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著者	Iwai Junichi
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Junichi Iwai

Institute of Geology and Paleontology, Tohoku University, Sendai, Japan

INTRODUCTION

It has been reported by many authors that the Pleistocene deposits comprising gravels and sands are distributed in the environs of Taira City, Fukushima Prefecture. They are largely the terrace deposits as observed in the northern hill of the city[13,48] except for the Sodetamayama formation. The Sodetamayama distributed in the northwestern area of Yotsukura-machi, mainly comprises sands and is unconformably overlain by the terrace gravels.[45] No fossil has been found in these deposits.

Lately the writer found Pleistocene deposits bearing fossil plants in the eastern part of Taira City (Fig. 1). Although its distribution is confined within a narrow area and has only a few plant remains, the stratigraphical and paleontological evidences seem to be worthy of note.

The writer expresses his sincere thanks to Professor Shōshirō Hanzawa of the Institute of Geology and Paleontology, Tōhoku University for his valuable advices. Acknowledgments are due to Professor Enzō Kon'no, Institute of Geology and Paleontology, Tōhoku University, Professor Shigeru Miki, Institute of Polytechnics, Osaka City University and Professor Shirō Kitamura, Botanical Institute, Kyōto University for their valuable

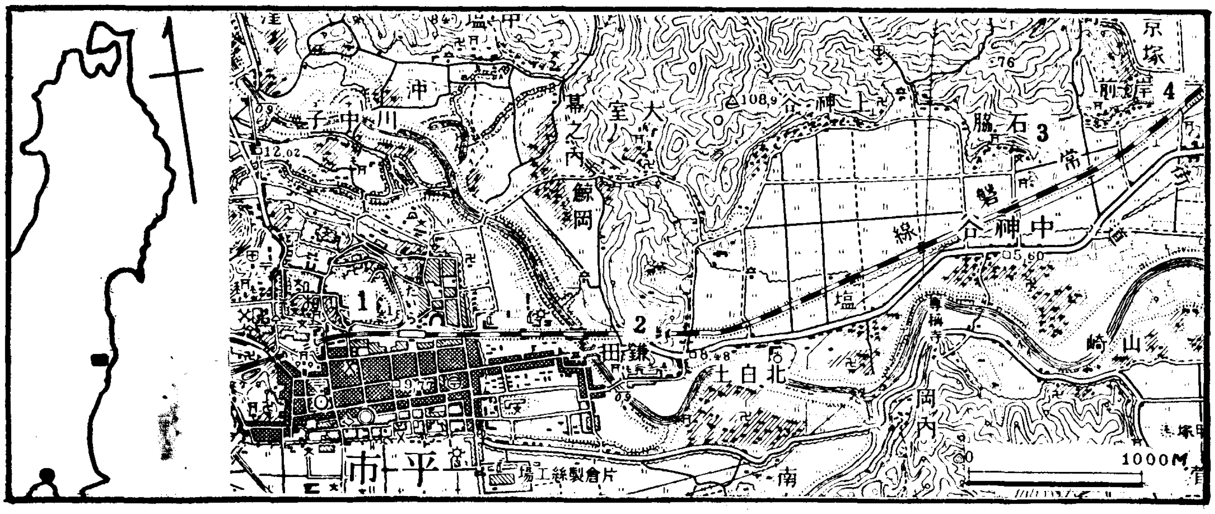


Fig. 1. Index map. • Tokyo, ▪ Taira, 1, Monomigaoka, 2, Kamada, 3, Ishiwaki, 4, Kishimae

advices concerning the fossil plants. The writer is indebted to Professor Misaburō Shimakura, Nara University of Liberal Arts and Education, who has done the pollen analysis, Mr. Hisao Nakagawa, Institute of Geology and Paleontology, Tōhoku University for his kind informations on the geomorphology and to Mr. Kankichi Sohma, Institute of Biology, Tōhoku University for his valuable advices on the palynology of the Pleistocene.

STRATIGRAPHY

The main road leading from Taira City to Yotsukura-machi in Iwaki-gun, Fukushima Prefecture, traverses a low hill of about 40 meters high above sea level at Kamada (Lat. 37°04′N., and Long. 140°54′40″E.) in the eastern part of Taira City. The deposits here under consideration are exposed along the road above-mentioned.

The basement of this hill is composed of the Misawa* and Nakayama formations, both of Miocene age and dips eastwards at about 15°. The top of the hill is occupied by the several meters thick terrace gravels. Beneath these deposits are found sandy silts intercalating a thin bed of volcanic ash.

The sandy silts yield fossil plants and have a thickness of about eight meters, though the base is unknown, because the road does not expose the basement composed of the Misawa formation, except for a small part where the basal conglomerate of the Nakayama is exposed. Along the eastern and westernmost parts of the road cut, however, the Nakayama and Misawa formations are exposed.

Judging from the exposure, the deposits here in question rest unconformably on the Misawa formation.

The order of succession observed in the road cut is as follows:

	Lithologic characters	Thickness
Uppermost:	Light brown to brownish ochre-colored incoherent gravels smaller than cobble size, intercalating light buff-to light brown-colored, cross-bedded, coarse-grained incoherent sands.	5m+
Upper:	Generally massive, but partly thin-bedded, dark gray-colored, micaceous sandy silt bearing plant remains such as nut, cone and drift wood.	2–3m
Middle:	Massive, bluish green-gray-colored micaceous sandy silt.	4m+
Lower:	Light pink-colored fine ash of 2–4 cm. thick and coarse ash bearing quartz grains of 6–10 cm. thick.	10 cm±
Lowermost:	Bluish heavy green-colored sand, silt and clay in mixture.	2m+

The uppermost bed is composed of small cobbles and pebbles of variable sizes of

* This part of the Misawa is assigned to the Yoshinoya conglomerate and sandstone member by K. Sugai *et al.*[45]

granitic rocks, green schists, rhyolite, hornfels, chert, slate and sandstone, etc. The gravels rest on the underlying massive, partly thin-bedded micaceous sandy silt bed. The boundary surface between them slightly undulates and the uppermost part of about 20 cm. thick of the sandy silt bed is stained with limonite. At the eastern limit of the exposure the sandy silt bed seems to be obliquely truncated by the gravels, thus they seem to rest disconformably on the sandy silt bed. However, the writer could separate the gravels into two beds, the one occupies the topmost of the higher terrace of about 40 m. high, and the other is distributed on the lower terrace of about 30 m. high. The former rests on the sandy silt with slight physiographical break, while the latter truncates obliquely the whole beds of sandy silt. Therefore the writer considers that the relation between the sandy silt bed and gravel bed occupying the higher terrace is conformable. The gravel bed which truncates the sandy silt bed rests unconformably on the Nakayama formation and forms the lower terrace deposits. This gravel bed dipping eastwards with a slight inclination contains a large number of blade-shaped, subangular and subrounded pebbles of shale smaller than large pebble size, and the size of the pebbles of other kinds of rock is also generally small and its matrix is more silty than that of the gravels which occupy the higher terrace. Based on the difference of the comprising materials, the height of the terrace and the relation to the underlying sandy silt bed, the writer distinguished the gravels into two beds as aforementioned.

At the western end of the road cut and at the foot of the western cliff of the hill, a gravel bed of about 5 m. thick directly overlies the upper part of the Misawa formation composed of agglomeratic lappilli tuff and tuffaceous shale with unconformity. Furthermore the higher terrace gravels are underlain with the buff-colored sandy silt, though the boundary between them is obscure. This outcrop is separated from the road cut where the sandy silt beds here in question are exposed, because of being partly concealed by the stone embankment for the protection of the road cut and partly by the talus and grasses. Judging from the features of these two exposures, the sandy silt beds here in question seem to continue to the buff-colored sandy silt situated between these gravel beds which have the same lithologic characters.

On the other hand, a gravel bed distributed in Shiroyama of Taira City is about 25 m. in thickness and intercalates incoherent sand and sandy silt of variable thickness.

At Ishiwaki and Kishimae, respectively about 2.5 km. and 3.5 km. east of Taira City, a gravel bed about 25 m. thick rests unconformably on the Misawa formation and abuts partly against the latter. This gravel bed also intercalates thin beds of cross-bedded sand, sandy silt or silty sand.

The terraces of Shiroyama, Kamada and Kishimae decrease eastwards in their height from about 40 m. to 30 m. The gravel beds of these terraces may be considered as the deposits of the same age. Consequently the writer proposes the formational name of "Monomigaoka"* for these gravel beds. The sandy silt bed intercalated in the gravel beds is designated as the Kamada sandy silt member of the Monomigaoka formation.

LITHOLOGY

The Kamada sandy silt member comprises micaceous sandy silt, except for a thin

Table 1

Sample No.	$Md\phi$	$M\varphi$	$\sigma\phi$	$\alpha\varphi$
1	5.70	5.64	2.34	− 0.025
2	4.15	4.95	1.80	0.445
3	4.86	5.21	2.10	0.74
4	4.05	4.70	1.80	0.391
5	4.62	5.05	2.15	0.200
Composite of 1-5	4.68	5.22	2.08	0.259
6	5.15	5.40	2.00	0.125
7	4.85	5.15	2.00	0.105
8	4.95	5.23	1.83	0.151
Composite of 6-8	4.96	5.30	1.90	0.178
9	4.30	5.15	1.70	0.500
10	5.25	5.45	1.90	0.105
11	4.50	4.90	2.30	0.173
12	1.40	1.64	0.76	0.315
13	4.70	5.85	2.70	0.425

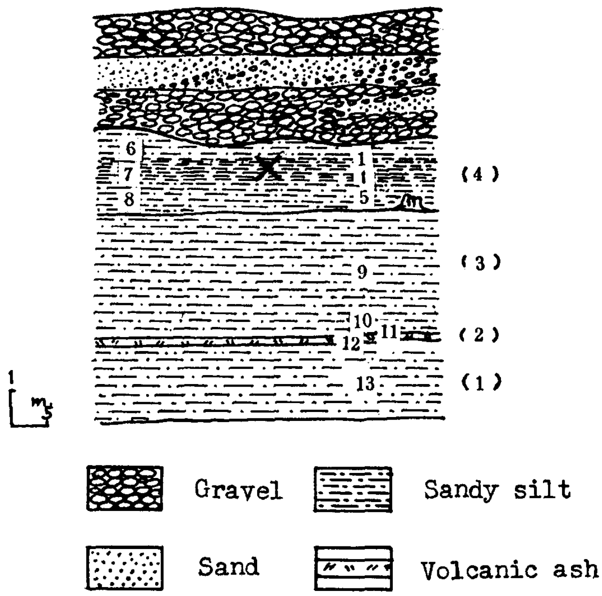


Fig. 2. Diagrammatic section of the Kamada sandy silt member. (1)-(4)… Classified beds described in the text. 1-13…Position of sample submitted to mechanical analysis. X…Plant fossils bearing part of bed (4) and position of sample submitted to pollen analysis.

* Y. Kamada[13] had previously proposed the name of "Shiroyama", but this name is preoccupied by a Pleistocene shell bed distributed in Shiroyama, Kagoshima City, Kyushu[35,38] and the Miocene Siroyama bed[19] or Siroyama sandstone beds[39] distributed in Siroyama, Kanbara-machi, Shizuoka Prefecture. (The Siroyama bed cited by T. Tomita and E. Sakai[46] from the papers of T. Makiyama[22] and S. Imamura[10,11] seems to have been misread. K. Tsuda[47] used the names of Joyama formation and Joyama mudstone.) Though the name of Monomigaoka cannot be found in the topographical map of "Taira", scale 1/50,000, the site of the old castle of Taira is called by this name.

bed of volcanic ash intercalated in its lower portion. Though the sediments have generally homogeneons appearance, it is composed of ill-sorted sand-silt-clay mixture abundant in silt and sand. The result of the mechanical analysis of them is shown in Table 1 and Fig. 3. The points from where the samples were collected are shown in Fig. 2.

The histograms given in Fig. 3 show that these sediments largely have the highest percentage in 3–4ϕ (very fine sand size). But they have peculiar size distribution of

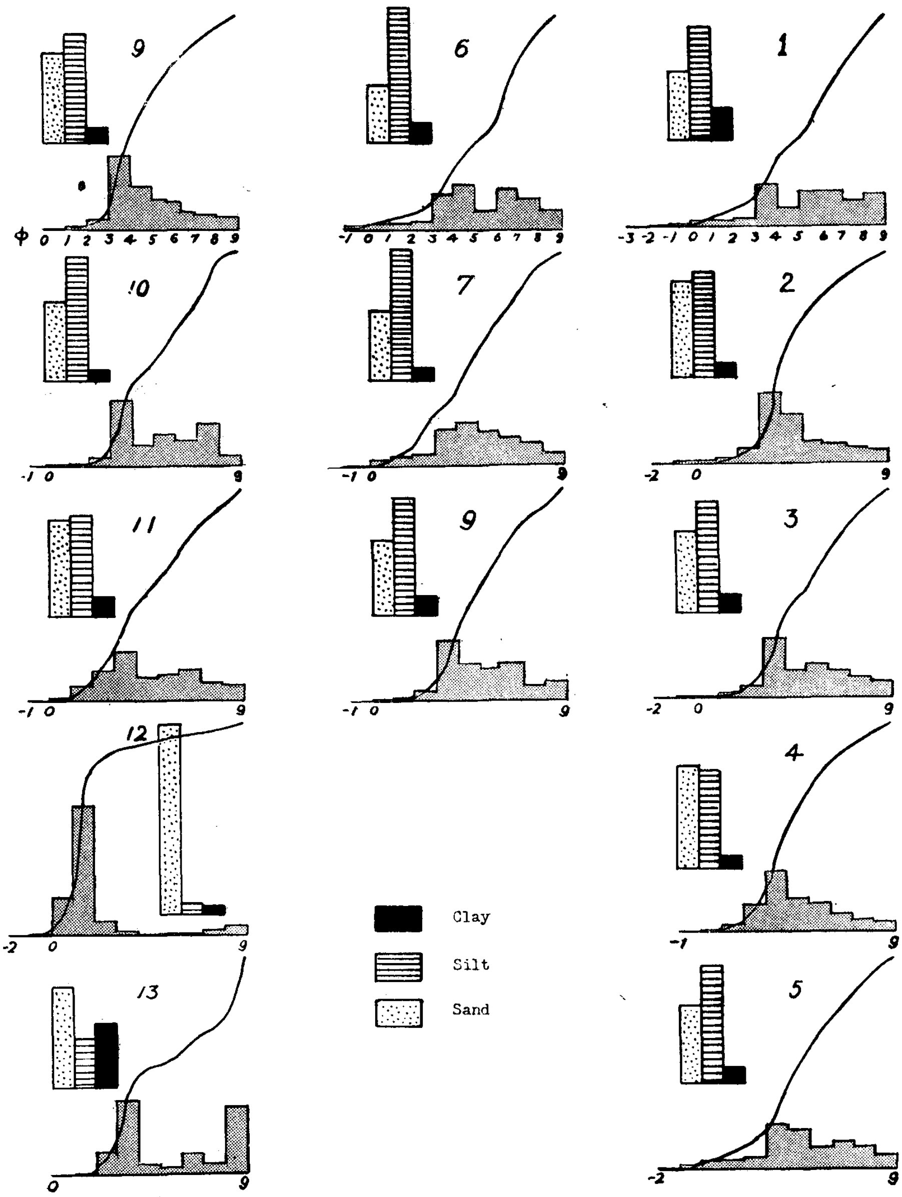


Fig. 3. Size distribution of the sediments of the Kamada sandy silt member.

polymodal character largely bimodal and even trimodal rarely with a few exceptions (No. 2, No. 4, No. 7 and No. 9) and secondary mode is found in 6–7ϕ (fine silt size). The peculiarity in size distribution of the present case may be explained by the mixing of sediments of variable size due to the dual nature of the load.

The writer divides the Kamada sandy silt member into four portions as aforementioned based on the difference of color, volume of organic contents and lithogenetic character in part. The lithologic characters of the sediments are given below in ascending order.

(1) Bluish heavy green-colored sand, silt and clay (lowermost). This bed occupies the lowest part of the Kamada sandy silt member overlying the basal gravel bed of the Monomigaoka formation. Its thickness is about two meters so far as known. The textural composition and size distribution are shown in Table 1 and Fig. 3 (No. 13). The size distribution is very peculiar, that is to say, trimodal and the clay is more than silt unlike the sediments of another part of this member.

(2) Light pink-colored fine-and coarse-grained volcanic ash (lower). This bed of volcanic ash comprising the glass shards rests on the just-mentioned bed (1) with distinct boundary and merges to the overlying bed (3) aftermentioned. It has only about 10 cm. in thickness, but is characterized by its nature of pyroclastic origin and may be a key bed of this member. The lower 6–10 cm. part of this bed is coarse-grained and comprises volcanic glass shards with quartz grains. The upper 2–4 cm. part is composed of fine ash having a feeling of polishing powder. As shown in Table 1 and Fig. 3 (Nos. 11 and 12), the coarse ash of the lower part is well sorted, but the fine ash of the upper part is ill-sorted like the sandy silt of another horizon. The well sorting of the coarse ash is probably due to the atomospheric sorting and direct deposition with less transportation by running water.

(3) Massive micaceous sandy silt (middle). This bed overlies the volcanic ash and is of bluish green-gray color, but light yellow-colored on the weathered surface. Its thickness is about 4 m. The lowermost part of this bed mixes with the volcanic ash and is ill-sorted. A sample collected from the middle part of this bed shows unimodal distribution. But it is very doubtful that the bed has this character of size distribution as a whole. Their size distributions are shown in Table 1 and Fig. 3 (Nos. 9 and 10).

(4) Massive, partly thin-bedded micaceous sandy silt with plant remains (upper). This bed occupies the upper part of the Kamada member and is 2–3 m. in thickness. The uppermost 10–20 cm. part of this bed is stained with limonite and shows heavy ochre color. It is overlain with gravels of the higher terrace of about 40 m. high above sea level.

This bed is characterized with abundant plant remains which are especially concentrated in the upper half part. The plant remains are largely of drift woods and fine specks of vegetable material. The writer found a nut remain, though only a half part, and many cones in this bed. The former is the nut of *Juglans* and the latter is the cone of *Alnus*. One of the drift woods rests on the upper surface of the underlying bed (3) aforementioned like an erect-stump. But there is neither the clayey deposits corresponding to the underclay nor remains of roots in the underlying bed. Therefore the writer considers that the wood looking like an erect-stump might have been transported with other woods and settled in the present attitude.

Eight samples were submitted for mechanical analysis from this bed, five (Nos. 1–5) from the western part of the exposure and three (Nos. 6–8) from the eastern portion. As shown in Table 1 and Fig. 3, two (No. 2 and No. 4) among them have the unimodal distribution like No. 9 of bed (3), and all have mode in 3–4ϕ (very fine sand size). Except for these two, the others show the bimodal and indistinct unimodal distribution. These generally have primary mode in 3–4ϕ (very fine sand size), and secondary mode in 5–6–7ϕ (medium to fine silt size), except for No. 7 which has one mode in 4–5ϕ (coarse silt size). From these evidences, it may be said that these sediments were deposited from the silty water which has dual nature of load transported under a similar hydraulic condition.

These beds taken as a whole are obliquely truncated by the younger silty gravel bed forming the lower terrace.

PALEONTOLOGICAL NOTE

As above mentioned, the fossil plants are concentrated in the uppermost part of the Kamada sandy silt member and the macroscopic remains such as nut of *Juglans*, cones of *Alnus* and drift woods are found.

The nut remain is small in size (2.3 cm. × 2.5 cm.), and its surface sculpture is very weak. The number of lacunae in the shell wall is unknown, because of its ill-preservation. Judging from its dimension, shape and surface sculpture, it may be identified with *Juglans Sieboldiana* Maxim. subsp. *hosenjiana* Kryshtofovich[20] (Fig. 4). This species was originally described by Kryshtofovich for the fossil nut obtained from Tsurumi, Yokohama City, Kanagawa Prefecture. The occurrence of this species had been reported from many localities[1,2,3,16,23,24] in Japan. Lately, H. Matsumoto *et al.*[25] reported an occurrence of this species from Hanaizumi, Iwate Prefecture. S. Miki[31] described the nut remains of Juglandaceae found in Japan and identified this species to the living species *J. mandshurica* Maxim. var. *sachalinensis* (Miyabe et Kudo) Kitamura.

Many authorities had debated on the small nut of this type and the fossil species has been identified with the living species by all except S. Endō, though different specific names have been used as follows:

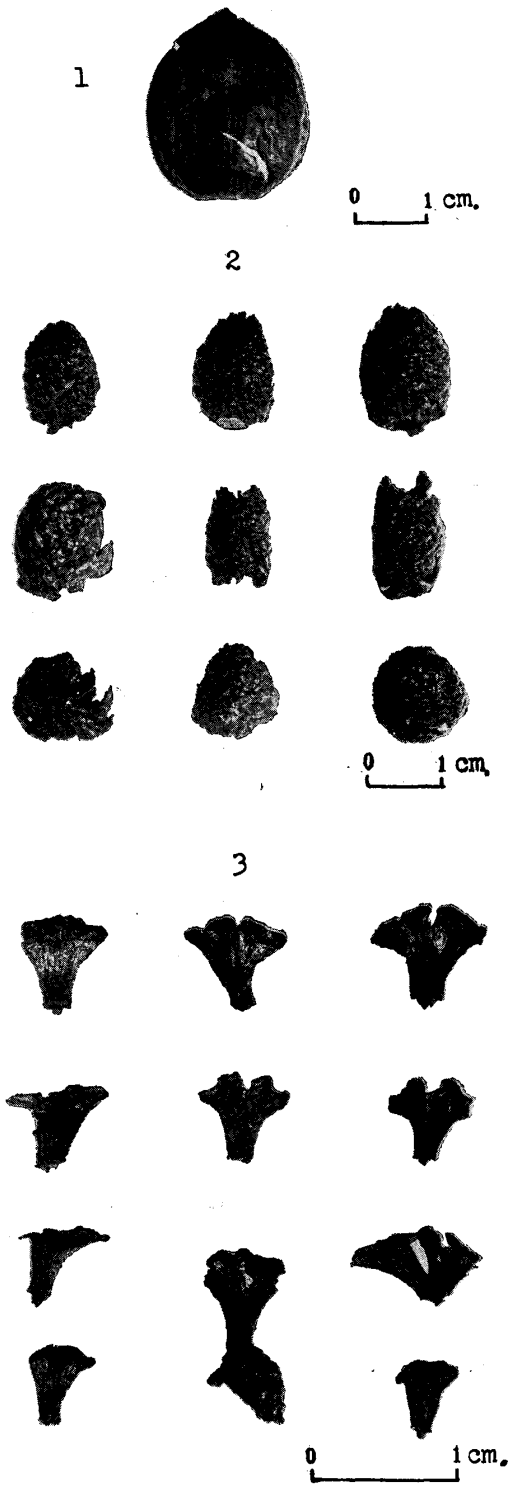
Juglans sachalinensis Komatsu[18], *J. Sieboldiana* Maxim. var. *sachalinensis* Miyabe et Kudō[34], *J. mandshurica* Maxim. var. *sachalinensis* (Miyabe et Kudo) Kitamura[15] and *J. mandshurica* Maxim. var. *Sieboldiana* Makino (=*J. mandshurica* Maxim. forma *Sieboldiana* Kitamura)[21]

But S. Endō[1], who lays stress on the horizon of its occurrence, identified the fossil nut of this type with the subspecies described by Kryshtofovich. According to the communication of S. Kitamura to E. Kon'no, he considers that *J. mandshurica* Maxim. var. *hosenjiana* may be used for the fossil nut of this small type. Though the determination is very difficult with only a specimen, the writer identified the present fossil nut with Kryshtofovich's subspecies.

The fossil cone of *Alnus* is identified with the living species *Alnus japonica* Sieb. et Zucc. on the basis of its dimension, shape of cone and its cone scale (Fig. 4).

Besides these macroscopic plant fossils, the pollen assemblage contained in the micaceous sandy silt was determined by M. Shimakura as shown in Table 2*. According to his verbal communication, this assemblage is characterized by the fair abundancy of *Larix*, scarcity of temperate broad-leafed trees such as *Alnus*, *Quercus*, *Carpinus*, etc.

* The samples submitted to the analysis was collected from the thin-bedded part of the bed (4) aforementioned.



(Kumagai photo.)

Fig. 4. Macroscopic plant fossils of the Kamada sandy silt member. 1. *Juglans Sieboldiana* Maxim. subsp. *hosenjiana* Kryshtofovich. 2. *Alnus japonica* Sieb. et Zucc. 3. Cone scales of *Alnus japonica* Sieb. et Zucc.

and the occurrence of *Tilia*. It is also very remarkable that the pollen of *Seqouia-* and *Taxodium*-type, both of which are usually dominant in the lignite of the Pliocene, are lacking in this pollen assemblage.

As far as writer's investigation is concerned, the following species of fresh water Diatoms are rarely found in the Kamada member.

Cymbella obtusiuscula (Kütz.) Grun., *C. lanceolata* (Ehr.) Van Heurck, *C.* cf. *turgida* (Greg.) Cleve, *C. ventricosa* Kütz., *Diploneis elliptica* (Kütz.) Cleve, *Epithemia argus* Kütz., *E. zebra* (Ehr.) Kütz., *Eunotia pectinalis* (Kütz.) Rabh. var. *minor* (Kütz.) Rabh., *E. sp.*, *Frustulia* cf. *rhomboides* (Ehr.) de Toni, *F.* cf. *vulgaris* Thwaites, *Hantzschia* sp., *Navicula* cf. *gracilis* Ehr., *N. gastrum* Ehr., *N. placentura* (Ehr.) Grun., *N. radiosa* Kütz., *Nitzschia vermicularis* (Kütz.) Grun., *Pinnularia gentilis* (Donkin) Cleve, *P. gibba* Ehr., *P. gibba* Ehr. var. *nipponica* Skvortzov, *P. gibba* Ehr. var. *okamurae* Skvortzov, *Stauroneis phaenicenteron* Ehr., *Synedra ulna* (Nitzsch.) Ehr. var. *aequalis* (Kütz.) Hust.

As cited above, the genera *Pinnularia*, *Navicula* and *Cymbella* are abundant in number of species and individuals. The genera *Melosira* and *Stephanodiscus*, both which are usually abundant in fresh water, are absent, though its reason is unknown.

On the basis of the pollen assemblage and the occurrence of *Juglans Sieboldiana* Maxim. subsp. *hosenjiana* Kryshtofovich, it may be considered that the Kamada sandy silt member was deposited during the Pleistocene under a cool climate. This consideration may be supported by the fact that the pollen assemblage of the Kamada resembles closely to that of the peat of the Sanbongi formation distributed in the southeastern part of Aomori Prefecture[12] and also to that of the Aobayama formation in the environs of Sendai

City[7]. The pollen assemblage of these two formations which contain the fossil seeds of *Menyanthes trifoliata* Linné was studied by K. Sohma[40,42,43,44]. Stratigraphically and paleontologically the Sanbongi and the Aobayama are considered respectively as the

Table 2

	Individuals	%
Abies	67	22.3
Picea	99	33.0
Pinus	16	5.3
Tsuga	37	12.3
Larix	20	6.7
Juglans	3	1.0
Quercus	4	1.3
Persicaria	17	5.7
Alnus	2	0.7
Tilia	22	7.3
Ericaceae	3	1.0
Lonicera	2	0.7
Patrinia	1	0.3
Compositae	7	2.3
Total	300	99.9

(after M. Shimakura)

deposits of Illinoian (Riss) and Wisconsin (Würm) glacial stages[6,12]. But *Tilia* is not found in these two formations just mentioned. Though the species of *Tilia* is unknown, *Tilia distans* Nathorst ?, *T. Miyabei* Jack, *T. japonica* Simk and *T.* sp. are found in the Pleistocene Shiobara flora[4,5]. Furthermore it is mentioned by K. Miyabe and Y. Kudō[34] that *Juglans Sieboldiana* Maxim., *Tilia japonica* Simk., *Alnus hirsuta* Turcz, *A. japonica* Sieb. et Zucc., etc. are usually associated in Hokkaido. Moreover, other living species of *Tilia* such as *T. Miyabe* Jack., *T. Miyabei* Jack. var. *yezoana* Nakai grows in Hokkaidō and Northeast Honshū. Consequently the occurrence of *Tilia* in the Kamada member seems not to be strange.

CORRELATION

The correlation of the Pleistocene deposits should be done from the view points of stratigraphy, paleontology, geomorphology and paleoclimatology. Especially, because of the repetition of the glacial age in the Pleistocene, paleoclimatological evidence should be associated with the other lines of consideration. However, the distribution of the Pleistocene deposits, except for the terrace gravels, is much limited in Northeast Honshū. They have only a short stratigraphical range and are scanty in paleontological evidences. Nevertheless, the writer herein attempts to make correlation between the Pleistocene deposists distributed in Northeast Honshū.

Y. Kamada[14] reported on the Tsukabara formation which is exposed along the sea-cliff of Tsukabara, northeast of Odaka-machi, Sōma-gun, Fukushima Prefecture. According to him, the Tsukabara rests unconformably on the Pliocene Nakamura formation and merges upwards to the terrace gravels and sands correlative with the Aobayama formation distributed in the environs of Sendai City, Miyagi Prefecture.

On the other hand, in the southeastern part of Aomori Prefecture, there are developed the Noheji, Sanbongi and Rokkasho formations in ascending order.[12] The Noheji and Sanbongi unconformably rest on the Tertiary or Paleozoic strata and are separated from one another with a disconformity. These two formations are disconformably overlain with the Rokkasho formation which is geomorphologically correlated with the Aobayama.[6]

The field occurrence of the Kamada sandy silt member resembles closely to that of the Pleistocene deposits of these two areas above-mentioned. And the pollen assemblage of the Kamada also resembles that of the Sanbongi and of the Aobayama.

As aforementioned in the stratigraphy of the present area, previously the writer considered that the Kamada is disconformably overlain with terrace gravels and may be correlated with the Sanbongi. But now the writer considers that the Kamada is a member occupying the lower part of the gravel beds named the Monomigaoka formation. The Monomigaoka taken as a whole is correlated with the Aobayama and underlying Tsukabara, and the Kamada sandy silt member is equivalent to the Tsukabara. The writer considers that the Kamada is the deposits of swamp or lake which was produced in the valley-flat when the Tsukabara sea commenced transgression. H. Nakagawa (verbal communication) recognizes this correlation from the view points of geomorphology and stratigraphy. K. Sohma is now engaged in the palynological study of the silt collected by H. Nakagawa from the middle part of the Tsukabara. According to his oral communication, the pollen assemblage of the middle part of the Tsukabara is much the same as that of the Kamada, especially in having the pollen of *Tilia*. This fact also supports the correlation above mentioned. Consequently the Kamada is younger than the Sanbongi and the larger part of the Monomigaoka is an equivalent of the Rokkasho of Aomori Prefecture.

Y. Kamada[14] mentioned that the molluscan fauna of the Tsukabara taken as a whole is much similar to that of Matsushima Bay (including Shiogama Bay), Miyagi Prefecture and suggested the similar thermal conditions. While K. Sohma, based on the pollen assemblage, suggests that the cooler climatic condition had prevailed when the middle part of the Tsukabara and upper part of the Kamada were deposited. This seems to reflect a fall in temperature from Sangamon to Wisconsin time.[6] The same evidences are known in the Pleistocene deposits of Atsumi Peninsula, Aichi Prefecture[41] and in the environs of Makinohara and Kunozan, Shizuoka Prefecture, etc.[36,42]

The Pleistocene deposits which yield abundant plant fossils are widely distributed in the Kinki district and have been studied in detail by S. Miki,[26,27,28,29,30,31,32] K. Huzita *et al*[9]., K. Huzita[8] and S. Miki *et al.*[33] S. Miki distinguished four plant beds in ascending order, namely *Paliurus* bed, *Cryptomeria* bed, *Larix* bed and *Sapium* bed. H. Sohma,[41] based on the palynological evidences and its order, mentioned that the Noheji and Sanbongi formations seem likely to correspond respectively to the *Cryptomeria* bed and the *Larix* bed. But K. Huzita[8] discriminated not only the *Cryptomeria* bed, but also the *Larix* bed respectively in the two horizons. He recognized the former in the uppermost part of Osaka group (J_1) and in the Shinodayama group (J_2), and the latter in the Manchidani formation (J_1) and in the Egota plant bed (J_3). As aforementioned, many lines of consideration and further investigation are necessary for the interregional correlation. But so far as known the stratigraphical relation between the Pliocene and Pleistocene deposits distributed in the Kinki district and southeastern part of Aomori Prefecture, the *Larix* bed of the Manchidani seems likely to be older than that of the Sanbongi which precedes the Kamada sandy silt member.

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