 km, 52.4%), and the Lake Nojiri site group (~100 km, 100%); the Ashitaka region is the exception (155 km, 14.4%), being located close to the obsidian sources of Hakone and Amagi (totaling 62.2% in the Ashitaka region). Notice that the Central Highlands obsidian had been exclusively used for the production of stone tools in the Lake Nojiri site group, from which more than 10,000 obsidian artifacts from the developed eEUP industries have been applied to provenance analysis.

It should also be noted that all residential areas, except for the Lake Nojiri region, contain obsidian that had always been transported complementarily into the regions and consumed in small quantities, indicating that obsidian procurement never depended on a single obsidian source. The obsidian consumed complementarily in each residential area is as follows (Tabl. 2; Fig. 5): northern Kanto is represented by obsidian from Kozu-Onbase (1.2%), Hakone (0.2%), and Amagi (0.2%); eastern Kanto is represented by obsidian from Hakone (0.1%); western Kanto is represented by obsidian from Kozu-Onbase (5.0%) and Mt. Takahara (2.1%); the Ashitaka region is represented by obsidian from the Central Highlands (14.4%). It can be seen that these complementary types of obsidian are lithic raw materials that had been transported from sources located at a relatively farther distance from the residential area.



The number of lithic artifacts
The number of lithic concentrations
The number of Lithic concentrations
Grade 1
Grade 2
Grade 3
Grade 4
Ryusuiji-ura, North CS
Shirakura-shimohara B
Minami-sanrizuka-miyahara 1, Loc 2, CS 2
Shibayama C.L.1
Toho-miyukibata-nishi,i Level I, area 3
Bungo-hassaki, Loc.1
Amabiki-mukaihara, Loc.A
Minami-sanrizuka-miyahara 1, Loc. 2, CS 3
Yotsuzuka, Unit 1-13
Hashie-nishijuku, Loc. A-1, 2, Level II
Sirakura-shimohara, Loc. A
Imaisankido, Level IV, Loc B
Tairaoppeno
Amagatsutsumi, Loc. II-III, Level 3
Nakayama-shinden I, Unit 4
Oyama, Level II, Unit 2
Ryusuiji-ura, south CS
Kojo, Loc. 1C
Mitsugo-sawanaka
Amabiki-kitsunezaki, Unit 1
Shirakawa-kasamatsu
Ikehana-minami, Level 1
Boyama, Level 5
Sekihata, Level 1a, Unit A
Toho-miyukibata-nishi, Level I, area 2
Tsukuijo-magome-chiku, Level 6
Yotsuzuka, Unit 14-30
Seiganji-maehara, Loc.2
Nomizu, Level IV
Minami-sanrizuka-miyahara 1, Loc. 1, CS 1
Koyanouchi, Level I
Higashi-ono 2
Imaisankido, Level IV, Loc. C
Toho-miyukibata-nishi, Level 1, area 1
Sanwa-kogyodanchi I, Level 4
Shimohure-ushibuse, Level II
Kamibayashi, Level 2
Minami-sanrizuka-miyahara 1, Loc. 2, CS 3: Grade 1
(After Ui and Fuse 2004)
Toho-miyukibata-nishi,
Level I, area 2: Grade 2
(After Miya et al. 2000)
Nomizu, Level IV: Grade 3
(After Kawabe et al. 2006)
Minami-sanrizuka-miyahara 1
Loc. 1, CS 1: Grade 4
(After Ui and Fuse 2004)
0
10m

The features of the obsidian distribution patterns of the eEUP industries in central Japan can be summarized in the following three points: 1) With regard to obsidian that had originated from all source areas except for the Central Highlands, biased distributions appear among the residential areas. This pattern reflects the geographical conditions shown by the difference in relative distance between a specific residential area and the obsidian source. The procurement of Kozu-Onbase obsidian occurred as a part of this biased distribution pattern. 2) On the contrary, the distinctive amount of artifacts made from Central Highlands obsidian prevails all over central Japan, regardless of the relative distance between the source and the residential areas. Obsidian from the Central Highlands was intensively transported to all residential areas except for the Ashitaka region, accounting for the high percentage (between 50-100%) of the source composition in each residential area. The exclusive use of Central Highlands obsidian in the Lake Nojiri site group can be understood at a first glance as the result of a biased distribution in response to the distance from the source area of the Central Highlands. However, an explanation only in terms of accessibility is insufficient in this case, when considering the different features with regard to both the large quantity of obsidian use and the large assemblage sizes observed in the Lake Nojiri site group as compared to the other residential areas. 3) Whereas the obsidian procurement in the Lake Nojiri site group depended 100% on the Central Highlands, that of the other residential areas is always composed of primary obsidian derived from a specific source and complementary obsidian derived from several other sources. The complementary obsidian often accounts for only a small percentage of the source composition and had been transported from sources located farther away from the region, and seems to be a complex network spreading between the residential areas and the sources.

C – Land use in the Lake Nojiri site group and changes in settlement landscape

The emergence of distinctive large sites that were formed by land use in the Lake Nojiri site group relate to the temporal changes in both lithic assemblage sizes and the newly employed settlement structure between the initial eEUP and the developed eEUP. These temporal changes can be explained by the emergence of circular settlements known to be a unique trait limited to the time range of the developed eEUP in the Japanese Islands (Fig. 6). To better understand the nature of land use in the Lake Nojiri site group, the features of the circular settlements will be examined below.

The initial eEUP sites are usually composed of one or several lithic concentrations that are often arranged with no regularity in the settlements, and in most cases only a small number of lithic artifacts scattered throughout the excavation areas. The circular settlements that are characterized by a regular distribution pattern of lithic concentrations appeared in the developed eEUP industries (Hashimoto 1989; Daikuhara 1990; 1991; Suto 1991). The definition of a circular settlement is one in which multiple lithic concentrations in a diameter of several meters are arranged in a circular position forming a circle of 10 to 70 meters in diameter. The lithic concentrations usually show mutual relationships, as represented by the frequent refitting of lithic artifacts across the settlements, indicating that the settlement landscapes had been formed concurrently. The circularly arranged lithic concentrations delimit the settlements' boundaries. As of 2010, 120 circular settlements from 102 sites, distributed mainly in eastern Honshu (central Japan and the Tohoku region), have been discovered (Hashimoto 2010). Almost all circular settlements can be assigned to the developed eEUP, having disappeared in the late part of the Early Upper Palaeolithic (lEUP) by ca. 35,000 cal BP (Hashimoto 2006).

For this paper 37 circular settlements discovered in the Kanto plain are selected for comparative analysis (Appendix Table 2). In these sites systematic excavations have uncovered the entire spatial distribution of the lithic artifacts. The circular settlements can be divided into four categories on the basis of the number of lithic concentrations; the mean value of the diameter of the circular arrangement measured in direction from

Figure 6 (Left page) – Classification of the circular settlements from the Kanto Plain in the eEUP north to south, and east to west; and the combination of lithic concentrations that are classified in response to the number of artifacts (Shimada 2011). Figure 6 shows the classification of the circular settlements. Grades 1 and 2 are the dominant categories, likely reflecting the basic size of the mobile groups and representing a standard for the circular settlements. Grade 3 is characterized by a dense distribution of lithic artifacts among the individual lithic concentrations, that is, the production of stone tools was carried out intensively, though the diameter of the circular arrangement and the number of lithic concentrations are similar to those of Grades 1 and 2. Grade 3 shows lithic assemblages of a larger size than those of Grades 1, 2 and 4. Grade 4 is characterized by an enlarged diameter, reaching a maximum of 74 m. The individual lithic concentrations of Grade 4 are comparable in size to those of Grades 1 and 2, indicating that the diameter of the settlements is enlarged by an increase in the number of lithic concentrations.

The author has interpreted elsewhere that the variation of the circular settlements from Grades 1 to 4 reflects the subsystems of behavior of the developed eEUP hunter-gatherers, as follows (Shimada 2011): the circular settlements of Grades 1 and 2 represent normal occupation sites that were formed by inter-site mobility accompanied by dispersing and gathering of a few mobile groups in the residential area. Grade 3 is recognized as being composed of special workshops in which subsistence activities were carried out intensively for a specific purpose, since the number of Grade 3 settlements is low in the Kanto Plain and they were not formed frequently. The formation of Grade 4 occurs when many mobile groups, which were usually dispersed, gather to live in one place. The Grade 4 settlements imply that large-sized alliance networks had been established among the developed eEUP hunter-gatherers.

From the chronological perspective of the eEUP industries, land use in the Lake Nojiri site group began along with the emergence of the circular settlements. All circular settlements of the developed eEUP sites in the Lake Nojiri site group are classified as Grade 3 (Appendix Table 2). Additionally, the other sites yielding >1,000 lithic artifacts often show settlement landscapes that have many lithic concentrations with high density closely distributed to one another over a wide settlement area, though they are not circular settlements. No other region can show this type of pattern for regional site composition. Accordingly, the Lake Nojiri site group is the place where special workshops for natural resource exploitation had been concentrated in a narrow area around Lake Nojiri instead of being used as a residential area for daily mobile life.

4 – Discussion

A – Origin of obsidian source exploitation

On the basis of currently available archaeological records, no reliable evidence indicating human habitations prior to 40,000 cal BP (i.e., before the initial eEUP) has been obtained from central Japan. On the other hand, some researchers have claimed the existence of Middle Palaeolithic industries succeeded by the initial eEUP industries (Anzai 2002; Tamura 2006; Sato 2008). Although the possibility cannot be absolutely disproved, the abrupt emergence and increase in the number of initial eEUP sites in the Japanese Islands seems to indicate that the colonization of the Japanese Islands by modern humans resulted in the establishment of the initial eEUP industries. Accordingly, the obsidian use of the initial eEUP represents the origins of obsidian source exploitation in central Japan. The initial eEUP site of Ide-Maruyama, occupation level 1 in the Ashitaka region, is one of the initial eEUP assemblages from which both radiocarbon dates and obsidian provenance data have been obtained. The provenance data indicate that three pieces have been identified as originating in the Central Highlands and 21 pieces come from the Kozu-Onbase Islet out of a total of 24 analyzed obsidian artifacts (Appendix Table 3). Radiocarbon dates obtained from charcoal associated with the lithic assemblage indicate it dates to ca. 37,000 to 38,000 cal BP (Takao and Harada 2011). In addition to Ide-Maruyama, the initial eEUP sites in which obsidian from both the Central Highlands and the Kozu-Onbase sources have been identified are the Fujiishi, occupation level BB-VII (Abe and Iwana 2010) in the

Ashitaka region, and the Musasidai, occupation level Xa (Fuchu Metropolitan Hospital site research group 1984; Hitai *et al.,* 2012) in western Kanto. Moreover, obsidian artifacts from the Mt. Takahara and the Kozu-Onbase sources are identified together from the initial eEUP site of the Kusakari-rokunodai, occupation level 1 (Shimadate and Udagawa 1994) in eastern Kanto (Appendix Table 3).

The obsidian use among the initial eEUP sites is characterized by the unimodal distribution of the quantitative frequency in less than 20 pieces (Fig. 3). The proportion of obsidian artifacts to all artifacts found in a lithic assemblage is also low at less than 10% (Fig. 4). This indicates that the initial eEUP population depended primarily on non-obsidian rocks for stone tool production and that the obsidian sources were first discovered as part of the early exploration and discovery of non-obsidian sources located closer to the Kanto plain than obsidian sources. Identifying procurement locations for lithic raw materials is assumed to have been a significant component of the natural resource exploration of the populations who first migrated to central Japan and settled in an unfamiliar land. It is likely that the first eEUP populations comprehensively explored the procurement locations by following the large river systems toward their origins (Fig. 2). Indeed, according to the provenance data (Appendix Table 3), the initial eEUP populations discovered all of the obsidian source areas including the Kozu-Onbase Islet. Although sites before discovery of obsidian sources are thought to have theoretically existed (Nakamura 2012), it is difficult to systematically distinguish and abstract them from the initial eEUP industries on the basis of the current chronological resolution.

The scenario that the early exploration of non-obsidian sources along the river systems triggered the discovery of obsidian sources, however, cannot explain the discovery of the obsidian source at the Onbase Islet near Kozu Island in the Pacific Ocean, because Kozu Island was separated from the mainland of Honshu at a distance of more than 30-40 km by the Pacific Ocean even in the Last Glacial Maximum (Tabl. 1; Fig. 2). No direct evidence, such as boats and marine products, has been obtained from Upper Palaeolithic sites in the Japanese Islands, but the distribution of artifacts made from Kozu-Onbase obsidian is collateral evidence verifying that the eEUP hunter-gatherers possessed sea navigation capabilities and carried out successfully the transportation of Kozu-Onbase obsidian over water (Ikeya and Mochizuki 1998; Ikeya et al. 2005). Accordingly, another scenario pertaining to the discovery of the Kozu-Onbase source in the initial eEUP is that subsistence activities related to marine resource exploitation resulted in the discovery of Kozu Island and its obsidian sources (Shimada 2012). The first landing at Kozu Island was probably via the water route coming down to the south from Oshima Island, which is located closer to the mainland (Fig. 2), because it is almost impossible to see Kozu Island from the mainland with the naked eye.

The initial discovery of obsidian sources and the patterns of obsidian use in the initial eEUP support the notion that the initial eEUP can be evaluated as a stage in which the integration of obsidian into the overall lithic raw material consumption was experimentally carried out, though the locations of obsidian sources were already known as a part of the natural resource environment among the eEUP hunter-gatherers. In other words, the ability to utilize the natural resource environment had remained in a developing state. This notion provides an explanation with regard to the delay of the initial land use in the regions of northern Kanto and Lake Nojiri where initial eEUP sites are absent.

B – Establishment of obsidian use

An increase in obsidian use during the developed eEUP indicates that obsidian procurement became effectively embedded in the mobility strategy. The quantitative frequency of obsidian artifacts shows a bimodal distribution in which the peaks appear in the group with 1-20 pieces and the groups with >100, >200 and >1,000 pieces (Figure 3), indicating that there was a cycle of obsidian use formed by recurrent obsidian procurement and its supply to the region, and a decrease in the amount of obsidian by successive reduction through inter-site regional mobility.

The scattered pattern seen in the correlation between assemblage size and the percentage of obsidian artifacts in a lithic assemblage (Fig. 4) represents diverse situations in the relationship between the cycle of obsidian procurement and supply, and lithic production. Even though the assemblage sizes are comparable to one another, in the site that shows a relatively lower percentage of obsidian artifacts—which indicates that obsidian had been exhausted— the lithic raw materials for stone tool production were secured by non-obsidian rock procurement.

Taking the geographical relations between the sources of obsidian and non-obsidian rocks into consideration, the procurement of non-obsidian rocks located closer to the residential areas and obsidian located relatively far from those regions were tightly integrated into the mobility strategy employed by the residential groups of the developed eEUP. The complex procurement cycle of non-obsidian rocks and obsidian was likely determined by the frequency of far-reaching travels using the large river systems and the duration of stay in a certain residential area. These observations support the notion that the developed eEUP population had become more knowledgeable than the initial eEUP population had been in terms of utilizing lithic raw material sources, as well as the entire natural resource environment.

C – Mobility strategies in the eEUP

The obsidian use in the initial eEUP represents a part of the initial situation of human adaptation to unfamiliar landscapes. It is assumed that because of the period before the emergence of the circular settlements, the residential groups were advancing in their organization of social relations. Nevertheless, the initial eEUP population discovered all of the obsidian source areas in central Japan. This fact indicates that far-reaching procurement routes were initially explored using the large river systems extending from the residential areas, connecting non-obsidian sources with obsidian sources. Although the residential areas of the initial eEUP had been less extensive in comparison with those of the following period, and details regarding mobility strategies are unclear, it is believed that the natural resource environment in central Japan was thoroughly explored.

The emergence of circular settlements in the developed eEUP drastically changed the settlement landscapes, establishing a residential pattern based on events of dispersal and congregation of the eEUP population. The organizational exploitation of natural resources was promoted by the circular settlements marked as Grade 3. As a result, the residential areas were more expanded in comparison with those of the previous period, and land use accompanied by intensive subsistence activities in the Lake Nojiri site group also appeared. The management of circular settlements increased the competence of the eEUP population in natural resource exploitation and social adaptation (Sato 2006). With changes in society and economy from the initial eEUP to the developed eEUP as a background, the developed eEUP population employed a mobility strategy that would cope with both regional adaptation and far-reaching land use in the following manner (Fig. 5).

According to comparative analysis of obsidian use between the initial eEUP and the developed eEUP, it is apparent that information literacy with regard to natural resource environment gradually increased by the developed eEUP. The obsidian distribution pattern showing regional biases reflects that regional subsistence activities had been developed, in which obsidian procurement depending on accessibility to the source areas was probably embedded. The obsidian used in the Ashitaka region mainly came from the Hakone (44.9%) and the Kozu-Onbase (23.5%) in preference to the Central Highlands (14.4%). The Kozu-Onbase obsidian indicates a biased distribution pattern. Accordingly, it is highly possible that a regional preference for Kozu-Onbase obsidian indicates that regional subsistence in the Ashitaka region focused on the exploitation of marine resources.

The transportation of obsidian that had been used complimentarily depicts a complex web between the sources and the regions. The complementary obsidian tended to be brought into residential areas from sources relatively far away, as mentioned above. It can be hypothesized that the distribution of complementary obsidian resulted from the inter-regional mobility of the eEUP population.

By integrating a trip to the Central Highlands for obsidian procurement with another for non-obsidian rocks in each residential area, the Central Highlands obsidian became the mainstream for obsidian procurement except for the Ashitaka region, and its global distribution occurred. As a result, the Central Highlands functioned as a focal point, in which the stone procurement routes extending from each residential area were connected. This hub inevitably opened a path that linked the regions of the Kanto Plain with the Lake Nojiri site group. Thus, it can be hypothesized that temporary or seasonal influxes of the developed eEUP population from the regions along the Pacific coast caused the intensive land use in the Lake Nojiri site group that led to the formation of the Grade 3 circular settlements and larger settlements. The procurement of Central Highlands obsidian and its transportation to the Lake Nojiri site group had been embedded in the far-reaching travel to the Lake Nojiri site group via the Central Highlands. This is the reason why the exclusive use of the central highlands obsidian is recognized in the Lake Nojiri site group.

The fundamental issue is to elucidate what specific subsistence activity had taken place in the Lake Nojiri site group. A promising candidate for the natural resources distributed unevenly in the Lake Nojiri site group is the extinct large herbivores, represented by Naumann's elephant (*Palaeoloxodon naumanni*) and Yabe's giant deer (*Shinomegaceros yabei*). They are believed to have become extinct during the Last Glacial Maximum (Iwase et al. 2011). Otaishi (1990) and Ono (2001) have argued that the seasonal migration routes of Naumann's elephant were extended far from the coastal areas of the Japan Sea to those of the Pacific Ocean, and that the Lake Nojiri site group was intensively used for hunting activities. Taking the difference of topographical elevation into consideration, the seasonal migration route is thought to have extended along the Shinano River system and the old Tone River system via the Usui Pass near northern Kanto (Fig. 2) (Ono 2001). On the basis of these assumptions, the land use in northern Kanto, which was a new practice during the developed eEUP, was also closely related to the exploitation of the large herbivores moving along the seasonal migration route.

A far-reaching mobility strategy over a distance of 300 km adopted by the developed eEUP population had first formed the impressive site distribution and outstanding obsidian use in the Lake Nojiri site group.

5 – Conclusions

The first discovery of obsidian sources and the trial use of obsidian in the initial eEUP indicate that, when modern humans migrate into an unfamiliar land, a comprehensive and wide-ranging exploration of the natural resources was a fundamental adaptive behavior. In particular, the early discovery of the Kozu-Onbase obsidian source implies that modern humans had conventionally exploited marine resources as a subsistence activity before reaching the Japanese Islands. However, the dispersal routes from the continental region to the Japanese Islands have not yet been clarified, whereas several researchers have assumed a possible route via the Korean Peninsula (Sato 2009; Tsutsumi 2012). The eEUP industries are mainly distributed in Kyushu, close to the Korean Peninsula (see the map of the Japanese Islands in Figure 2 for the location) and central Japan. The distribution of the eEUP industries is very sparse in Hokkaido, the northernmost part of the Japanese Islands (see the map in Figure 2). Few lithic industries comparable to the eEUP industries in the Japanese Islands have been discovered so far on the continental side. Thus, it is highly possible that the eEUP industries were independently developed by adapting to the landscape of the Japanese Islands, which was a *cul-de-sac* for modern human dispersals at the eastern tip of the continental Asia. The author estimates that the developed eEUP period was a settling-in phase following initial exploration and colonization, and that at least the developed eEUP populations in central Japan who coped with both regional adaptation and the far-reaching mobility strategy inevitably shared the information of natural resource environment all over central Japan. This type of information sharing across a broad area can be explained by the "corridor-territory" hypothesis, as follows.

Kunitake (2008) first presented the "corridor-territory" hypothesis on the basis of the work of Tamura et al. (2004b) (Fig. 2). The hypothesis states that the groups that inhabited the Kanto Plain had established mobility corridors between the residential areas and procurement zones for lithic raw materials that had been arranged in concentric circles around the Kanto Plain. The different residential areas were connected via the specific procurement zones that played the role of focal points, as for example the Central Highlands. He also pointed out that the corridors continued to provide the Upper Palaeolithic hunter-gatherers with territories along the corridors in which subsistence activities were undertaken and information was extensively exchanged. Thus, the establishment of obsidian procurement system and mobility strategy based on far-reaching land use adopted by the eEUP populations represent the first emergence of the Upper Palaeolithic corridors that ensured the survival of the population by effective food procurement and information exchanges.

The mobility strategy of the eEUP hunter-gatherers this paper discussed on the basis of the analysis of obsidian use represents the structure of the mobility strategy on the largest possible macroscale, that of central Japan, because of the nature of obsidian procurement. The macroscale mobility strategy functions as a system by interacting with the middle-distance (inter-residential area) and short-distance (intra-residential area) mobility. Thus, further analysis based on the archaeological evidence reflecting the mobility of inter- and intra-residential areas is required. For example, details of the reduction of complementary obsidian in the lithic assemblages may be useful as an indicator of middle-distance mobility. The regional inter-site analysis on the *chaînes opératoires* of non-obsidian materials may be effective for an examination of short-distance mobility.

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Initial eEUP sites	Number of artifacts	Obsidian artifacts	Ratio of obsidian	Region	Circular settlements
Seta, Level 8	437	0	0.0%	Western Kanto	-
Tamaranzaka 8-A, Level 1	398	0	0.0%	Western Kanto	-
Shimoyama, Level 4	364	0	0.0%	Western Kanto	-
Tamaranzaka 5, Level 1	274	18	6.6%	Western Kanto	-
Takaidohigashi, Level X	204	0	0.0%	Western Kanto	-
Musashidai, Level Xa	170	170	100.0%	Western Kanto	-
Tamaranzaka 1, Level 1	165	0	0.0%	Western Kanto	-
Hakeue, Level X	142	1	0.7%	Western Kanto	-
Suzuki-miyuki, Loc 1, Level IV	137	0	0.0%	Western Kanto	-
Nishidai-gotoda, Loc 1, Level Xa	123	8	6.5%	Western Kanto	-
Yoshioka, Loc D	100	1	1.0%	Western Kanto	-
Musashi-kokubunji-kanren-musashidai, Loc A, Level 1	88	0	0.0%	Western Kanto	-
Tamaranzaka 8, Loc B, level 1	79	0	0.0%	Western Kanto	-
Musashidai-nishi-chiku, Level 1, SX 50	48	0	0.0%	Western Kanto	-
Tamaranzaka 4, Level 1	32	0	0.0%	Western Kanto	-
Nogawa-nakasu-kita	32	0	0.0%	Western Kanto	-
Higashi-hayabuchi	23	0	0.0%	Western Kanto	-
Shimayashiki, Level IV	22	2	9.1%	Western Kanto	-
Minamiaono, Loc. 1	434	1	0.2%	Eastern Kanto	-
Boyama, Level 6, S48	259	178	68.7%	Eastern Kanto	-
Nishinodai B, Level X-U	227	0	0.0%	Eastern Kanto	-
Kusakari, Loc D, Level 2, C77-D	200	9	4.5%	Eastern Kanto	-
Kusakari-rokunodai, Level 1, N	173	16	9.2%	Eastern Kanto	-
Nishi-ono 1, Loc. C, 6-11	169	1	0.6%	Eastern Kanto	-
Nakayama-shinden II, Level 11	101	0	0.0%	Eastern Kanto	-
Kusakari-rokunodai, Level 1, J	90	2	2.2%	Eastern Kanto	-
Kusakari, Loc C, Level 1, C13-B	28	0	0.0%	Eastern Kanto	-
Mukoyama-yatsu	27	0	0.0%	Eastern Kanto	-
Fukuda-tonozawa 1	27	0	0.0%	Eastern Kanto	-
Wosaru-yama, Level 4, 21	22	1	4.5%	Eastern Kanto	-
Hitokuwada-jinbei-yama 1	22	0	0.0%	Eastern Kanto	-
Takaido-higashi, Level X	21	0	0.0%	Eastern Kanto	-
Obayashi, Level VII, 42	20	0	0.0%	Eastern Kanto	-
Ide-maruyama, Level SC-IV	1,329	37	2.8%	Ashitaka	-
Fujiishi, Level BB-VII	491	189	38.5%	Ashitaka	-

Appendix Table 1 – Obsidian artifacts in the initial eEUP industries in central Japan.

Appendix Table 2 (p. 192) – Obsidian artifacts in the developed eEUP industries in central Japan.

Appendix Table 3 (p. 193-194) – List of obsidian provenance data in central Japan.

Developed eEUP sites	Number of artifacts	Obsidian artifacts	Ratio of obsidian	Region	Circular settlements
Nomizu, Level IV	6,003	11	0.2%	Western Kanto	Grade 3
Seiganji-maehara, Loc.2	1,472	1293	87.8%	Western Kanto	Grade 3
Tsukuijo-magome-chiku, Level 6	1,384	50	3.6%	Western Kanto	Grade 3
Nakahigashi, Loc.2 and 3, Level IX	820	814	99.3%	Western Kanto	-
Kamibayashi, Level 2	3,480	382	11.0%	Northern Kanto	Grade 4
Shimohure-ushibuse, Level II	2,037	4	0.2%	Northern Kanto	Grade 4
Sanwa-kogyodanchi I, Level 4	1,340	622	46.4%	Northern Kanto	Grade 4
Imaisankido, Level IV, Loc. C	823	6	0.7%	Northern Kanto	Grade 4
Shirakawa-kasamatsu	599	5	0.8%	Northern Kanto	Grade 2
Amabiki-kitsunezaki, Unit 1	532	0	0.0%	Northern Kanto	Grade 2
Mitsugo-sawanaka	531	0	0.0%	Northern Kanto	Grade 2
Kojo, Loc. 1C	523	283	54.1%	Northern Kanto	Grade 2
Ogami, Level 4	457	218	47.7%	Northern Kanto	Not available*
Amagatsutsumi, Loc. II-III, Level 3	451	24	5.3%	Northern Kanto	Grade 2
Tairaoppeno	442	199	45.0%	Northern Kanto	Grade 2
Imaisankido, Level IV, Loc B	414	2	0.5%	Northern Kanto	Grade 2
Sirakura-shimohara, Loc. A	403	0	0.0%	Northern Kanto	Grade 2
Hashie-nishijuku, Loc. A-1, 2, Level II	391	1	0.3%	Northern Kanto	Grade 2
Amabiki-mukaihara, Loc. A	268	3	1.1%	Northern Kanto	Grade 1
Bungo-hassaki, Loc.1	257	9	3.5%	Northern Kanto	Grade 1
Shirakura-shimohara Loc. B	102	86	84.3%	Northern Kanto	Grade 1
Yotsuzuka, Unit 14-30	1,433	12	0.8%	Eastern Kanto	Grade 3
Toho-miyukibata-nishi, Level 1, area 1	1,075	2	0.2%	Eastern Kanto	Grade 4
Toho-miyukibata-nishi, Level I, area 2	869	1	0.1%	Eastern Kanto	Grade 2
Higashi-ono 2	819	127	15.5%	Eastern Kanto	Grade 4
Sekihata, Level 1a, Unit A	760	5	0.7%	Eastern Kanto	Grade 2
Boyama, Level 5	750	23	3.1%	Eastern Kanto	Grade 2
Ikehana-minami, Level 1	733	12	1.6%	Eastern Kanto	Grade 2
Koyanouchi, Level I	649	75	11.6%	Eastern Kanto	Grade 4
Minami-sanrizuka-miyahara 1, Loc. 1, CS 1	633	117	18.5%	Eastern Kanto	Grade 4
Sekihata, Level 1a, Unit B	547	41	7.5%	Eastern Kanto	Not available
Ryusuiji-ura, south CS	544	1	0.2%	Eastern Kanto	Grade 2
Oyama, Level II, Unit 2	478	2	0.4%	Eastern Kanto	Grade 2
Nakayama-shinden I, Unit 4	452	12	2.7%	Eastern Kanto	Grade 2
Yotsuzuka, Unit 1-13	356	4	1.1%	Eastern Kanto	Grade 2
Minami-sanrizuka-miyahara 1, Loc. 2, CS 3	299	112	37.5%	Eastern Kanto	Grade 1
Toho-miyukibata-nish,i Level I, area 3	240	1	0.4%	Eastern Kanto	Grade 1
Shibayama, Level 1, Unit 1	194	1	0.5%	Eastern Kanto	Grade 1
Minami-sanrizuka-miyahara 1, Loc 2, CS 2	135	0	0.0%	Eastern Kanto	Grade 1
Ryusuiji-ura, North CS	48	1	2.1%	Eastern Kanto	Grade 1
Doteue, I	2,223	1475	66.4%	Ashitaka	Not available
Nakamiyo I, Level 5	1,856	1606	86.5%	Ashitaka	Grade 3
Doteue, Loc. III	1,172	928	79.2%	Ashitaka	Not available
Doteue, Loc. II	995	635	63.8%	Ashitaka	-
Oidaira-B, Level 2	773	119	15.4%	Ashitaka	-
Matoba	729	8	1.1%	Ashitaka	-
Umenokizawa, Level 2	474	345	72.8%	Ashitaka	-
Nishibora b	434	144	33.2%	Ashitaka	Grade 2
Shimizuyanagi-kita-higashi-one	400	118	29.5%	Ashitaka	-
Fijiishi, Level BB-VI	33	32	97.0%	Ashitaka	-
Hinatabayashi B	9,001	6489	72.1%	Lake Nojiri	Grade 3
Kannoki, Loc. H3, Lebel I, Layer V	8,795	2819	32.1%	Lake Nojiri	Grade 3
Kannoki, H4, Level I, Layer V	7,897	1733	21.9%	Lake Nojiri	-
Nakamachi, Loc. BP 2	6,337	1044	16.5%	Lake Nojiri	-
Nakamachi, Loc. JS	5,708	368	6.4%	Lake Nojiri	Grade 3**
Nakamachi, Loc. BP3	4,567	177	3.9%	Lake Nojiri	-
Shogetsudai, Loc. BP	3,835	1504	39.2%	Lake Nojiri	-
Kannoki, Loc. H2, Level I, Layer V	2,195	184	8.4%	Lake Nojiri	-
Nakamachi, Loc. BP 1	1,886	1107	58.7%	Lake Nojiri	-
Uenohara, Loc. H, Layer 5	1,874	403	21.5%	Lake Nojiri	-
Okubo-minami, Loc. H, Level Ia and Ib	1,224	616	50.3%	Lake Nojiri	-
Kannoki, Loc. H1, Level I, Later V	961	142	14.8%	Lake Nojiri	-
Higashi-ura, H1, Level I	461	406	88.1%	Lake Nojiri	-
Higashi-ura, H1, Level II	332	59	17.8%	Lake Nojiri	-

* circular settlements but not fully excavated. ** composed of two circular settlements.

Appendix Table 3. List of obsidian provenance data in central Japan

Northern Kanto	Mt. Takahara	Central Highlands	Kozu-Onbase	Hakone	Amagi	Total	Num. of obsidian	(%)	Num. of lithics	Method	References (obsidian analysis)
Kamibayashi,Level 2	17	345	10	2	1	375	382	98.2%	3,480	EDXRF	Idei (2004)
Nakane	29				1	30	-	-	-	EDXRF	Tateishi et al. (2011)
Teranohigashi A, level 1	3					3	8	37.5%	8	EDXRF	Morishima (2003)
Mineyama, Level 2		14	1			15	18	83.3%	646	EDXRF	Takehara (2009)
Imai-sankido, level 4	1	97				98	531	18.5%	2,108	EDXRF	Inoue (2004)
Ogami, level 4	216	2				218	218	100.0%	470	EDFRX	Takehara (2008a)
Shirakura-shimohara Loc. B		20				20	86	23.3%	120	EDXRF	Warashina et al. (1994)
Amabiki-mukaihara, Loc. A		3				3	3	100.0%	268	EDXRF	Warashina et al. (1994)
Shikashimizu	4	99				103	>100	-	-	EDXRF	Sugihara et al. (2009a)
Yamagamijo-ato IX	10					10	66	15.2%	180	EDXRF	Tateishi et al. (2010)
Yamauchide B		8				8	55	14.5%	94	EDXRF	Tateishi et al. (2010)
Orimo III, Loc. B		7				7	~70	-	257	EDXRF	Tateishi et al. (2010)
Kakiage, Level 4		1				1	1	100.0%	2	EDXRF	Takehara (2008b)
Shiraiwa-minbu, cultural layer 2		21				21	37	56.8%	722	EDXRF	Tateishi et al. (2010)
Total of northern Kanto (%)	**280 (30.7)**	**617 (67.7)**	**11 (1.2)**	**2 (0.2)**	**2 (0.2)**	**912**					
Eastern Kanto	**Mt. Takahara**	**Central Highlands**	**Kozu-Onbase**	**Hakone**	**Amagi**	**Total**	**Num. of obsidian**	**(%)**	**Num. of lithics**	**Method**	**References (obsidian analysis)**
Nakayama-shinden I	5	1	1			7	354	2.0%	1,434	NAA, WDXRF	Ninomiya (1988), Oya et al. (2008)
Kusakari-rokunodai, Level 3	11	551	4			566	1031	54.9%	1,750	EDXRF	Ninomiya et al. (1994)
Kusakari-rokunodai, Level 2	7	1	4	1		13	25	52.0%	145	EDXRF	Ninomiya et al. (1994)
Harayama, Level 1	2					2	4	50.0%	76	WDXRF	Nitta (2009)
Harayama, Level 2a		2				2	132	1.5%	452	WDXRF	Nitta (2009)
Harayama, Level 2b	25	1				26	837	3.1%	989	WDXRF	Nitta (2009)
Minamisanrizuka-miyahara 1, Loc. 1	2		64			66	117	56.4%	633	EDXRF	Sugihara et al. (2005)
Minamisanrizuka-miyahara 1, Loc. 2			91			91	112	81.3%	434	EDXRF	Sugihara et al. (2005)
Kusakari-rokunodai, level 1*	5		1			6	18	33.3%	262	EDXRF	Ninomiya (1994)
Total of eastern Kanto (%)	**57 (7.3)**	**556 (71.4)**	**165 (21.2)**	**1 (0.1)**	**0 (0.0)**	**779**					
Western Kanto	**Mt. Takahara**	**Central Highlands**	**Kozu-Onbase**	**Hakone**	**Amagi**	**Total**	**Num. of obsidian**	**(%)**	**Num. of lithics**	**Method**	**References (obsidian analysis)**
Fujikubo-higashi, Level IX	1	8	2	2	61	74	635	11.7%	765	EDXRF	Sugihara et al. (2009b)
Fujikubo-higashi, Level X*					1	1	1	100.0%	32	EDXRF	Sugihara et al. (2009b)
Nakahigashi 2, Level IX		2		5	48	55	458	12.0%	820	EDXRF	Sugihara et al. (2011)
Shimosato-honmura, Level IX		2				2	30	6.7%	282	EDXRF	Kadouchi (2001)
kamagaya, Level IXa		14				14	35	40.0%	225	EDXRF	Hitai et al. (2012)
Shimosato-honmura, Level VII	1					1	3	33.3%	32	EDXRF	Kadouchi (2001)
Tanashi-minamicho, phase 1		79		37	34	150	158	94.9%	1,056	EDXRF	Ninomiya et al. (1992)
Nishidai-gotoda, Level Xa*		2				2	8	25.0%	123	WDXRF	Palynosurvey (1999)
Tamonji-mae, Level IX		4		12	2	18	57	31.6%	589	EDXRF	Kadouchi (2001)
Musashidai, Level Xa		136	1			137	~170	-	~170	EDXRF	Hitai et al. (2012)
Tamaranzaka 5, Level X, IX	9	1	3		1	14	174	8.0%	450	EDXRF	Hitai et al. (2012)
Tsukuijo-ato-magome-chiku, Level 6		22	20		2	44	50	88.0%	1,384	EDXRF	Sugihara et al. (2010)

...continued on next page

Yoshioka D, Level BB-5		1				1	1	100.0%	100	EDXRF	Warashina et al. (1999)
Yoshioka D, Level BB-4 lower				4		4	49	8.2%	54	EDXRF	Warashina et al. (1999)
Total of western Kanto (%)	**11 (2.1)**	**271 (52.4)**	**26 (5.0)**	**60 (11.6)**	**149 (28.8)**	**517**					
Ashitaka	**Mt. Takahara**	**Central Highlands**	**Kozu-Onbase**	**Hakone**	**Amagi**	**Total**	**Num. of obsidian**	**(%)**	**Num. of lithics**	**Method**	**References (obsidian analysis)**
Fujiishi, Level BB-IV*				1	4	5	5	100.0%	7	EDXRF	Mochizuki (2010a)
Sakurabatake-ue, Level I*			4			4	4	100.0%	4	EDXRF	Mochizuki (2009a)
Shimizu-yanagi-kita-higashi-one, Level BB-V		59			5	64	118	54.2%	400	EDXRF	Ikeya et al. 1998
Doteue-I, Level BB-V		72	125	407	281	885	1472	60.1%	2,203	EDXRF	Ikeya (1998): 22-138
Doteue-II, layer BB-V		7	41	276	32	356	635	56.1%	995	EDXRF	Ikeya (1998): 139-196
Doteue-III, Level BB-V		11	323	255	15	604	928	65.1%	1,117	EDXRF	Ikeya (1998): 197-268
Oidaira, Level 2		87	1	1	31	120	121	99.2%	773	EDXRF	Nakamura (2011)
Fujiishi, Level BB-VI*			28		2	30	32	93.8%	33	EDXRF	Mochizuki (2010a)
Nishibora b, Level BB-VI*			84		34	118	144	81.9%	434	EDXRF	Sasahara (1999): 14-125
Umenokizawa, Level 2		29	1	252	7	289	345	83.8%	474	EDXRF	Mochizuki (2009b)
Hosoo, Level 1*				11		11	13	84.6%	14	EDXRF	Mochizuki (2010b)
Fujiishi, Level BB-VII*		115	1		51	167	189	88.4%	491	EDXRF	Mochizuki (2010a)
Mukaida-A, Level SC-IV*		1			2	3	3	100.0%	6	EDXRF	Togashi et al. (2007): 203-206
Motono, Level SC-IV*		1				1	1	100.0%	3	EDXRF	Mochizuki (2008)
Ide-maruyama, Level SC-IV*		3	21			24	37	64.9%	1,329	EDXRF	Ikeya (2011)
Total of Ashitaka (%)	**0 (0)**	**385 (14.4)**	**629 (23.5)**	**1,203 (44.9)**	**464 (17.3)**	**2,681**					
Lake Nojiri site group	**Mt. Takahara**	**Central Highlands**	**Kozu-Onbase**	**Hakone**	**Amagi**	**Total**	**Num. of obsidian**	**(%)**	**Num. of lithics**	**Method**	**References (obsidian analysis)**
Uenohara Loc. H		289				289	403	71.7%	1874	EDXRF	Mochizuki (2000)
Uranoyama H Level1		5				5	5	100.0%	16	EDXRF	Mochizuki (2000)
Nakamachi Loc. JS		321				321	368	87.2%	5706	EDXRF	Mochizuki (2004a)
Nakamachi Loc.BP1		836				836	1107	75.5%	1886	EDXRF	Mochizuki (2004a)
Nakamachi Loc. BP2		857				857	1044	82.1%	6337	EDXRF	Mochizuki (2004a)
Nakamachi Loc.BP3		137				137	177	77.4%	4567	EDXRF	Mochizuki (2004a)
Kannoki H1 Level 1		97				97	142	68.3%	961	EDXRF	Mochizuki et al. (2000)
Kannoki H2 Level 1		142				142	184	77.2%	1178	EDXRF	Mochizuki et al. (2000)
Kannoki H3 Level 1		1,909				1909	2819	67.7%	8795	EDXRF	Mochizuki et al. (2000)
Kannoki H4 Level 1		998				998	1733	57.6%	7897	EDXRF	Mochizuki et al. (2000)
Higashiura H1 Lebel 1		303				303	406	74.6%	461	EDXRF	Mochizuki (2000)
Higashiura H1 Lebel 2		49				49	59	83.1%	332	EDXRF	Mochizuki (2000)
Hinatabayashi		3,495				3495	6489	53.9%	9001	EDXRF	Mochizuki (2000)
Okubo-minami Loc. H		492				492	616	79.9%	1224	EDXRF	Mochizuki (2000)
Shogetsudai Loc. BP		1230				1230	1504	81.8%	3835	EDXRF	Mochizuki (2004b)
Total of Lake Nojiri (%)	**0 (0)**	**11,160 (100)**	**0 (0)**	**0 (0)**	**0 (0)**	**11,160**					

* The initial eEUP industries. EDXRF: energy dispersive X-ray fluorescence. WDXRF: wavelength dispersive X-ray fluorescence. NAA: neutron activation analysis.

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