PAST HUMAN ACTIVITIES AROUND THE AKKA KARST, NORTHEASTERN JAPAN

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Summary

Past human activities around the Akka Karst, Northeastern Japan, were investigated archaeologically and pedologically. The first appreciable human occupation in the study area was during the Middle Paleolithic. Some tools such as scrapers were excavated from the entrance of the Hyotan-ana Cave. The vegetation change from forest to grassland induced by human activities, such as forest burning, occurred around the Akka Karst during the early-middle Holocene. There are many archeological sites of the Jomon Period (12-2.4 ka BP) on the fluvial terraces and in caves around the Akka Karst. Thick melanic Andisols (black volcanic ash soils), which were associated with grassland vegetation, mainly occurred along the rivers in the study area. Moreover, a buried humus horizon was found on the karstic plateau, which contained To-Nb tephra (8.6 ka BP) and was covered with To-Cu tephra (5.5 ka BP). This horizon was very dark (10YR2/1) in colour and had humus dominated by A type humic acid. Therefore, grassland vegetation occurred not only on the fluvial terraces but also on part of the karstic plateau in the early-middle Holocene. Intensive deforestation of the karst commenced around the 17th century. An iron smelting industry thrived around the Akka Karst between the 17th to 19th centuries, which required a lot of charcoal. Therefore, the forests on the karst were used as charcoal-fuel woods and repeatedly cleared. The land transformation of iron sand mining and the destruction of forests caused soil erosion on the steep slopes, water pollution, and floods during heavy rains.

Introduction

The present landscapes of many karst areas are the result of human activities, as the term "karst" itself implies rocky and barren landscape made by human impact over a long time (*Gams, 1993*). In the Mediterranean karsts, human impact for thousands of years have been reviewed in detail (e.g., *Gams, 1993, Gams et al., 1993, Sauro, 1993*). In Japan, the Akiyoshi-dai Plateau has been well known in terms of past human activities on karst (e.g., *Kuramoto, 1996*). Most parts of the Akiyoshi-dai Plateau are now occupied by grassland vegetation (*Shiomi & Nakamura, 1981*), and were used as hayfields at least in the middle 18th century (*Kuramoto, 1996*). Kita (1996) reconstructed past human land use on the Akiyoshi-dai Plateau since the 16th century on the basis of historical documents. However, the period of vegetation change from forest to grassland is still unclear, although it appears to have been induced by human activities.

Melanic Andisols (black volcanic ash soils) are usually found around the volcanoes in Japan. They are also observed around the Akka Karst, Northeastern Japan (*Fig. 1*). The present vegetation of the Akka Karst is mainly secondary forests and plantations. However, grassland vegetation probably occurred in the Akka Karst as well as on the Akiyoshi-dai Plateau, because melanic Andisols are formed under grassland vegetation (e.g., *Shoji et al., 1993; Sase & Hosono, 1996; Soil Survey Stuff, 1997;*

Sugiyama, 1999). Moreover, several Quaternary tephras can be used as time-markers to estimate the formation age of melanic Andisols. Therefore, it is possible to clarify the period of vegetation change from forest to grassland in the Akka Karst.

The aim of this paper is to clarify the past human activities around the Akka Karst. First we review archaeological studies around the Akka Karst. Then we discuss past human land use on the karst on the basis of relationships between pedological analysis and archeological studies.

Outline of the Akka Karst

Fig. 1 shows the location of the Akka Karst. The Akka Limestone is distributed in the northeastern part of the Kitakami Mountains, northeastern Japan. Several rivers flow eastward from a non-limestone area in the Kitakami Mountains and dissect the Akka Limestone into blocks of karstic plateau up to 400-700 m above sea level (*Fig. 1*). More than 100 caves have been recognised in the Akka Limestone. Dolines are well developed, especially in the northern part of the study area. The Akka Limestone, which is 50 km wide

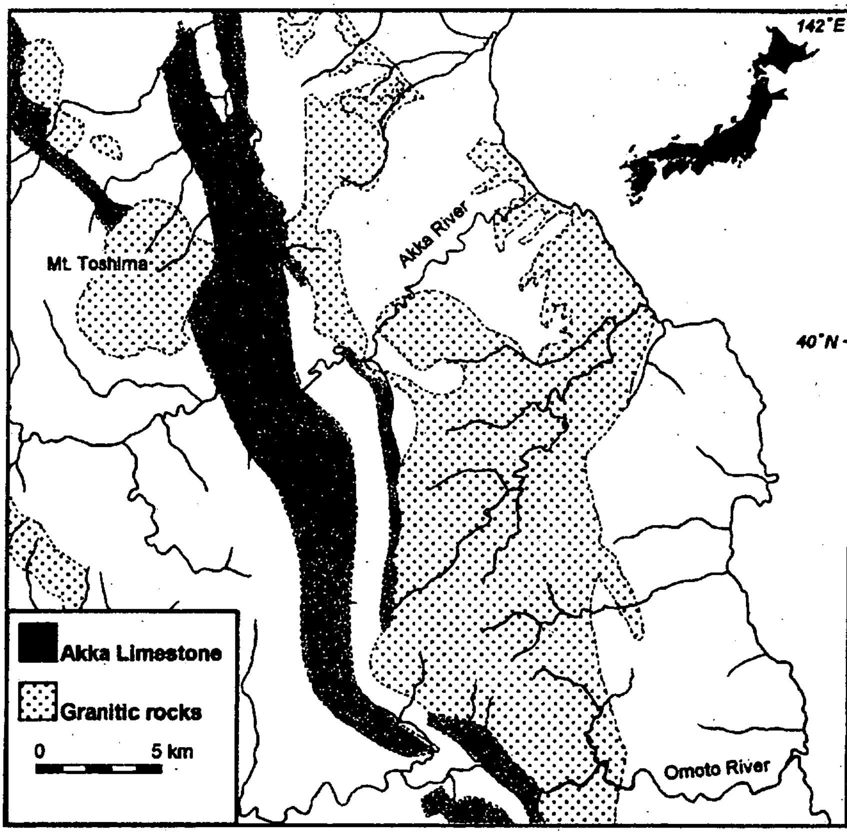


Fig. 1 Location map of the Akka Karst. Closed circle shows the location of the Hyotan-ana Cave

in the N-S direction and 1-4 km wide along the E-W direction, is a member of the Akka Formation (50-700 m in thickness) which consists of bedded limestones, alternating strata of limestone and chert, and chert in an upward sequence (*Sugimoto, 1974; Murai et al., 1985; Okami & Ehiro, 1988*). The Akka Formation is considered to have formed on sea-mounts in the late Triassic. The limestone bedrock is overlain by several late Quaternary tephras (*Okamoto, 1998*), which are not only the main soil parent materials but also good time-markers.

Soil Sample (< 2 mm, 0.5~1 g)

← 0.5% NaOH, 25 ml

Extraction

30℃ , 24 hour

Centrifuge (4,000 rpm, 15 min)

Clear Supernatant

Dilution

Clear Supernatant (0.5~1 ml)
← 0.1% NaOH, 20 ml

Measurement of the absorbance
(wavelength - 400, 450, 520, 600, 610 nm)

ΔlogK (color coefficient) = log(K400/K600)
MI (Melanic Index) = K450/K520
PI (Pg Index) = K610/K600

Fig. 2 Method of humic acid analysis proposed by *Honna & Yamamoto* (1992)

The Akka Karst is characterized by warm humid summers and cold wet winters. The mean annual precipitation and temperature are 1,131 mm and 9.9 °C. Precipitation is distributed throughout the year although there is a greater amount from July to September. Snow often falls during December to March. The present vegetation of the Kitakami Mountains including the Akka Karst is influenced by past human land use (*Osumi, 1998*). Beech (*Fagus crenata*) and deciduous oak (*Quercus mongolica* var. *grosseserrata*) forests presumably occupied most parts of the Kitakami Mountains (*Sugawara, 1987*), before human activities changed the landscape. Now, most of the Akka Karst is occupied by secondary forests dominated by deciduous oak (*Q. mongolica* var. *grosseserrata*) or birch (*Betula ermanii*), and by plantations of Japanese larch (*Larix karmpgeri*), Japanese cedar (*Cryptomeria japonica*) and Japanese red pine (*Pinus densiflora*). Pastures are distributed on the karstic plateau in the northern part of the study area.

type	values
A type	MI≦1.7, ΔlogK≦0.650
B type	1.7<MI≦2.0
P type	MI>2.0, PI≧1
Rp type	MI>2.0

ΔlogK = log(K400/K600)
MI = K450/K520
Pg = K610/K600

Table 1 Classification of humic acid type (*Honna & Yamamoto, 1992*).

Method of Soil Analysis

In Japan, melanic Andisols which have a thick black horizon at or near the soil surface are generally found near the volcanoes. Their colour are 2/2 or darker (Munsell colour value and chroma). The intense black colour is attributed to the accumulation of organic matter from which A type humic acid is *extracted (Shoji et al., 1993; Soil Survey Stuff, 1997)*. A type humic acid indicates a high degree of humification, and originates from a large amount of root residues supplied by grassland vegetation (*Sase & Hosono, 1996; Soil Survey Stuff, 1997*) or from charcoal and cinder (*Kumada, 1983*). Furthermore, melanic Andisols contain 6 % or more organic carbon *(Shoji et al., 1993; Soil Survey Stuff, 1997)*. According to humic acid analysis and phytolith (plant opal) studies (e.g., *Sase & Hosono, 1996; Sugiyama, 1999*), the vegetation changes from forest to grassland were probably the results of human-induced deforestation including the burning of forests. In other words, the occurrence of melanic Andisols implies grassland vegetation.

(1) humic acid analysis

Humic acid was extracted from about 0.5 gram of air-dried soil (< 2 mm) by suspending it in 0.5 % NaOH for 24 hours (30 °C). The method proposed *by Honna & Yamamoto* (1992) was adopted for classification of humic acid types as shown in *Figure 2.* The extract was centrifuged at 4,000 rpm for 15 minutes. About 0.5-1 ml of clear supernatant was diluted with 20 ml of 0.1 % NaOH. The absorbencies at wavelength 400, 450, 520, 600 and 610 nm were measured with spectrophotometer. *Kumada* (1965) recognised four types of humic acid, A type, B type, Rp Type and P type. To classify humic acids, ΔlogK (the colour coefficient), MI (the Melanic Index) and PI (the Pg Index) were calculated as follows:

$$\Delta \log K = \log(K400/K600)$$
$$MI = K450/K520$$
$$Pg = K610/K600$$

where K400, K450, K520, K600 and K610 are the absorbencies at 400, 450, 520, 600 and 610 nm, respectively (*Honna & Yamamoto, 1992*). Classification of humic acid types on the basis of ΔlogK, MI and Pg are shown in Table 1 (*Honna et al., 1988; Honna & Yamamoto, 1992*). A type humic acid is employed as one of the criteria for the melanic Andisols, which indicates an MI of 1.70 or less and a ΔlogK of 0.650 or less.

(2) carbon and nitrate contents

The carbon and nitrate contents in air-dried soils were measured with a CHNS/O analyzer (PE2400 Series II, Perkin Elmer). Then, the C/N ratio was calculated.

Vegetation change on the karst estimated by soil analysis

Fig. 3 shows columnar sections of melanic Andisols around the Akka Karst. Melanic Andisols occur along the rivers and on the mountain slopes. They contain Towada-Chuseri (To-Cu) and Towada-Nanbu (To-Nb) tephras. These tephras were supplied from

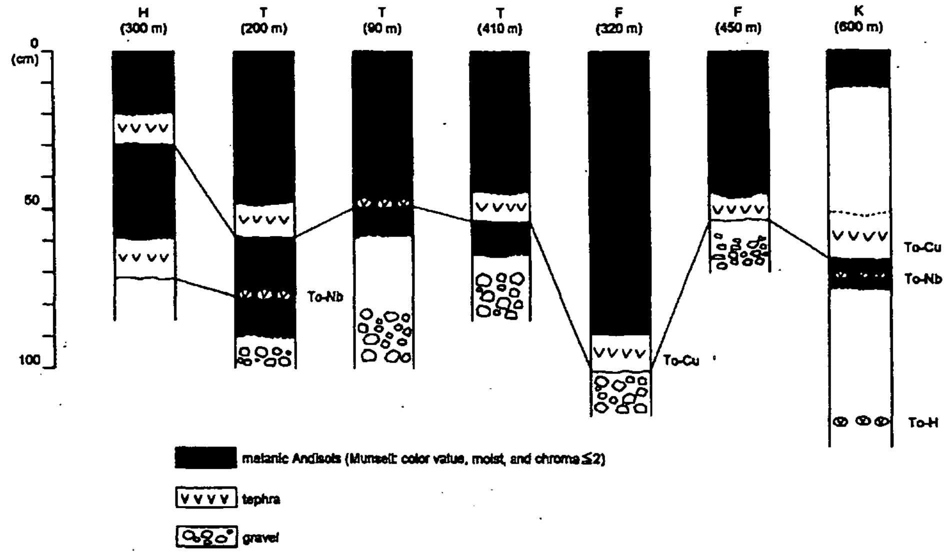


Fig. 3 Columnar sections of melanic Andisols around the Akka Karst.
H: hills, T: fluvial terrace, F: foot slope of karstic escarpment, K: karstic plateau, ( ): above sea level

the Towada Caldera about 5.5 ka BP and 8.6 ka BP, respectively (*Oike, 1972; Machida & Arai, 1992*). Moreover, a soil pit was excavated on the karstic plateau about 600 m above sea level (*Fig. 4*). The present vegetation at this site was a secondary forest dominated by deciduous oak (*Quercus mongolica* var. *grosseserrata*). Samples were taken from all horizons except the tephras in this soil profile (*Fig. 5*). The results of the soil analysis are shown in *Table 2*. The A1, A2 and 2A1 horizons had intense black colour. Carbon and nitrate contents ranged from 0.6 % to 14.9 % and 0.06 % to 1.00 %, respectively. The highest carbon and nitrate contents were found in surface horizon (A1). Distinct peaks of 7.1 % and 0.42 % occurred in the buried humus horizon (2A1), which dated from about 5-9 ka BP based on the tephras ages. The humic acids of the A1, B, 2A1 and 2A2 horizons were classified into A type, because MI was less than 1.7 and ΔlogK was less than 0.650. The MI of the A2 and B-horizons was greater than 1.7 and less than 2.0, so the humic acids in these horizons were classified into B type humic acid. The humic acid of the 2BC horizon was C type because its MI > 2 and PI = 1. These results suggest that the A1 and 2A1 horizons should be classified into melanic Andisols. Although the B and 2A2 horizon indicated non-melanic and low carbon content, their humic acids were of the A type. This would have been influenced by A type humic acid which originated from charcoal (*Kumada, 1983*), because both horizons contained many small charcoal fragments. The surface horizon (A1) had characteristics of melanic Andisols, which was probably affected by repeated forest clearing between the 17th and 19th centuries. According to *Shoji et al.*(1993) and *Sase & Hosono* (1996), grassland vegetation promotes melanic Andisols whereas forest vegetation promotes non-melanic Andisols. Forests probably occurred about 9 ka BP around the sites. Then vegetation changes from forest to grassland, which was maintained before falling of To-Cu tephra (5.5 ka BP). The forests started to regenerate around 5 ka BP and were repeatedly cleared during the 17th and 19th centuries, because *Q.*

mongolica var. *grosseserrata* became dominants in the fuel and charcoal woods in the Kitakami Mountains (*Osumi, 1998*).

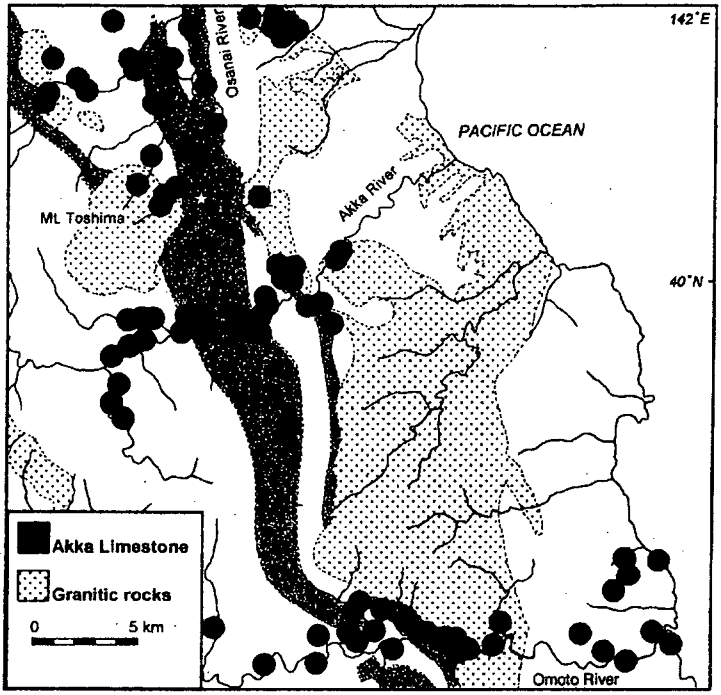


Fig. 4 Location map of archeological sites in the early-middle Holocene (Jomon Period). Complied after *Okami* (1992), The Board of Education in Iwaizumi Town (1991), The Board of Education in Yamagata ~llage (1992), and The Board of Education in Kuji City (1997). Closed circles show the location of archeological sites. Star shows the location of soil pit on the karstic plateau (Its soil profile is shown in *Fig. 5*)

Paleolithic Cave Occupation

Caves in the Akka Karst were shown to be occupied during the Paleolithic period by the archeological research of the Hyotan-ana Cave Site Research Group (1998, 1999). Several chipped stone tools as scrapers and mammalian fauna have been excavated from the entrance of the Hyotan-ana Cave. These remains were found in the sediments above a thick travertine and were covered with fallen limestone blocks. This travertine would have been deposited during a temperate phase, such as the Last Interglacial. In the north and middle parts of the Kitakami Mountains including the Akka Karst, the Last Glacial Stage was under a periglacial climate (*Higaki, 1987, 1988; Saijo et al., 1993*). There are some fossil periglacial deposits on the plateau in the Akka Karst, which were presumably formed around 50 ka BP and during 30 to 10 ka BP (*Okamoto, 1998*). Therefore, the fallen blocks would have been mainly formed by frost shattering under the periglacial climate during the Last Glacial. According to Okami (1992), the sediments above the fallen limestone blocks

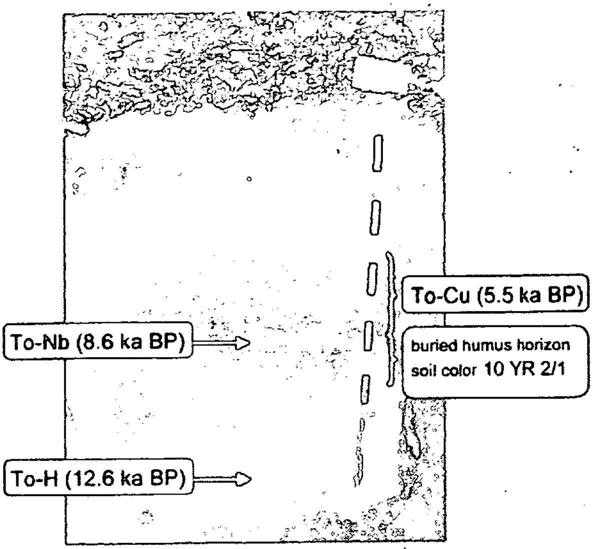


Fig. 5 Buried hums horizon in the soil profile on the karstic plateau. To-Cu, To-Nb and To-H tephras were supplied from Towada Caldera.

contain human remains since the Jomon Period (12-2.4 ka BP). Consequently, the ages of the stone tools in the Hyotan-ana Cave were estimated to data from about 12 ka BP to about 100 ka BP. As mentioned above, the first appreciable signs of human activity in the caves in the Akka Karst probably dated to the Middle Paleolithic.

Land use in the early-middle Holocene (Jomon Period)

Most of the melanic Andisols around the Akka Karst contain To-Cu (5.5 ka BP) and To-Nb (8.6 ka BP) tephras (*Fig. 3*). Thus, the formation of melanic Andisols around the Akka Karst began in the early-middle Holocene (Jomon Period), before the falling of To-Nb and To-Cu tephras. There are many archeological sites of the Jomon Period around the Akka Karst on the fluvial terraces and in the caves along rivers (*Fig. 4*). These facts suggest that there is a significant relationship between the formation of melanic Andisols and human activities in the early-middle Holocene. Moreover, a buried humus horizon that contained To-Nb tephra was found on the karstic plateau, which was covered with To-Cu tephra (*Fig. 5*). Pumice of Towada-Hachinohe tephra (To-H), which was supplied from the Towada Caldera about 12.6 ka BP (*Machida & Okumura, 1996*), was observed under this horizon. The present vegetation of this site is a secondary forest dominated by deciduous oak.

Table 2 Characteristics of soils on the karstic plateau.

horizon	Soil color (Munsell)	Soil color	C (%)	N (%)	C/N	Melanic Index (MI)	ΔlogK	Pg Index (PI)	humic acid type
A1	7.5YR2/1	black	14.9	1.00	14.98	1.69	0.640	0.947	A
A2	7.5YR2/2	brownish black	7.4	0.56	13.31	1.73	0.610	0.966	B
B	7.5YR2/3	very dark brown	4.3	0.32	13.60	1.69	0.606	0.960	A
2A1	10YR2/1	black	7.1	0.42	16.81	1.55	0.555	0.945	A
2A2	10YR2/3	brownish black	2.0	0.18	10.94	1.62	0.574	0.951	A
2B	10YR3/4	dark brown	0.8	0.08	9.38	1.79	0.617	0.981	B
2BC	10YR3/4	dark brown	0.6	0.06	9.00	2.67	1.045	1.000	P

As mentioned above, a buried humus horizon (2A1) was classified into melanic Andisols because of its soil colour, humic acid type and carbon content (*Table 2*). Melanic Andisols are formed under grassland vegetation while non-melanic Andisols are formed under forest vegetation (*Shoji et al., 1993; Sase & Hosono, 1996*). On the basis of tephra

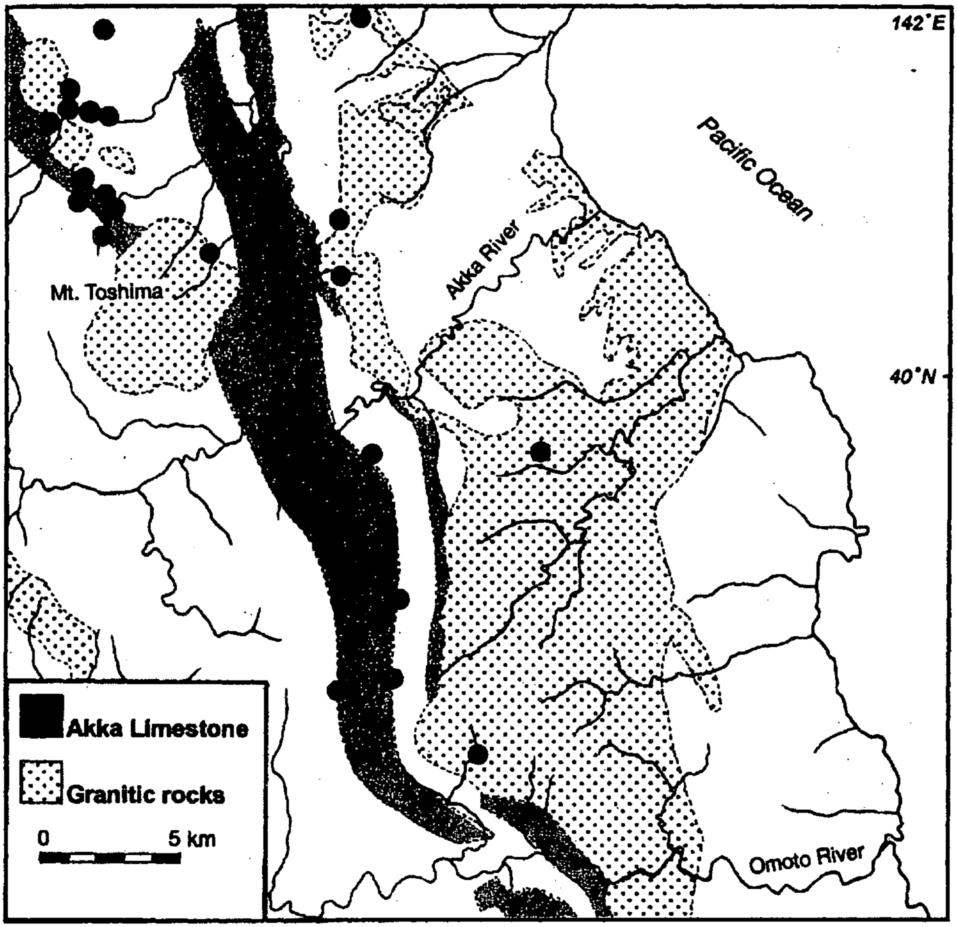


Fig. 6 Location map of the remains of iron smelting industry during the 17th-19th centuries. Closed circles show the location of archeological sites. Complied after *Takusari* (1995), *Hashiba et al.* (1996), The Board of Education in Yamagata Village (1992), and The Board of Education in Kuji City (1997).

ages, a buried humus horizon was formed during about 9-5 ka BP, and grassland vegetation was probably maintained over a period of several thousand years. This grassland appears to have been maintained by human activities such as repeatedly burning. Therefore, intense human activities probably began in the early Holocene around the Akka Karst. At that time, grassland occurred not only on the fluvial terraces but also on the part of the karstic plateau. The starting period of formation of melanic Andisols around the Akka Karst is in accord with that of a hilly area near Towada Caldera, northeastern Japan (*Sase & Hosono, 1996*), before the falling of the To-Nb tephra. The occurrence of melanic Andisols also indicates the occurrence of human activities leading to deforestation and maintenance of grassland in both areas.

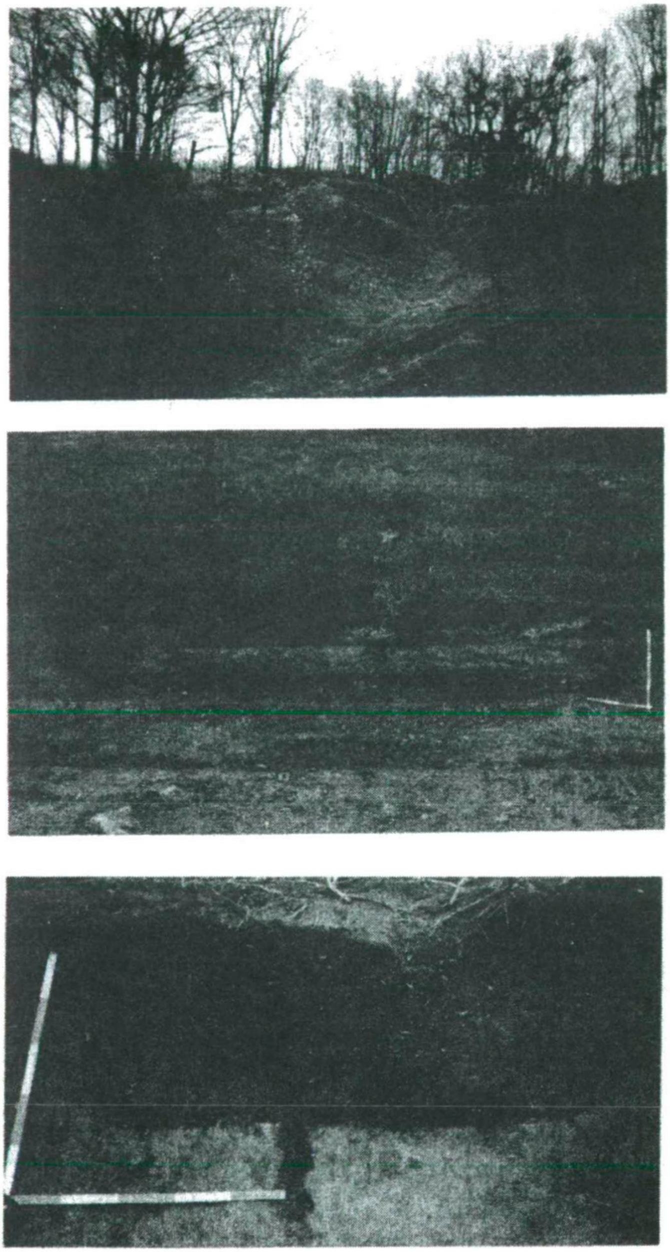
There are a few historical documents during the Medieval Age in northern Japan including the area around the Akka Karst, because the people of this area had no written language. Therefore, human activities around the Akka Karst during the Medieval Age are unclear, although several excavations have been carried out. It was not until the 17th century that that detailed accounts were made of human activities around the Akka Karst, because the number of historical documents increased starting in the 17th century and many archeological studies concerning the 17th-19th centuries have been carried out.

The iron Smelting Industry between the 17th and 19th centuries

The iron smelting industry using iron sand in the weathered granitic rock thrived around the Akka Karst between the 17th and 19th centuries *(Mori, 1983; Takusari, 1995; Hashiba et al., 1996)*. Over 20 ancient iron smelting industry sites have been found around the Akka Karst (*Fig. 6*). The remains of many traditional iron sand mines called "*kanahoppa*" have been found in the weathered granitic rock areas (*Fig. 7a*). The remains of iron smelting furnaces (*Fig. 7b*) and charcoal furnaces (*Fig. 7c*) are located around the Akka Karst. The radiocarbon age of charcoal fragments from a charcoal furnace (*Fig. 7c*), was 60±50 yrs BP (Beta-100615) and was calibrated to AD 1825-1835 and/or 1880-1915. The former period was consistent with the period of operation of the neighbouring ironworks (*Mori, 1983*). In order to obtain 1 ton of pig iron, iron production requires about 5 tons each of iron sand and charcoal. Therefore, a huge quantity of earth was excavated to collect iron sands in the weathered granitic rock area, and a large area was used as fuel-charcoal wood forests, which were repeatedly cut at intervals of 25-30 years. As mentioned above, the surface soil on the karstic plateau (*Fig. 5*) was classified as melanic Andisols due to its soil colour, carbon content and humic acid type (*Table 2*), although the present vegetation is a secondary forest dominated by *Q. mongolica* var. *grosseserrata*. This was probably the result of repeated clearings during the 17th and 19th centuries, because *Q. mongolica* var. *grosseserrata* has become the dominant species in the fuel-charcoal woods forests (*Osumi, 1998*). Limestone was used in the iron furnaces for flux (i.e., to prevent formation of iron oxides). Because the forest surrounding the ironworks was entirely cut for fuel and charcoal production over periods of 10-15 years, the ironworks had to transfer to other places (*Hashiba et al., 1996*). As the iron smelting industry expanded, the demand for fuel and charcoal wood increased. Thus, large destruction of forests began in the 17th century and continued to the late 19th century.

The land transformation caused by the mining of iron sand and the destruction of forests caused many problems. The waste earth from the mines was mainly thrown into the rivers. The destruction of the forests probably accelerated soil erosion on the steep slopes, especially on karst. The waste earth from the mines and the erosion on the steep slopes caused a rise of riverbed downstream of the mines. The loss of vegetation resulted in floods during heavy rains. Moreover, the disposal of solid and liquid wastes from the ironworks caused serious water pollution problems (*Mori, 1983*).

The traditional iron sand mining and iron smelting industry gradually declined starting in the middle 19th century. Coal and oil replaced charcoal as fuel in the late 19th century. These major changes contributed to natural reforestation. Large areas in the Akka Karst became secondary forests dominated by deciduous oak or birch (*Betula ermanii*).



(a)

(b)

(c)

Fig. 7 The remains of iron smelting industry around the Akka Karst between the 17[th] and 19[th] Centuries showing the remains of traditional iron sand mines (*kanahoppa*) in the weathered granite rock areas (a), iron smelting furnaces (b), and charcoal furnaces (c).

Conclusion

The Akka karst has been greatly affected by human activities since the early Holocene. There was a significant relationship between the distribution of archeological sites and vegetation changes based on soil analyses. In the early-middle Holocene, human-induced deforestation and maintenance of grasslands caused the formation of melanic Andisols. During the 17th-19th centuries an iron smelting industry thrived around the Akka Karst, the forests on the karst were used as fuel and charcoal wood and repeatedly cleared. These human activities caused many problems, such as soil erosion on the steep slopes, water pollution and floods during heavy rains. Following the decline of the iron smelting industry, most of the karst became secondary forests.

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