Paleoenvironmental Changes during the Past 110,000 Years in the Nakaikemi Basin and the Kuroi Basin, Central Japan

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Abstract

Both of the Nakaikemi basin in Fukui prefecture and the Kuroi basin in Hyogo prefecture in central Japan revealed the high resolution paleo-monsoon climatic change from analysing of eolian dust deposition during the past 110,000 years. In the last Interglacial period of stage, 5 fluvial materials were dominated. Last glacial periods of stages 2, 3 and 4, eolian dust of two areas were transported from the North Asian continent by the NW winter monsoon judging from higher ESR signal intensity. Especially, spikes that were transported from north Asian continent by the NW winter monsoon. Correlated to the cool Younger Dryas and Heinrich events H1 – H6 eolian dust deposition increased. However, eolian dust deposition was decreased and fluvial materials increased during Interglacial/Interstadial climate events, such as Dansgaard- Oescheger IS 1 – 24 climate intervals. Lower ESR signal intensity showed eolian dust was transported from Chinese mid-latitude arid zone by summer westerlies. The Holocene period, of stage 1, ESR signal intensity were very lower. On the contrary, the median diameter of local fluvial inorganic material increased in the warmer period.

Key words: Eolian dust, Nakaikemi basin, Kuroi basin, Heinrich events, paleo-monsoon.

1. Introduction :

The Japanese Islands are located in the mid-latitude westerly zone from the Chinese loess lands and on the NW monsoon zone from the north Asian PreCambrian areas and at about 24°N to 45°N and 122.5°E to 146°E in the East Asia. Studies of eolian dust in this country have been starting from the 1980s. Quaternary studies including eolian dust closely connected to the PAGES(Past Global Changes Project) in IGBP(International Geoshere-Bioshere Project) started in Japan in 1992.

In the 1980s, Naruse and Inoue(1982) and Uematsu *et al.*(1983) elucidated that eolian dust has been transporting in this country from some Asian localities since the late Pleistocene. Uematsu *et al.*(1985) pointed out atmospheric dust have been deposited over the western north and central Pacific Ocean. Furthermore, the Japanese soils have been affected considerably by deposition of the eolian dust blown up from China between the last glacial age and the Holocene(Inoue,1981; Naruse and Inoue,1982, 1983). Studies of eolian dust and loess transported from the Asian continent began at several localities in East Asia(Inoue and Naruse,1987).

In 1990s, Inoue and Naruse(1991) made clear eolian dust origin and derived courses by tracing back the trajectory of dust clouds by using satellite image. Eolian dust was found out in the paleosol horizons with in the Pleistocene tephra stratums, in the deep sea sediment and in lake sediments(Inoue and Naruse,1991; Tada and Irono,1994; Fukusawa and Koizumi,1994; Xiao *et al.*,1992). Eolian dust transported a long distance from Asian continent deposits on the sea floor and in the paleosols extensively in the East Asia since the last Interglacial periods(Naruse,1993). Electron Spin Resonance(ESR) spectra of quartz grain are measured in the East Asia, the ESR values are place to place different(Naruse *et al.*,1996, 1997 and Ono *et al.*,1998) marked the eolian dust from the Asian continent to the Japanese Islands on the depending on the ESR(electron spin resonance) signal intensity of eolian dust quartz.

At the begging of 1990s, the major oscillation of eolian dust deposition of Vostok-core in the Antarctica made it appear a certain relationship between eolian dust fall and high resolutional climatic change for the first time(Petit *et al.*,1990). In 1993, GISP2 and GRIP from the Greenland ice cap revealed the high resolutional climatic records since the last Interglacial period(Dansgaard *et al.*,1993; Grootes *et al.*,1993). Sequences of the cyclic climatic episode record during the last glacial period were reconstructed apparently from the two ice core sites on Greenland. In the North Atlantic region, pelagic sediment cores also showed high resolutional climatic changes since the last Interglacial period(Bond *et al.*,1992, 1993). Recently, Petit *et al.*(1999) pointed out that the accumulation of eolian dust in the Vostok ice core is a proxy for high resolution climatic changes over the past 420,000 years.

The Tibetan plateau is the basic central place where provokes the East Asian Monsoon. Heating of the Tibetan plateau in summer induces a development of the Tibetan high pressure. Fang *et al.*(1999) hypothesized that a change of subtropical jet stream in summer is controlled by the intensity of Tibetan high pressure. The North Atlantic region gives us an actual knowledge to understand the relationship between the East Asian monsoon change and global climate change during the last interglacial age(Overpeck *et al.*,1996a; Sirocko *et al.*,1996). Xiao *et al.*(1995, 1997) recognized a change of granulometry of eolian dust quartz in the sediments of lake Biwa, central Japan. They pointed out the relationship eolian dust granulometry and the fluctuation of winter monsoon. Fukusawa(1998) gave a clear conception of the relationship between eolian quartz flux in the lake Togo, southern Japan and Asian monsoon intensity. Strengthening of westerlies and winter monsoon during the stages 2 and 4, transported eolian dust from the source area to the Japanese Islands(Ono and Naruse,1997; Xiao *et al.*,1992). East Asian Monsoon changes have relation to the environmental changes in the North Atlantic region during the Quaternary(Ono,1999).

At the Begging of 2000s, Chowdhury *et al.*(2001) pointed out that eolian dust of the Tanigumi moor in the central Japan, derived from some localities of the Asian continent has been deposited according to the monsoonal climatic changes since the last glacial period. East Asian monsoon and Indian monsoon are also closely interrelated with each other during the late Quaternary(Jian *et al.*,2001). Indian summer monsoon have been dominated in the Northern Hemisphere during the starting of Interglacial (Kudrass *et al.*,2001). Loess and paleosols were controlled by the monsoon climate since the last glacial-Interglacial cycle(Chen *et al.*,2000; An *et al.*,2000).

1.1 Purpose/Objective of the present study :

The main objective of the study is to identify the eolian dust deposition and paleomonsoon climatic changes since the last Interglacial periods central Japan. Some specific objectives of this experimental study are:

1. to understand the relation between processes deposition of eolian dust and the monsoonal climatic changing in the central Japan in relation with the climatic changes of Greenland.
2. to examine the role of monsoon climate and wind in the changing of depositional rate in the central Japan.
3. to find out the various Geomorphological eolian dust source areas, viewed from ESR signal intensity from where come to the central Japan.
4. to compare, the trigger of the changing of the climate on the East Asia, with the other areas of the World.
5. to estimate, viewed from eolian dust deposition of the Nakaikemi basin, and the Kuroi basin the derived courses of eolian dust from Asian continent from MIS 3 to MIS 2 by ESR signal intensity.
6. to located of polar front from the last Interglacial period to Holocene period in central Japan.

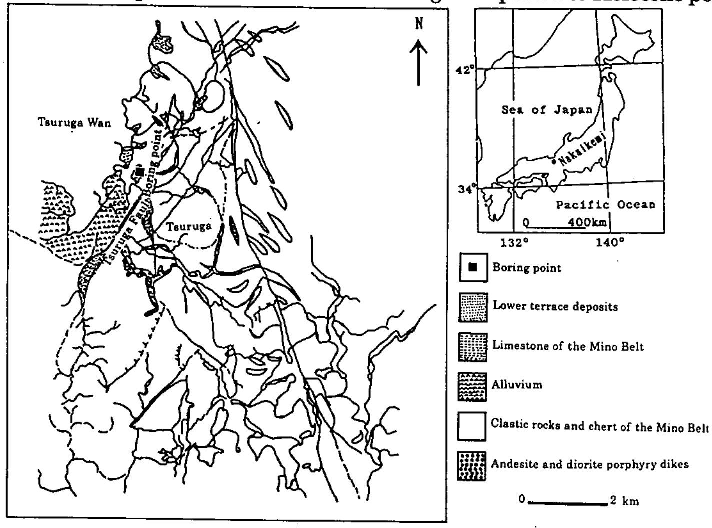


Fig. 1 Map of Nakaikemi showing the location of boring point and geology
Source : Sugiyama, Y., Awata, Y., Yoshioka, T. (1994) Strip map of Yanagase-Yôro fault (1/100,000) Geological survey of Japan.

Table 1.1 Volcanic ash in the Nakaikemi basin

Depth(m)	Tephra	Total mineral assembly	Glass diffraction ND	Heavy mineral assembly
-4.50	K-Ah	volcanic glass, plagio glass	1.511 – 1.515	Opq. Opx(trace)
-17.06	AT	volcanic glass, plagio glass	1.498 – 1.501	Opx. GHo. Opq(trace)
-27.50	DKP	hornblende, pyroxene plagio glass, quartz	1.505 – 1.507	GHo. Opq. Opx>Bi
-34.50	Aso-4	volcanic glass, pyroxene hornblende	1.507 – 1.511	Opx. Opq. GHo. BHo
-35.52	K-Tz	volcanic glass, plagio glass quartz, hornblende	1.498 – 1.500	Opx. Opq(trace)
-37.83	Ata	volcanic glass, plagio glass pyroxene	1.510 – 1.512	Opx. Opq. Ap. Cpx. GHo

GHo: green hornblende, BHo: brown hornblende, Opx: orthopyroxene, Cpx: clinopyroxene, Opq: opaque minerals, Ap: apatite, Bi: biotite.

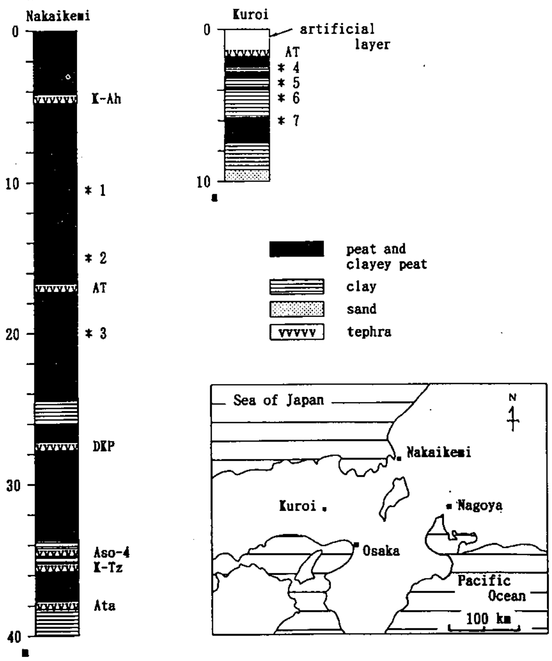
2. Geology, Core lithology and the depositional rate

2.1 Geology of the Nakaikemi basin

The Nakaikemi basin is located at Tsuruga, Nakaikemi village in Fukui Prefecture at 35°39′ N, 13°67′ E (Fig.1). The moor is surrounded by low relief hills from 163 to 171 meters above sea level, which are composed of lower terrace deposits, limestone of the Mino Belt, alluvium, Pre-Cretaceous, clastic rocks and chert of the Mino Belt, andesite and diorite porphyry dikes. The moor is 40 to 47 meters high above sea level and about 2 km long in N-S direction and the width is about 2 km in E-W direction, like square size. The basin was reclaimed as paddy fields in the Showa Era. The mean temperature of Nakaikemi is 15.4°C, and an average annual precipitation is 2600 mm. (Japanese data book of Rika Nenpyo, Chronological Scientific Tables, National Astronomical Observatory(ed.), Maruzen Co., Ltd. 2000 – 2001).

2.2 Core lithology and the depositional rate of the Nakaikemi

I collected a drilling core of 40 meters long deposited near the center of the Nakaikemi moor(Fig.1). The deposit consists of peat and tephra. ^{14}C dating AMS method of a peat plant fragment at a depth of (1.00 – 1.10) meters was 1969±60 yBP, (NZA 10147, NZA 10148). Wood fragment at a depth of (4.30 – 4.40) meters was 6063±58 yBP, (NZA 10149). Leaf fragment at a depth of (10.00 – 10.10) meters was 14008±80 yBP, (NZA 10151). Plant fragment at a depth of (14.90 – 15.00) meters was 22340±200 yBP, (NZA 10152). And Peat fragment at a depth of (20.05 – 20.10) meters was 33400±790 yBP, (NZA 10177) Table.1.1. I recognized six volcanic tephras, name K-Ah, AT, DKP, Aso-4, K-Tz and Ata in the core.



*1 14,008± 80 yBP. (NZA-10151) *2 22,340± 200 yBP. (NZA-10152)
*3 33,400± 790 yBP. (NZA-10177) *4 32,180± 690 yBP. (GrA-10448)
*5 35,940±1040 yBP. (GrA-10489) *6 44,000±2600 yBP. (GrA-10490)
*7 45,100-51,000 yBP. (GrA-10491)

Fig. 2 Location and geological sections of the Nakaikemi basin and the Kuroi basin

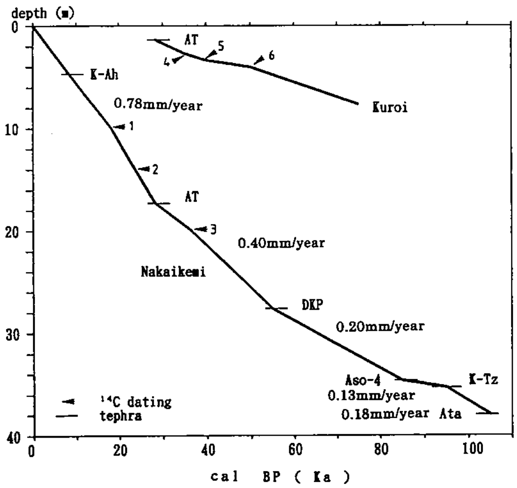


Fig. 3 Depositional rate in the Nakaikemi basin and the Kuroi basin

Top layer from 0 to 40 meters consist of peat (Fig.2). The later from 4.6 meters deep to the bottom consists of peat and tephra deposits. Six tephras were identified in this core as shown in Table 1.1. The K-Ah tephra with age of 8 ka (Machida and Arai,1992) is at 4.6 meters deep. The AT tephra with age of 24 ka (Machida and Arai,1992) was at 17.1 meters deep. The DKP tephra with age of 50 ka(Yoshikawa,1996) was at 27.6 meters deep. The Aso-4 tephra with age of 85 ka(Oba,1991) was at 34.6 meters deep. The K-Tz tephra with age of 93 ka(Machida and Arai,1992) was at 35.6 meters deep. And the Ata tephra with age of 105 ka(Oba,1991; Machida and Arai,1992) was at 37.8 meters deep.

From the above tephra chronology and assumption of constant accumulation of the peat, the boundary between the Holocene and the Pleistocene was estimated to be at 4.6 meters deep. Based on the ages of six tephra layers and the ^{14}C age, the average deposition rate of peat between 8 ka (K-Ah) and 24 ka (AT) is calculated to be 0.78mm/year (Fig.3). The deposition rate between 24 ka (AT) and 50 ka (DKP) is calculated to be 0.40 mm/year. The average deposition rate before 50 ka (DKP) back to 85 ka (Aso-4) is calculated to be 0.20 mm/year. The deposition rate before 85 ka (Aso-4) back to 93 ka (K-Tz) is calculated to be 0.13 mm/year. And the deposition rate before 93 ka (K-Tz) back to 105 ka (Ata) is calculated to be 0.18 mm/year.

3. Method and Meterials

3.1 Step of Experimental Process

Step – 1:

Samples from the Nakaikemi basin were selected up to 40 m long and Kuroi basin up to 10 m long.

Step – 2:

In the laboratory at Hyogo University of Teacher Education, sediment cores were split, usually described and subsampled at interuals ranging from 12 to 20 cm for the Nakaikemi basin. Sediment core was collected from the Nakaikemi basin (N=357 samples).

Step – 3:

Every sample treated by H_2O_2 (Ca.20wt%).

Step – 4:

Every sample wash by HCl (2N).

Step – 5:

To remove plant opal and diatom, I drew 27 samples at random from total Nakaikemi samples, was used by Na_2CO_3 (2M)

Step – 6:

Grain size analysis of all samples was measured by Shimadzu SALD – 2000, from the research Laboratory of Eolian dust, Department of Geography at Hyogo University of Teacher Education.

Step – 7:

For the X – ray diffractometer analysis, 25 samples from the Nakaikemi basin was selected, and measured by Shimadzu XD – type 5, from the research Laboratory of Earth Science, at Hyogo University of Teacher Education.

Step – 8:

ESR (Electron Spin Resonance) analysis of quartz (SiO_2), was measured at the Department of Applied Physics, Okayama University of Science.

Step – 9:

For the AMS ^{14}C measurement, the 6 samples from the Nakaikemi basin was selected. ^{14}C measurement was done at the Geo – Science Laboratory in Nagoya.

Step – 10:

Tephra identification in the Nakaikemi core was measurement at the Kyoto Fission – Track Co., Ltd.

3.2 Analytical method and procedure

The Nakaikemi core used in this study was analyzed every 20 cm^3 and 12 cm^3 between 0 m to 5 m and 5 m to 40 m deep. Three hundred fifty seven samples in total were examined. These leads to time resolution of 55 to 110 years in average. Each sample was treated with 20% H_2O_2 for two weeks under the room temperature to resolve organic matter. Then we treated them with 2M Na_2CO_3 to resolve diatom and plant opal. After drying, inorganic materials were measured. Grain size distribution from 0.5 to 12(Ø) phi scale was analyzed by the laser diffraction grain size analyzer of Shimadu SALD-2000J. <20μm fractions were collected using by repeated dispersion and sedimentation at pH 10. We measured the ESR intensity signal of the Eí center (an electron at an oxygen vacancy) of fine quatrz with diameters of <20μm. Air dried samples were pretreated by 6M HCl at 100°C for 15 minutes to remove calcite and dolomite. To determine the quartz contents in the prepared sample, we used an X-ray diffraction by the extrapolation method (30kV, 20mA, Cu, step scan 28-25 2θ, preset time 4.0s, scan speed 0.01/s., sampling pitch 0.01, full scale 0.5 kcps) Naruse *et al.,*1997).

The method used to evaluate the ESR intensity signal of the Eí center (an electron at an oxygen vacancy) of fine quartz with diameters of <20μm follows that of Toyoda *et al.*(1992, 1996). Samples were irradiated by γ–rays from a ^{60}CO source to 2.5 kGy and heated at 300°C for 15 minutes to convert oxygen vacancies to Eí center. The samples were measured by an ESR spectrometer (JEOL, RE-IX) at room temperature under the following conditions: microwave power, 0.01mW; magnetic field modulation, 0.1 mT, Scan range 5 mT, scan time 4 or 8 min, time constant 0.03 or 0.3 sec. Depending on the signal intensity. The peak to peak ESR signals intensities at δ=2.001 were measured. The intensity of ESR is expressed by a unit: 1.3×10^{15} spin/g in the following (Naruse *et al.,*1997).

4. Results:

4.1 Content of inorganic material and ESR intensity of fine quartz of the Nakaikemi and the Kuroi basin

The inorganic material of the Nakaikemi and Kuroi cores in MIS 5 of the last Interglacial periods consists of local and fluvial material including volcanic tephras Aso-4 at 85 ka, K-Tz at 93 ka and Ata at 105 ka as shown in (Fig.2). During marine isotope stage 5 between 74 ka and 110 ka, the content of total inorganic material increased ranging from 0.3 to 1.8 g/cm^3. The ESR intensity of fine quartz (<20μm) is 5.8 as shown in Table 1.2. Several spikes between 74 ka and

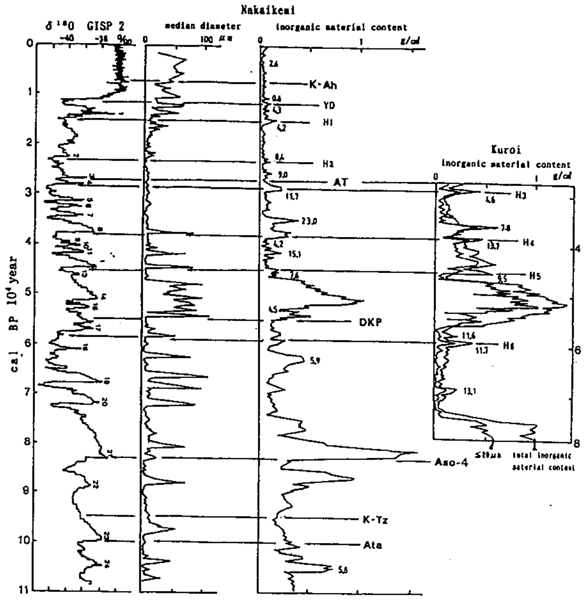


Fig. 4 Inorganic material content and mean diameter in the Nakaikemi basin and the Kuroi basin during the past 110,000 years

Table 1.2 ESR signal intensity of quartz of the drilling cores in the Nakaikemi basin and the Kuroi basin

Nakaikemi basin			Kuroi basin	
Depth(m)	ESR signal intensity		Depth(m)	ESR signal intensity
	<20μm	>20μm		<20μm
MIS 1				
4.30	2.6 (1)	0.2		
5.50	0.6			
MIS 2				
6.40	4.3 (2)	2.4		
9.60	4.2			
13.0	8.4 (3)			
MIS 3				
16.80	9.0		2.00	4.6 (8)
17.80	11.7 (4)		2.60	7.8
19.00	23.0 (5)		3.20	13.7 (9)
22.30	15.1 (6)		3.45	9.5
24.30	7.6		5.00	11.6 (10)
28.50	4.5 (7)			
MIS 4				
31.20	5.9		5.70	11.7 (11)
			6.25	13.1
MIS 5				
38.60	5.8			

(1.3×10^{15}spin/g)

(1 – 11): indicates in Fig.

ESR signal intensity of quartz (Naruse *et al.*, 1996)

Quaternary : <0.7 Tertiary : 2.0 – 2.8 Mesozoic and Paleozoic : 3.3 – 4.7 Chinese Loess Plateau loess : 5.8 – 8.7 PreCambrian : >11.0

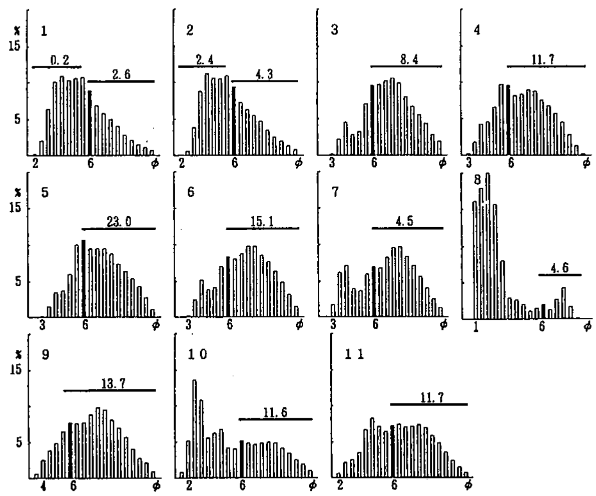


Fig. 5 Grain size distribution and ESR signal intensity of the drilling cores in the Nakaikemi basin and the Kuroi basin
A black bar shows 6 ø (<20μm)

110 ka, are correlated with the Interstadials 21 to 24. Median diameters change according to the fluctuation of inorganic material content. It seems that increasing in grain size reflected the fluvial activity induced by strong summer monsoon correlated with the Interstadial climatic events.

In the last glacial period, the inorganic material content decreases except that of some spikes. In marine isotope stages 2, 3 and 4 between 74 ka and 10 ka, the content of total inorganic materials are ranging from 0.2 to 1.05 g/cm^3 (Fig.4). In the stages 2 and 3 the ESR intensities of fine quartz (<20μm) are 4.2 to 23.0 in Table 1.2. However, ESR value of a spike of the Nakaikemi in the stage 4 is 5.9. It is same value of ESR in Interglacial period of warmer phases and was a fluvial material. But in the Kurio basin ESR value of a spike in the stage 4 correlated with the Heinrich event 6 of colder phases was 11.7. ESR value of another spike of 6.25 m deep correlated with the colder (stadial) phases was 13.1. Inorganic materials of two spikes are eolian dust transported from the PreCambrian rock areas. In the stage 3, a large spike between 47 ka and 55 ka, contents of inorganic material more than 1 g/cm^3 in Nakaikemi and the Kuroi basin. Two spikes increase gradually from 55 ka and reaches a peak at 50 ka, after the spike decrease abruptly at 47 ka. As Md value increase from 55 ka to 47 ka and ESR values are 4.5, two spikes consist of fluvial material.

Another many spikes in the stage 3 are recognized at 58 ka, 46 ka, 38 ka, 35 ka and 28 ka. These spikes are correlated with H6, H5, H4, H3 and other colder period respectively. The ESR values in Nakaikemi and the Kuroi basin are ranging from 4.6 to 23.0. In the stage 2, deposition of inorganic material decreased, Md values increase just after spikes. Spikes of inspite of inorganic material content was low, Heinrich events 1, 2 and YD are recognized. The ESR intensities of two spikes are 8.4 and 9.0 originated in the both of PreCambrian rock areas and Chinese mid-latitude areas. From 16 ka in the MIS 2, Md value was gradually increasing upto Holocene. It may be considered that climate changes to the warmer condition and fluvial material increased by the increasing of summer monsoon and changes the depositional amount.

In the Holocene period, deposition amount of inorganic materials decreases from 0.01 to 0.2 g/cm^3 (Fig.4). The ESR intensities of fine quartz (<20μm) are 0.6 – 2.6.

4.2 Grain size distribution and ESR intensity of the Nakaikemi and the Kuroi basin

In the Nakaikemi and Kuroi basin, Histogram of the grain size distribution are classified into uni-modal and bi-modal types as shown in Fig.5. Sample Nos. 1, 2, 3, 4, 5, 6 and 9 are uni-modal type. Sample Nos. 7, 8, 10 and 11 are bi-modal type. Uni-modal types of Nos. 1 and 2, the ESR values of <20 μm are 0.2 and 2.4 which are local origin. The ESR values of <20 μm are 2.6 and 4.3, which orginated (mesozoic) in surrounding areas. The ESR values (<20 μm) of sample No.3 are 8.4 and 9.0. These material are a long-range transported eolian dust from both of the Chinese mid-latitude and the PreCambrian rock areas. The ESR intensities (<20 μm) of sample Nos. 4, 5, 6 and 9 are 11.7, 23.0, 15.1 and 13.7. These materials are originated in the PreCambrian rock areas, grain size fraction of >20 μm are local fluvial origin.

Sample No. 7 in the Nakaikemi basin and sample No. 8 in the Kuroi basin are bi-modal. Two modes are recognized in histograms of two samples. <20 μm fraction is a local fluvial material. On the other hand, <20 μm fraction, is local fluvial material deposited in the warmer period, judging from ESR values of 4.5. Histograms of sample Nos. 10 and 11 in the Kuroi basin, have two modes. One mode (<20 μm) is local fluvial origin, and the other mode (<20 μm) is the eolian dust. The ESR values of these two sample are higher ranging from 11.6 to 11.7 transported from PreCambrian rock areas.

5. Discussion

5.1 Discussion of the Nakaikemi basin and the Kuroi basin

Oscillations of eolian dust in both of the Nakaikemi and the Kuroi basin would be due to changing strength in winter monsoon which controls the transportation of eolian dust. Low concentration of fine materials may be caused by climatic warming of correlated with the Interglacial periods. The cyclic oscillations may be also associated with the isotopic episode recognized from summit ice core by GRIP(Bond *et al.,* 1993). In the last Interglacial periods from 74 ka to 110 ka of marine isotope stage 5, Md values were fluctuated largely. Deposition of inorganic material and Md values increased, and the ESR intensity of fine quartz is 5.8. These evidences indicate that deposition of local fluvial material dominated in the basins by increasing summer rain in warming MIS 5.

In the last Interglacial periods, peaks of Md value and inorganic material content in Nakaikemi and Kuroi basin were correlated with the Interstadial events from 21 to 24. Higher Md value layers are correlated with the warmer periods in relation to the Interstadial periods, such as Dansgaard-Oescheger cycle from 1 to 24 climate intervals, respectively seen in the Greenland temperature record(Bond *et al.,*1993; Bond and Lotti,1995; Dansgaard *et al.,*1993; Taylor *et al.,*1993, 1997; Mayewski *et al.,*1997).

The fine materials of <20 μm from 74 ka to 10 ka in the last glacial period cores are identified to be eolian dust derived from PreCambrian rock areas in the North Asian continent transported by North Western winter monsoon as indicated by the high ESR signal intensities(Naruse *et al.,*1997). Some of eolian dust has been transported from Chinese mid-latitude areas by subtropical jet in summer. In stage 4, some spikes while higher Md values in the Nakaikemi and the Kuroi basin were correlated with the warmer Interstadial periods. In the Nakaikemi basin, the ESR value is 5.9 indicates a fluvial material increased by the summer rain. But in the Kuroi basin higher ESR intensity values of 11.7 and 13.1 indicates eolian dust came from PreCambrian rock areas by the North western winter monsoon. The ESR intensity signal rates seems to reflect a paleoenvironmental change of the source area of eolian dust(Naruse and Ono, 1997).

Large spikes of Nakaikemi and Kuroi basin in MIS 3 coincide with d18O of GISP2 from 47 ka to 55 ka. In the warmer Interstadial period, Md values were higher and fluvial materials increased from 0.2 to 1.05 g/cm^3 by summer rain. In MIS 3, from 58 ka to 25 ka, of the Nakaikemi and the Kuroi basin, ESR intensities were some of higher and some of lower. The higher ESR intensities indicate eolian dust transported from the PreCambrian rock areas by the North Western winter monsoon. On the contrary, the lower ESR values and increasing of inorganic material content indicate the fluvial material by the many summer rain. Strengthened East Asian winter monsoon are indicated by eolian quartz flux value. Weak winter monsoon in East Asia indicates decreasing of eolian quartz flux value (Xiao *et al.*,1997). In marine isotope stage 3, Md value of a spike of 38 ka was abruptly increased. It seems that climate changed in cool and deposition of eolian dust increased. Heinrich events 4 is correlated with the colder phases and Heinrich events 3,5 also correlated with the colder phases(Bond *et al.*,1993).

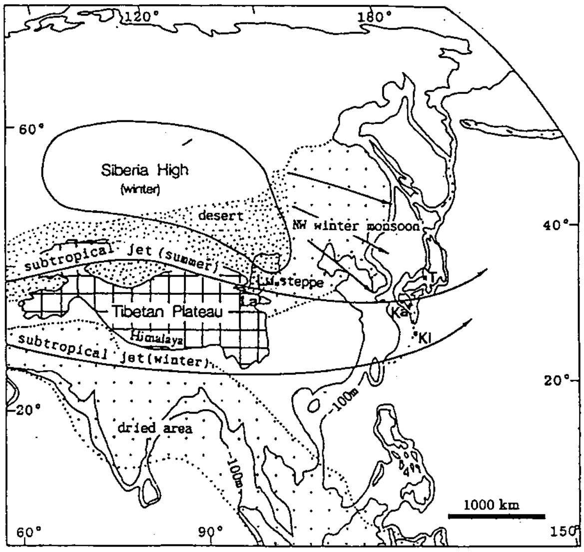


Fig. 6 Paleoenvironments of Asia during MIS 2 (Naruse, 1998).

The difference from isotope stage 2 to stage 3 regarding the dust source, seems to have been induced by an environmental change. In marine isotope stage 2 of the Nakaikemi basin, the ESR intensities are 8.4 and 9.0. It shows that eolian dust was contaminated by fluvial material. These eolian dusts were transported from PreCambrian rock areas by the North western winter monsoon and Chinese mid-latitude areas by the subtropical jet in summer. It suggest that Nakaikemi and Kuroi basin was located at the near of south polar front, and eolian dust was transported from the PreCambrian rock areas in the MIS 2. During MIS 2, a southward shift of the subtropical jet in summer was suggested by a decrease of summer precipitation(Ono, 1986). But when the polar front shift in the north, then subtropical jet in summer shifted to the North and eolian dust came from Chinese mid-latitude areas in Fig.6. The ESR intensities of two spikes are 4.3 and 4.2, these eolian dust come from Chinese mid-latitude areas by the subtropical jet in summer. The ESR intensities are lower because when the polar front was shifted to the north, then climate changed in the warmer, stage 2 from 16 ka Md value is gradually increasing upto Holocene and changes the depositional amount.

In the Holocene periods, of stage 1, the ESR intensities of fine quartz are 0.6 and 2.6. Both of large Md values and lower ESR intensities show that fine materials consist of a local fluvial material.

6. Conclusion:

(1) The Nakaikemi and the Kuroi basins were 40 meters and 10 meters long analyzed by every 55 to 110 years/12 to 20 cm and 3 to 4 cm, from the last Interglacial period to the Holocene period, stages 1, 2, 3, 4 and 5 from 110 ka to 0 ka and 80 ka to 25 ka.

(2) The inorganic material of the Nakaikemi and Kuroi cores in MIS 5 of the last Interglacial period consists of local and fluvial material. During marine isotope stage 5 between 110 ka and 74 ka, the content of total inorganic material increased ranging from 0.3 to 1.8 g/cm³. In the last glacial period, the inorganic material content decreases except that of some spike. In marine isotope stages 2, 3 and 4 between 74 ka and 10 ka, the content of total inorganic materials are ranging from 0.2 to 1.05 g/cm³. In the Holocene period, stage 1 deposition amount of inorganic materials decreases from 0.01 to 0.2 g/cm³.

(3) In the median diameter (Md) in (Ø) phi scale in the Nakaikemi and the Kuroi basin, I found in the last glacial period, stages 2, 3 and 4. MIS 2 a sample show in the Nakaikemi basin symmetric curves, is 8.00 to 6.00 (Ø) phi scale. Stages 3 and 4 many of samples are between 8.50 to 6.25 (Ø) phi scale. From 74 ka to 10 ka, the Md values fluctuate considerably. Rest of samples are show asymmetric curves toward the coarse fluvial material.

(4) In the Nakaikemi basin, eolian dust of the marine isotope stage 2, had been transported from both of North Asian continent by NW winter monsoon and Chinese mid-latitude areas by summer westerlies. In the Nakaikemi basin and the Kuroi basin, eolian dust of the marine isotope stage 3, was transported from North Asian continent by NW winter monsoon in Fig.7.

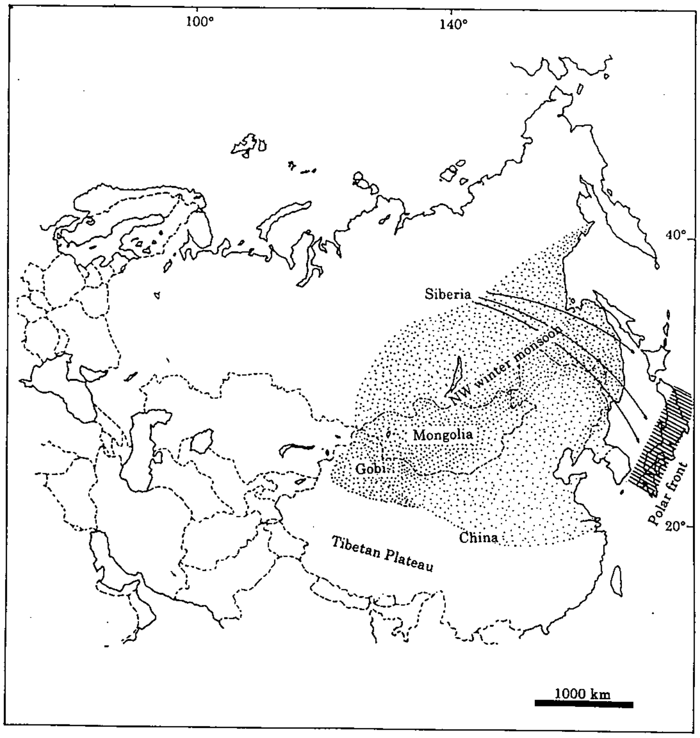


Fig. 7 Inferred source areas and derived high-latitude courses of eolian dust in winter during MIS 3

(5) The Nakaikemi and the Kuroi basin from the last Interglacial to Holocene period, monsoonal climatic change viewed from eolian dust, stage to stage. MIS 5, in the warmer period fluvial material has increased correlation with the IS-24, IS-23, IS-22, IS-21. In the last glacial period isotope stage 3, from 55 ka to 47 ka in the warmer (Interstadials) period fluvial material has increased. After 16 ka (Md) value indicated abruptly climatic changes upto Holocene. But in the marine isotope stage 2, 3 and 4, eolian dust deposition were correlated with the polar front and polar front indicated monsoonal climatic changes in the Japanese Islands. Because polar front was correlated with the Siberian high/low pressure. When polar front was shifted in the north then eolian dust transported from Chinese mid-latitude areas by the summer westerlies. Some time Siberian high pressure was developed, then NW winter monsoon was strong and polar front was shifted in the south, eolian dust transported from North Asian continent.

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