PALEOENVIRONMENT OF MEDIEVAL ARCHAEOLOGICAL SITES IN CENTRAL JAPAN: ASSEMBLAGE ANALYSIS AND ^{14}C DATING OF INSECT FOSSILS

Emi Okuno[1] • Yuichi Mori[2] • Toshio Nakamura[3]

ABSTRACT. This study aimed to investigate the paleoenvironment of 2 Medieval archaeological sites, Onigashioya and Ooke, in central Japan, by assemblage analyses of insect fossils preserved in sediments at the sites. In the Onigashioya site located in Mie Prefecture, the sclerites of insect fossils classified as the "village" type were detected, which indicates that human activities, and in particular farming, were taking place there. Rice paddies and fields existed near the site, which explains why many insects harmful to rice plants and crops were detected in the area. The radiocarbon date for sclerite remains of *Hydrophilus acuminatus*, an aquatic beetle that live in rice paddy fields, was calibrated to be cal AD 1010–1155. Analysis of sclerite remains of *Craspedonotus tibialis*, a ground beetle that typically inhabits seashore environments, resulted in a date of cal AD 1020–1155. This finding suggests that human settlements existed in the seaside areas of the Onigashioya site in the 11th century AD. In the Ooke site located in Aichi Prefecture, "insect pits" were found, which are structural remains containing a large number of *Anomala rufocuprea*, an insect that preys on field crops. Farmers would have gathered the insects from the fields and buried the dead remains in the pits. Accelerator mass spectrometry (AMS) ^{14}C dates on sclerite remains of *A. rufocuprea* ranged from cal AD 1264 to 1385. It should be noted that fruit trees and vegetable crops were planted widely around the site in the 13th century AD. As the result, *A. rufocuprea* propagated greatly around the site in that period. It is probable that many insects harmful to field crops multiplied largely in this region due to the development of local woods and plains into farming fields. This type of development occurred throughout Japan during the Medieval period.

INTRODUCTION

Assemblage analysis of insect fossils plays an important role in the reconstruction of paleoenvironment compared to other microfossil analyses because not only do insects respond quickly to environmental changes, but they also enable us to reconstruct in detail the paleoenvironmental phenomena specific to, in particular, human activities. In Japan, several researchers have proven the human impact on the environment based on assemblage analysis of insect fossils. Hiura (1984) defined the specific insects useful for studying paleoenvironment in Japanese archaeological sites, and established the basis of environmental analysis based on insect fossil assemblages. The Fossil Insects Research Group for Nojiri-ko Excavation (1984) studied the changing climate in the Paleolithic period. Mori (1999) showed that the assemblages of living things were affected mainly by climatic changes from the prehistoric age to the historic age, and were influenced by human activities in the historical age. However, what seems to be lacking from previous research is age determination of insect fossils in Japan. Therefore, we have tried to reconstruct the paleoenvironment of 2 Medieval archaeological sites by conducting accelerator mass spectrometry (AMS) radiocarbon dating on fossil remains of indicator insects.

EXPERIMENTAL PROCEDURE

Archaeological Sites and Sample Materials

This study focuses on 2 Japanese archaeological sites: the Onigashioya site (34°53′38″N, 136°31′20″E) in Mie Prefecture and the Ooke site (35°20′28″N, 136°47′47″E) in Aichi Prefecture (see Figure 1).

[1]Aichi Archaeological Center, Aichi, Japan. Email: okunoemi@yahoo.co.jp.
[2]Kinjo Gakuin University, Nagoya, Japan.
[3]Center for Chronological Research, Nagoya University, Nagoya, Japan.

Proceedings of the 20th International Radiocarbon Conference, edited by A J T Jull
RADIOCARBON, Vol 52, Nr 2–3, 2010, p 511–519

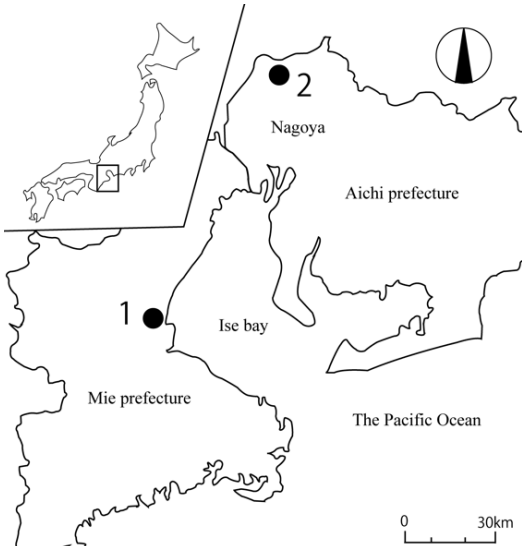

Figure 1 Location of archaeological sites: 1) Onigashioya site (Mie Prefecture); 2) Ooke sites (Aichi Prefecture).

Onigashioya Site

The Onigashioya site is located at the center of the main island, Honshu, in Japan, at ~2 m above sea level. The site is situated on the present-day coast of Ise Bay, with the Sitomo River nearby. According to an excavation study (Mie University Archaeological Laboratory 2003), the site was settled from the Late Yayoi to the Medieval period. Pottery sherds including those identified as salt-making pottery, fossil shells, and seed remains were excavated. Regarding structural remains, only some ditches and pits were identified (Mie University Archaeological Laboratory 2003).

A sediment block sample of ~20 kg was collected from the dark-brown silt layer. The age of the layer is not obvious because it included pottery fragments dating from the Late Yayoi to Medieval period. Therefore, we focused on collecting large fragments of insect fossils to conduct AMS ^{14}C dating on the sclerite remains from the layer. Insect fossils were generally suitable for ^{14}C dating because nearly all the insects found are short-lived organisms (annual or biannual).

Ooke Site

The Ooke site was subdivided into 3 areas (Ooke 1, Ooke 2, and Ooke 3) consisting of structural remains of human settlements from the Heian period to the Medieval period (8th–16th century BC). The Ooke site, ~70 km north of the Onigashioya site, is located on the alluvial lowland of the Noubi Plain. In this paper, we mainly describe the insect fossil analysis of the Ooke 1 site.

The Ooke 1 site was investigated in 1993 by the Aichi Archaeology Center established by Aichi Prefecture. Several pit dwellings, ditches, ridges, and 9 insect pits were excavated (Aichi Archaeology Center 1996), and plenty of sclerite remains of insect fossils were detected in the pits. The thickness of the lump of sediments in which sclerite remains piled up was about 10–20 mm. The insect pits ranged from 200 to 300 mm width with depths of 40–100 mm. A yellow-brown silt layer covered the sclerite deposits.

https://doi.org/10.1017/S0033822200045549 Published online by Cambridge University Press

Figure 2 *Hydrophilus acuminatus* Motschulsky upper part of right elytron (112 mm length), collected from the Onigashioya site.

Figure 3 *Craspedonotus tibialis* Motschulsky pronotum (61 mm width), collected from the Onigashioya site.

Figure 4 "Insect pit" comprising many sclerite remains of *Anomala rufocuprea* Motschulsky collected in the Ooke site (~200 mm width).

Sample 1 consists of several blocks of sediments that were collected from 2 ditches and 3 earthen pits. The age of the sample estimated by archaeological remains ranged from the Heian period to the Medieval period. Sample 2, a sediment block of 230 mm diameter, 40 mm depth, and 7.3 kg weight, was collected from one of the insect pits. Since the insect pit did not contain any archaeological artifacts to estimate the age, we conducted AMS ^{14}C dating on the sclerite remains of insect fossils from sample 2.

We gathered sediment samples at these sites and collected insect fossils from the samples by manual cutting and the water-flow separation method. The insect fossils thus separated were identified by species under a binocular microscope. We selected 2 sclerite remains of insect fossils for AMS ^{14}C dating (Table 1), including 1 seed sample from the Onigashioya site. ^{14}C ages were calibrated to calendar dates by using OxCal 4.1 (Bronk Ramsey 1995, 2001) and the IntCal04 calibration curve (Reimer et al. 2004) (see Figure 5).

https://doi.org/10.1017/S0033822200045549 Published online by Cambridge University Press

Table 1 ^{14}C ages obtained for sclerite remains of insect fossils and seed residues collected from the Onigashioya and the Ooke 1 archeological sites in central Japan.

Lab nr	Material	Species name	^{14}C age (BP)	Site name
PLD-11504	Elytron	*Hydrophilus acuminatus* Motschulsky	977 ± 28	Onigashioya
PLD-11505	Pronotum	*Craspedonotus tibialis* Schaum	969 ± 19	Onigashioya
PLD-11506	Seed	*Scirpus triangulates*	956 ± 20	Onigashioya
PLD-12850	3 pronotum, 3 elytra	*Anomala rufocuprea* Motschulsky	698 ± 27	Ooke 1

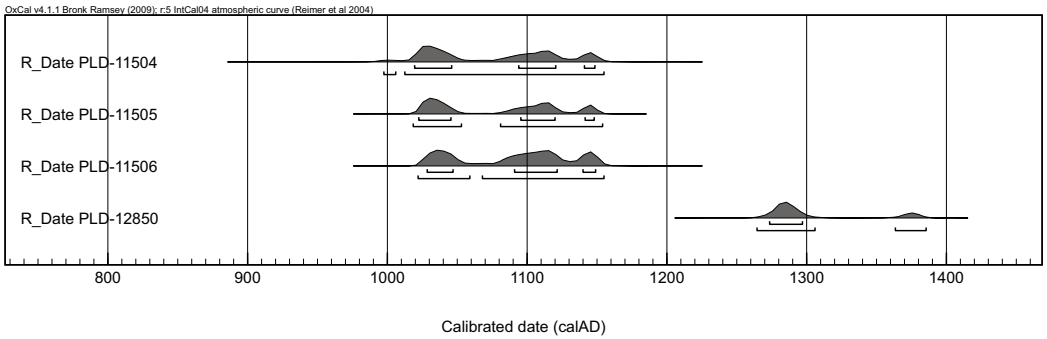

Figure 5 Probability distributions of the calibrated ^{14}C dates for the sclerite remains of insect fossils (PLD-11504, -11505, -12850) and a seed sample (PLD-12850) from the Onigashiya and Ooke 1 archaeological sites, central Japan.

For the 2 insect and 1 seed samples (PLD-11504 to -11506), sample preparation including pretreatment with the acid-alkali-acid (AAA) method and AMS ^{14}C dating were conducted by Paleo Labo Co Ltd. in Japan. For insect sample PLD-12850, AAA pretreatment was performed at the Center for Chronological Research, Nagoya University. For the AAA treatments, samples were rinsed once in 0.2M HCl for 24 hr to remove any possible carbonate contamination. Next, the samples were rinsed with 0.2M NaOH solution for 2 hr. The samples were then treated again with 0.2M HCl for 24 hr. Since the samples were so fragile and melted easily in the acid and alkali solutions, AAA treatments were conducted at room temperature. To remove the HCl component completely from the samples, decanting was repeated after each rinse with distilled water. After chemical cleaning of the samples, CO_2 extraction from the carbonaceous materials, graphite production from the produced CO_2, and AMS ^{14}C dating were performed by Paleo Labo Co. Ltd.

RESULTS AND DISCUSSION

Insect Fossil Analysis and AMS ^{14}C Dating

Onigashioya Site

At the Onigashioya site, 197 sclerite remains of insect fossils were identified from the dark-brown silt layer (Table 2). Sclerites were classified into 3 types depending on their ecological habitat: terrestrial phytophagous insects (52.8%), ground insects (31.7%), and aquatic insects (15.5%).

Regarding the terrestrial phytophagous insects, *Popillia japonica* and *Apogonia amida* were identified. The former is a destructive beetle that eats leaves of leguminous plants. The latter eats leaves of grapes and chestnut trees. The existence of these kinds of insects indicates that fruit trees and vegetable crops were planted near the Onigashioya site. Also, *Anomala* spp. was found, which is most likely identified as *Anomara rufocuprea*, another insect known to prey on leguminous plants. These insects are closely linked to human life and are thus identified as "village" insects.

https://doi.org/10.1017/S0033822200045549 Published online by Cambridge University Press

Table 2 Assemblage analysis results for sclerite remains of insect fossils collected from the Onigashioya site in Mie Prefecture (Okuno and Mori 2009).

Family	Lower taxon	Ecology	Eating habits	Nr and parts of fossils[a]	Sum
Hydrophilidae					
	Hydrophilidae gen. et sp. indet	Aquatic	Phytophagous	E1 T1	2
	Hydrophilus acuminatus Motschulsky	Aquatic	Phytophagous	E4	4
	Sternolophus rufipes Fabricius	Aquatic	Phytophagous	S1 E2 L1	4
	Coelostoma stultum Walker	Aquatic	Phytophagous	P3 E3	6
Dytiscudae					
	Ilybius apicalis Sharp	Aquatic	Carnivorous	E13 T1	14
Histeridae					
	Merohister jekeli Marseul	Geophilous	Carnivorous	E1	1
Staphylinidae					
	Staphylinidae gen. et sp. indet	Geophilous	Omnivorous	E1 A2	3
Carabidae					
	Carabidae gen. et sp. index	Geophilous	Omnivorous	H1 S1 P5 E6 T1 A2 L2	18
	Craspedonotus tibialis Schaum	Geophilous	Carnivorous	H1 P2 E3	6
	Harpalidae	Geophilous	Omnivorous	E1	1
	Synuchus sp.	Geophilous	Omnivorous	E1	1
	Lachnocrepis japonica Bates	Geophilous	Omnivorous	E1	1
Scarabaeidae					
	Scarabaeidae gen. et sp. indet	Terrestrial	Phytophagous	L1	1
	Onthophagus spp.	Geophilous	Coprophagous	P1 E1	2
	Onthophagus atripennis Waterhouse	Geophilous	Coprophagous	P1	1
	Aphodius rectus Motschulsky	Geophilous	Coprophagous	P5 E20	25
	Anomala spp.	Terrestrial	Phytophagous	H17 P6 E53 L19	95
	Anomala albopilosa Hope	Terrestrial	Phytophagous	E1	1
	Popillia japonica Newmann	Terrestrial	Phytophagous	H2	2
	Rutelinae gen. et sp. indet	Terrestrial	Phytophagous	E2	2
	Apogonia amida Lewis	Terrestrial	Phytophagous	E1	1
Elateridae					
	Elateridae gen. et sp. indet	Terrestrial	Omnivorous	E1	1
Curculionidae					
	Curculionidae gen. et sp. indet	Terrestrial	Phytophagous	E1	1
Total					**193**

[a]E: elytron, H: head, P: pronotum, A: abdomen, T: thorax, L: legs, S: scutellum.

As for the aquatic insects, the herbivorous beetles *Ilybius apicalis*, *Hydrophilus acuminatus*, *Sternolophus rufipes*, and *Coelostoma stultum* were detected. They dwell in rice paddy fields (Mori 2002). *C. stultum* has been frequently found in prehistoric as well as historic rice paddy field layers in Japan (Mori 1999). Larger beetles such as *H. acuminatus* and *S. rufipes* feed upon plants or humus in rice paddy fields and thus have been frequently found in rice paddy layers. Aquatic carnivorous beetles such as *I. apicalis* inhabit paddy fields, too. From these findings, it is probable that rice paddy fields existed near the Onigashioya site at that time.

As for the ground insects, *Onthophagu*s spp., *Onthophagus atripennis*, and *Aphodius rectus* were detected. These species are dung-eating beetles that eat feces from humans and domestic animals. The dung-eating beetles have been found in many archaeological settlements with large human populations, such as the Asahi site (Mori 1992) and the Ikegamisone site (Miyatake and Kanazawa 1990). These insects are so-called “urban” insects (Mori 1992), found in environments containing a great deal of human excrement and/or food waste. Therefore, it is inferred that many people and animals lived in and around the site.

We also detected remains of the omnivorous insect *Lachnocrepis japonica*. It exists today in damp soil, near streams or other water bodies. This finding combined with the presence of the aquatic beetles indicates that shallow waters existed around the site at that time. Meanwhile, the presence of the carnivorous beetles (*Craspedonotus tibialis*), found today in seashore environments, indicates that this site was probably located at the mouth of a river near the sea.

Two sclerite samples were AMS dated. Sample PLD-11504 is a sclerite remain of *Hydrophilus acuminatus* (Figure 2) and dated to cal AD 1010–1155. The insect is an aquatic beetle that feeds upon plants or humus in ponds, marshes, or rice paddy fields. The second sample (PLD-11505) is sclerite remains of *Craspedonotus tibialis* (Figure 3), which today inhabits in seashore areas, dated to cal AD 1020–1155. In addition, a seed sample of *Scirpus triangulates* (PLD-11506), an aquatic plant, was also dated to cal AD 1022–1155. This is a perennial plant often growing in ponds, marshes, rivers, and paddy fields. Calibrated ages of all 3 samples (2 insects and 1 seed fragment) are consistent with one another, suggesting the 11th century AD. During that time, the environment around the Onigashioya site had been modified largely by human activities. It is noted that human activities extended to the seaside areas at that time.

Ooke Site

From the Ooke 1 site, a total of 278 sclerite remains of insect fossils were identified (Table 3) and classified into 4 types according to ecological habitat: terrestrial phytophagous insects (45.0%), ground insects (54.0%), aquatic insects (0.7%), and unclassified sclerite remains (0.3%).

Phytophagous insects (Scarabaeidae) such as *Anomara rufocuprea*, *Popillia japonica*, *Anomala cuprea*, *Maladera japonoca*, and Chrysomelidae were found. They mainly eat leaves of fruit trees. *A. rufocuprea* is a beetle known to prey on leguminous plants. We also found *Freutiauxia armata*, which eats mulberry leaves; *Chrysolina exanthematica*, which eats mint leaves; and *C. aurichalcea*, which eats mugworts leaves. These beetles are useful for reconstruction of the paleovegetation around the Ooke 1 site.

As for ground insects, *Chlaenius naeviger* and *Dolichus halensis* were found. These beetles have been frequently observed in crop field layers (Mori 1997). The coprophagous beetles *Onthophagus atripennis*, *Aphodius rectus*, and *A. pusillus* were detected, along with the aquatic beetles *Hydrophilus acuminatus* and *Cybister japonicus*.

Sclerite remains of insect fossils separated from sediment sample 2, which was collected from one of the insect pits, included several thousands of *Anomala rufocuprea* a phytophagous Scarabaeidae known to eat leaves of many cultivated crops. It has been pointed out that *A. rufocuprea* increased rapidly throughout Japan during the development of open land into the agricultural fields in the Medieval period (Mori 1999). *A. rufocuprea* sclerites (PLD-12850) were dated to cal AD 1264–1385 (Table 2). Thus, the insect pit was probably produced in the 13th century AD. Assemblage analysis of insects from insect pits suggest that fruit trees and vegetable crops existed at the site. At Ooke 1, *A. rufocuprea* seem to have propagated greatly at this site during the 13th century AD, preying on the harvest of cultivated crops. To get rid of the noxious insects, local residents would likely have captured the insects and dumped the dead insect remains in the pits.

The Ooke 2 site is located just north of the Ooke 1 site. Similar insect pits were also found here (Mori 1996). Many sclerite remains of *A. rufocuprea* were also packed in the pits. Moreover, insect pits were also found in the Ooke 3 site north of Ooke 2. In the Ooke 3 site, *Chlaenius naeviger* and *Dolichus halensis*, which have been generally detected in crop field layers, were also observed along with the insects known to prey on crops (Mori 1997). It is concluded that *A. rufocuprea* spread widely in this region due to agricultural development that was promoted nationwide at the time.

Table 3 Assemblage analysis results for sclerite remains of insect fossils collected from Ooke 1 site, Aichi Prefecture (Mori 1996).

				Nr and parts of fossils[a] (Ooke 1-)						
Family	Lower taxon	Ecology	Eating habits	-1	-2	-3	-4	-5	-6	Sum
Dytiscudae										
	Cybister japonicus Sharp	Aquatic	Carnivorous				E1			1
Hydrophilidae										
	Hydrophilus acuminatus Motschulsky	Aquatic	Phytophagous				E1			1
Silphidae										
	Silphidae gen. et sp. indet	Geophilous	Filthphagous		E1					1
Carabidae										
	Harpalidae gen. et sp. indet	Geophilous	Omnivorous	A1	E9 P5 H3 A3	P2	P2 H1 A1 L2	E8 P6 H5 A4		52
	Pterostichus sp.	Geophilous	Carnivorous		P1					1
	Pterostichus fortis Morawitz	Geophilous	Carnivorous					E1		1
	Dolichus halensis Schaller	Geophilous	Carnivorous					E3		3
	Synuchus sp.	Geophilous	Omnivorous		E1			E7		8
	Chlaenius sp.	Geophilous	Carnivorous		P1					1
	Chlaenius naeviger Morawitz	Geophilous	Carnivorous					E1		1
Tenebrionidae										
	Plesiophthalmus sp.	Terrestrial	Omnivorous		L1					1
Histeridae										
	Merohister jekeli Marseul	Terrestrial	Carnivorous		E1					1
Staphylinidae										
	Staphylinidae gen. et sp. indet	Geophilous	Omnivorous		P2		E1 A1			4
Scarabaeidae										
	Scarabaeidae gen. et sp. indet	Terrestrial	Phytophagous		E1 L1		L1			3
	Onthophagus spp.	Geophilous	Coprophagous		P1 T1 A1 L1		A1			5
	Onthophagus atripennis Waterhouse	Geophilous	Coprophagous		E7 P7 H1 A2		E2 P1	P1 T1		22
	Aphodius sp.	Geophilous	Coprophagous		P1					1
	Aphodius rectus Motschulsky	Geophilous	Coprophagous		E1		E2	E1 P3		7
	Aphodius pusillus Herbst	Geophilous	Coprophagous		E1					1
	Anomala spp.	Terrestrial	Phytophagous		E2 L3		E1 A1 L2		E1	10
	Anomala cuprea Hope	Terrestrial	Phytophagous	A1				A1		2
	Anomala rufocuprea Motschulsky	Terrestrial	Phytophagous	E2 A1	E20 P5 S1 H3 T2 A6 L3		E9 P1 H4 T1 A4 L2	E8 P4 T2 A2 L10	E13 P7 A3 L2	115
	Mimela splendens Gyllenhal	Terrestrial	Phytophagous				E1	E1		2

https://doi.org/10.1017/S0033822200045549 Published online by Cambridge University Press

Table 3 Assemblage analysis results for sclerite remains of insect fossils collected from Ooke 1 site, Aichi Prefecture (Mori 1996). *(Continued)*

				Nr and parts of fossils[a] (Ooke 1-)						
Family	Lower taxon	Ecology	Eating habits	-1	-2	-3	-4	-5	-6	Sum
	Popillia japonica Newmann	Terrestrial	Phytophagous				L3			3
	Maladera japonica Motschulsky	Terrestrial	Phytophagous		E1			E2		3
Cerambycidae										
	Cerambycidae gen. et sp. indet.	Terrestrial	Phytophagous		L1		L1			2
	Massicus raddei Blessing	Terrestrial	Phytophagous					E1		1
Chrysomelidae										
	Chrysomelidae gen. et sp. indet.	Terrestrial	Phytophagous		E5			E2 P1		8
	Fleutiauxia armata Baly	Terrestrial	Phytophagous					E1		1
	Plagiodera versicolora Laicharting	Terrestrial	Phytophagous					E1		1
	Basilepta fulvipes Motschulsky	Terrestrial	Phytophagous					E1		1
	Nomarthra cyaneum Baly	Terrestrial	Phytophagous					E1		1
	Chrysolina exanthematica Wiedemann	Terrestrial	Phytophagous		E2					2
	Chrysolina aurichalcea Mannerheim	Terrestrial	Phytophagous					E1		1
Tenebrionidae										
	Agrypnus binodulus Motschulsky	Terrestrial	Phytophagous				P1			1
Elateridae										
	Elateridae gen. et sp. indet.	Terrestrial	Phytophagous				E1 T1			2
	Agrypnus binodulus Motschulsky	Terrestrial	Phytophagous				P1			1
Coccinellidae										
	Coccinellidae gen. et sp. indet.	Terrestrial	Omnivorous					E1		1
	Harmonia axyridis Rallas	Terrestrial	Carnivorous					E1		1
Formicidae										
	Formicidae gen. et sp. indet.	Terrestrial	Omnivorous				H1			1
Unidentified										
	unknown	Unknown	Unknown		E2		E1			3
Total										**278**

[a]E: elytron, H: head, P: pronotum, A: abdomen, t: thorax, l: legs, s: scutellum.

https://doi.org/10.1017/S0033822200045549 Published online by Cambridge University Press

CONCLUSION

In the Onigashioya site, nearly all the insect fossils detected were produced from "village" type insects. These indicate that the environment near the site was largely influenced by human activities. The AMS ^{14}C dates of *Hydrophilus acuminatus* (an aquatic beetle), *Craspedonotus tibialis* (a ground beetle), and *Scirpus triangulates* (an aquatic plant) were found to be from the 11th century AD. It is noted that human activities extended to the seaside areas at that time.

At the Ooke site, many "insect pits" were detected. These were structural remains of large holes that were dug in the ground and held a lot of sclerite remains of *Anomala rufocuprea* (an insect harmful to crops). It is important to note that fruit trees and vegetable crops were planted at this site. *A. rufocuprea* sclerites dated to ~13th century AD. Therefore, it is likely that the insect pits were made around this time. At the Ooke site, residents probably raised crops, bringing *A. rufocuprea* to prey on the crops in the 13th century AD. Many harmful insects would have multiplied in this region with the development of wild woods and plains into farming fields that was promoted throughout Japan in the Medieval period.

ACKNOWLEDGMENTS

We are grateful to Mr Tuyoshi Kito of the Aichi Archaeology Center for his assistance. This work was supported technically (working space, equipment for sample preparation and insect identification, etc.) by the Aichi Archaeology Center. We thank Dr Akira Yamanaka of Mie University for providing us valuable samples. The 4th term fund for the young scholars offered by Paleo Labo Co. Ltd. is heartily acknowledged.

REFERENCES

Aichi Archaeology Center. 1996. The Ooke-oki site. *Bulletin of the Aichi Archaeology Center* 66. In Japanese.

Bronk Ramsey C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37(2):425–30.

Bronk Ramsey C. 2001. Development of the radiocarbon calibration program. *Radiocarbon* 43(2A):355–63.

Fossil Insects Research Group for Nojiri-ko Excavation. 1984. Fossil insects obtained from the Nojiri-ko excavation in 1978–1982. *Association for the Geological Collaboration in Japan* 27:137–56. In Japanese.

Hiura O. 1984. The basic study of reconstruction paleoenvironment in archaeological sites by insect remains assemblages. In: Committee for Ancient Culture Properties, editor. *Scientific Approaches to the Study of Cultural Property*. p 411–29. In Japanese.

Mie University Archaeological Laboratory. 2003. Summary of the Onigashioya site 1st excavation. *Bulletin of Mie University Archaeological Laboratory* 3:2–3. In Japanese.

Miyatake Y, Kanazawa I. 1990. Report of insect remains. In: Osaka Prefecture Board of Education. *Summary of the Ikegamisone Site*. p 107–16. In Japanese.

Mori Y. 1992. The assemblages of urban insects from the Asahi site (the Yayoi period), Aichi Prefecture. *Bulletin of the Aichi Archaeology Center* 31:183–205. In Japanese.

Mori Y. 1996. Insect fossils assemblages found from the Ooke-oki site, Ichinomiya city, Aichi Prefecture. *Bulletin of the Aichi Archaeology Center* 66:188–94. In Japanese.

Mori Y. 1997. Ground-wandering insects which characterize crop farm villages in the Tadokoro site. *Bulletin of the Aichi Archaeology Center* 71:154–8. In Japanese.

Mori Y. 1999. Paleoenvironmental changes during the Pre-historical and Historical ages based on insect fossils. *Bulletin of the National Museum of Japanese History* 81:311–42. In Japanese.

Mori Y. 2002. The origin and development of rice paddy cultivation in Japan based on evidence from insect and diatom fossils. In: Yoshida Y, editor. *Origins of Pottery and Agriculture*. New Delhi: Lustre Press. p 273–96.

Okuno E, Mori Y. 2009. Reconstruction of paleoenvironment based on village-inhabiting insect fossils in the Onigashioya archaeological site, Mie Prefecture, Japan. *Journal of History and Archaeology Mie University* 9:1–8. In Japanese.

Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Bertrand CJH, Blackwell PG, Buck CE, Burr GS, Cutler KB, Damon PE, Edwards RL, Fairbanks RG, Friedrich M, Guilderson TP, Hogg AG, Hughen KA, Kromer B, McCormac G, Manning S, Bronk Ramsey C, Reimer RW, Remmele S, Southon JR, Stuiver M, Talamo S, Taylor FW, van der Plicht J, Weyhenmeyer CE. 2004. IntCal04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon* 46(3):1029–58.