(Original Paper)

New Data on Miocene Pollen Floras of the Oga Peninsula, Northeast Honshu of Japan, with Comparison to those of Northern China

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Miocene pollen data are described as supplement to the Neogene pollen studies of the Oga Peninsula. A variation in the pollen flora of the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation is recognized for the first time. The lower part of the member is represented by the predominant conifer elements, while its upper part shows a recovery of some broad-leaved types, specially indicated by a number of amentiferous elements. The current pollen record is thought representing a floral changing tendency in the latest Oligocene-earliest Miocene time. The pollen flora from the middle and upper parts of the Daijima Formation, as well as the lower part of the marine Nishikurosawa Formation, shows a flourish of broad-leaved elements with now-extinct Tertiary types well represented, including abundance of *Liquidambar, Carya* and evergreen *Quercus*. This flora is considered to reflect a major Neogene warming occurred around the late Early Miocene-earliest Middle Miocene. The pollen data then imply such a process of changes as the Tertiary types gradually declined, and conifers (including Taxodiaceae and *Metasequoia*) and *Ulmus, Alnus*, etc. played an increasing role in the upper part of the Nishikurosawa Formation and the Onnagawa Formation. These changes in the floral components are supposed to be largely in correspondence with the climatic deterioration occurred in the late period of the early Middle Miocene in spite of then intensified transgression.

The Miocene pollen floras from the Oga Peninsula of Japan and Northern China have many common points due to their closely related geographic locations. Both the floras show a peak in the content of the conifer elements at the early Early Miocene, followed by a distinctive increase in the broad-leaved elements at the late Early Miocene-early Middle Miocene. The pollen flora in Northern China then shows a gradual development of herbs ; while the one in the region along the Sea of Japan displays an expansion of Taxodiaceae and *Fagus*. Causes of the difference are supposed by two reasons: the opening of the Sea of Japan at the Middle Miocene ; and the prevailed marine environment surrounded Japan, in contrast to the dominantly continental condition in the mainland of China.

Key words : Pollen floras, Miocene, Oga Peninsula, Northern China

Introduction

The well-outcropped succession of the Neogene strata in the Oga Peninsula was regarded commonly as a standard sequence in the regions along the Sea of Japan [1, 2]. Many studies covering various aspects of the succession had already been carried out by different authors. Pollen record was reported by Yamanoi [1] and he established a primary Neogene pollen-stratigraphic sequence with emphasis specifically lying on the strata above the Nishikurosawa Formation. The current study is mainly the pollen analysis of the materials from the lower part of the succession, including the Monzen, Daijima, Nishikurosawa and Onnagawa Formations.

It is considered that the Japanese Islands and the Asian continent were connected each other prior to the complete opening of the Sea of Japan in the Middle Miocene [3]. A comparison study on the Miocene pollen floras between Japan and Northern China is anticipated to make clear some interesting facts raised by the opening of the Sea of Japan. This paper gives a general feature of the Miocene floras in Northern China, and then attempts to illustrate the similarities and differences between the Miocene floras of the Oga Peninsula of Japan and Northern China.

Stratigraphy

The Miocene deposits in the Oga Peninsula comprise the upper part of the Monzen Formation, the Daijima, Nishikurosawa and Onnagawa Formations, and the basal part of the Funakawa Formation in ascending order [2].

Unconformably overlying the Middle Eocene Nyudozaki Igneous Rock Member of the Akashima Formation, the Late Oligocene-Earliest Miocene Monzen Formation is composed mainly of volcanic rocks and their pyroclastics, and partly of conglomerate, sandstone and plant fossil-bearing siltstone. It includes the Kuguriiwa Lava, the Kamo Lava, the Shiosenomisaki Sandstone and Conglomerate, and the Shinzan Rhyolite Members in ascending order [2, 4] with a thickness about 960m.

The Early Miocene Daijima Formation lies unconformably on the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation. It consists of pumiceous lapilli tuff, tuff breccia, welded tuff particularly in its lower and middle parts, and deltaic tuffaceous sandstone, conglomerate and mudstone in the upper part. The Hokakejima Dacite Member in the basal part consists of a reddish purple to yellowish brown welded tuff, dacitic agglomerate and tuff breccia. The Sugoroku and Daijima Basalt Members in the upper part consist of olivine two-pyroxene basalt and its pyroclastics, and olivine basalt respectively [2]. Thickness of the formation is about 250m.

The early Middle Miocene Nishikurosawa Formation, which is unconformable to the underlying Daijima Formation, is dominated by about 25m thick sandstone and conglomerate beds in the northern area, and by about 150m thick sandy siltstone beds in the southern area [2].

The Middle-Late Miocene Onnagawa Formation is composed of a brownish gray siliceous shale and diatomite. A glauconitic sandstone at the base of the formation overlies conformably the Nishikurosawa Formation. The thickness of the formation is about 300m in the typical area along the southern coast [2]. The Shinzan Diatomaceous Mudstone Member [5] of the formation contains a massive and partly laminated diatomite, about 160m in the maximum thickness. This member is distributed in the northern part of the peninsula where it overlies the siliceous shale of the main part of the formation and changes laterally to the siliceous shale southward [2].

The latest Late Miocene-Pliocene Funakawa Formation consists chiefly of dark gray mudstone intercalated with tuff and tuffaceous sandstone. In the lower part of the formation, a pumiceous tuff bed with more than 3m in thickness is called the Minamihirasawa Tuff Member. The thickness of this formation is about 800m on the southern coast, and 500m in the northern area [2].

Materials and Methods

The samples for pollen analysis were taken from the northwestern and southern coastal areas of the Oga Peninsula. In the northwestern coastal area, the Nishikurosawa Formation is exposed in a sea cliff, west of Nishikurosawa Village. Six samples collected from the section were numbered from N-1 to N-6 in ascending order (Fig. 1, A). In the southern coastal area, the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation is distributed around the beach of the Shiosenomisaki Cape. Three samples numbered M-1 to M-3 were collected from the upper part of the member. Among them, samples M-1 and M-2 may possibly represent the same bed. Another sample numbered Ni-1 from the beach of Daijima Village indicates the basal part of the Nishikurosawa Formation (Fig. 1, B).

As the Daijima Formation is not well outcropped in the peninsula because of the modern vegetation and many kinds of constructions, more samples were obtained after from Dr. K. Uemura of

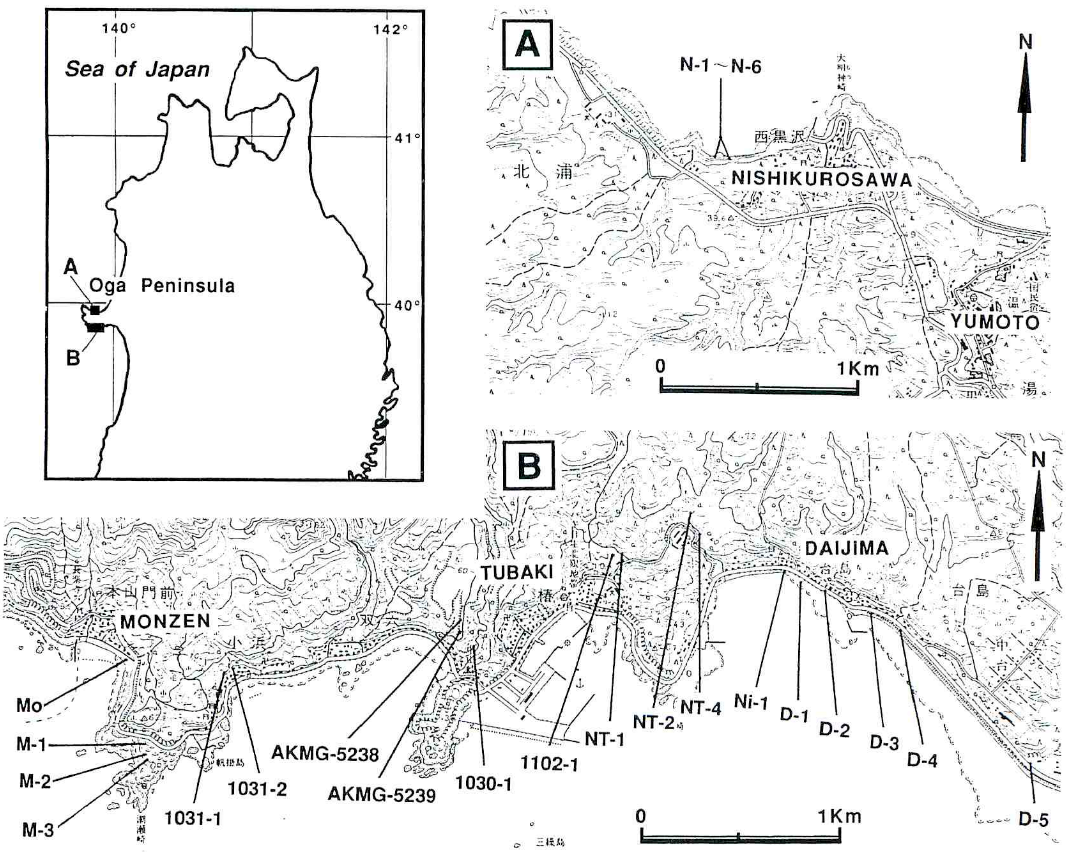

Fig. 1. Location map of the sampling sites in the northwest coastal area (A) and the southern coastal area (B) of the Oga Peninsula.

National Science Museum, Tokyo, including samples 1031-1, 1031-2, 1030-1, 1102-1, NT-1, NT-2 and NT-4 of the Daijima Formation, together with sample Mo of the Monzen Formation, samples D-1, D-2 and D-3 of the Nishikurosawa Formation, and samples D-4 and D-5 of the Onnagawa Formation in ascending order. Samples of AKMG-5238 and AKMG-5239 are a part of plant fossil bearing specimen which have been stored in the collection of the Institute of Applied Earth Science, Mining College, Akita University. These samples are mostly from the different collections of the previous studies and all of them contain plant fossils invariably.

All of the samples from Dr. K. Uemura were collected from the southern coastal areas of the peninsula. Among them, the sample Mo is from the lower part of the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation which is located at not so long distance from the outcrop for the samples M-1 to M-3 ; the samples from the Daijima Formation are 1031-1 and 1031-2 (lower part), AKMG-5238, AKMG-5239 and 1030-1 (middle part), and 1102-1, NT-1, NT-2 and NT-4 (upper part) ; the samples from the Nishikurosawa Formation are D-1 and D-2 (lower part), and D-3 (upper part) ; and the samples from the Onnagawa Formation are D-4 (basal part) and D-5 (upper part) (Fig. 1, B).

The samples examined were first dried and sieved through the 60 mesh screen after powdered, then macerated with KOH (10%), HF (47%), $HCl + HNO_3$ (3 : 1) and treated with the acetolysis method, and finally soaked in $ZnCl_2$ solution compounded to the specific gravity 2. Slides were prepared by mounting the pollen grains in the glycerine jelly.

Pollen percentages were calculated following the Yamanoi's method [(1)] with two fixed sum of pollen groups being used : one is to count 100 to obtain the vesicular Pinaceae pollen and spores vs. other pollen ratio ; the other is to count 200 to get a pollen diagram without consideration of the vesicular Pinaceae and spores.

Result of Pollen Analysis

The samples from the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation contain many fossils. The pollen composition of this member shows certain variations between its lower and upper parts. The lower part is featured by the predominant occurrence of vesicular Pinaceae pollen, represented by *Picea, Tsuga* and *Pinus.* Their content reaches 89% as indicated by sample Mo. Among the angiosperm pollen, *Alnus, Betula, Ulmus* and *Corylus* are numerically the most important pollen taxa, while some other taxa, such as D. (deciduous type) *Quercus, Pterocarya, Carpinus, Tilia, Zelkova, Ephedra,* Chenopodiaceae, etc. are relatively lower in content (Fig. 2). This result is comparable with the one derived from the Yamanoi's sample M-4 [(1)] that is also located in the lower part of the member. In the previous study, only a large number of vesicular Pinaceae pollen were recognized in the sample M-4. In the present study, we observed more slides than in the previous study and consequently found a small number of *Betula, Ulmus, Corylus, Alnus, Tilia, Celtis* and Taxodiaceae, etc. except the majority of Pinaceae pollen.

The upper part of the member shows a decrease of the Pinaceae pollen occupying a slight more than 50%, dominantly represented by *Tsuga. Betula* becomes the main element in the flora, while *Pterocarya* occurs more often than in the lower part, together with *Ulmus, Corylus* and *Alnus.* Other elements including *Tilia,* D. *Quercus, Juglans, Zelkova,* Taxodiaceae, *Carpinus, Carya, Fagus, Celtis, Ilex, Fraxinus, Rosa,* Rhamnaceae, etc. are less common. There are also some forms of *Tricolpopollenites* and *Tricolporopollenites* (Fig. 2).

Both pollen number and preservation in the lower part of the Daijima formation are poor. We

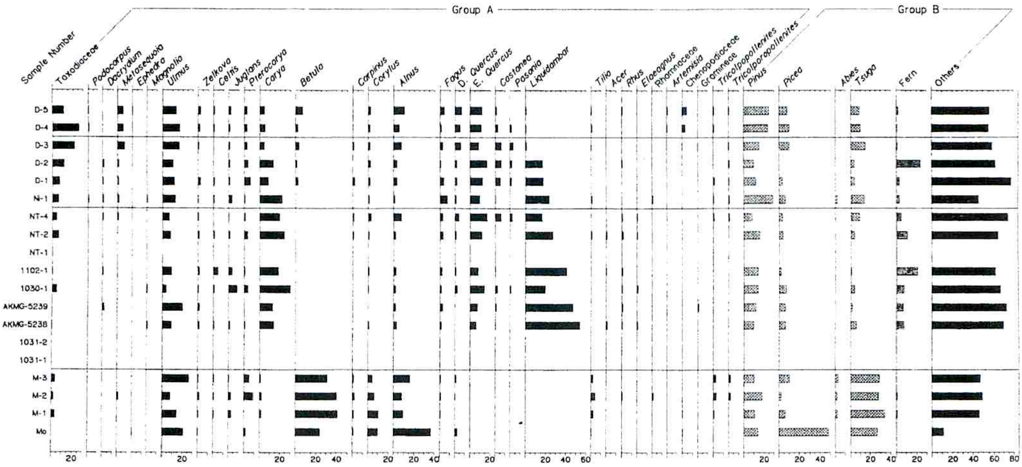

Fig. 2. Pollen diagram showing major floral components of the samples Mo-1, M-1, M-3 (Monzen Formation), 1031-1, NT-4 (Daijima Formation), Ni-1, D-3 (Nishikurosawa Formation), and D-4, D-5 (Onnagawa Formation) in the southern coastal area. Two groups with fixed sums are represented : all pollen except for the vesiculate Pinaceae and spores, N= 200 (Group A) ; and all pollen for the "Pinaceae, spores vs. others" diagram, N= 100 (Group B).

tried twice to examine the samples in the laboratory, but couldn't get a better result mainly due to its lithologic character. The following elements are what we have found from the samples 1031-1 and 1031-2 : *Pinus, Picea, Tsuga, Alnus, Ulmus, Juglans, Carya, Tilia, Liquidambar,* D. *Quercus,* E. (ever green type) *Quercus, Betula, Corylus,* Taxodiaceae and *Pterocarya* among the pollen, and *Osmunda* and Polypodiaceae among the spores. The total amounts of these taxa are not enough number to show in Fig. 2.

The middle and upper parts of the Daijima Formation generally contain many fossils. In the flora, Pinaceae pollen are around 20% on the average, mostly represented by *Pinus,* together with a small number of *Picea* and *Tsuga.* The most distinctive features of the flora are displayed by the predominant occurrence of *Liquidambar, Carya,* E. *Quercus,* and some new elements represented by *Castanea, Pasania, Rhus, Acer, Magnolia, Elaeagnus* and *Dacrydium,* Oleaceae, etc. despite their lower contents, while the main components in the Monzen Formation reduced or even disappeared. There are also some spores of Polypodiaceae, *Pteris, Ceratopteris, Osmuda,* etc. in the samples. *Ceratopteris* shows relatively higher component in the sample 1102-1 (Fig. 2).

The samples of the Nishikurosawa Formation were obtained from the northwestern and southern coastal areas. In the northwestern coastal area, pollen flora from the lower part of the section shares the main features of the middle and upper parts of the Daijima Formation. In addition, there are more pollen taxa in the present flora than in the Daijima Formation, including some small amount of herbaceous pollen, such as Gramineae, *Artemisia,* Cyperaceae, etc. Some changes are recognized in the upper part of the section, as indicated by the increase of Taxodiaceae, *Metasequoia, Betula,* as well as *Pinus, Picea* and *Tsuga,* and the decrease of *Liquidambar* and *Carya* (Fig. 3). A similar changing tendency is also recognized from the southern coastal section (Fig. 2).

The samples D-4 and D-5 of the Onnagawa Formation continue to hold those features of the upper

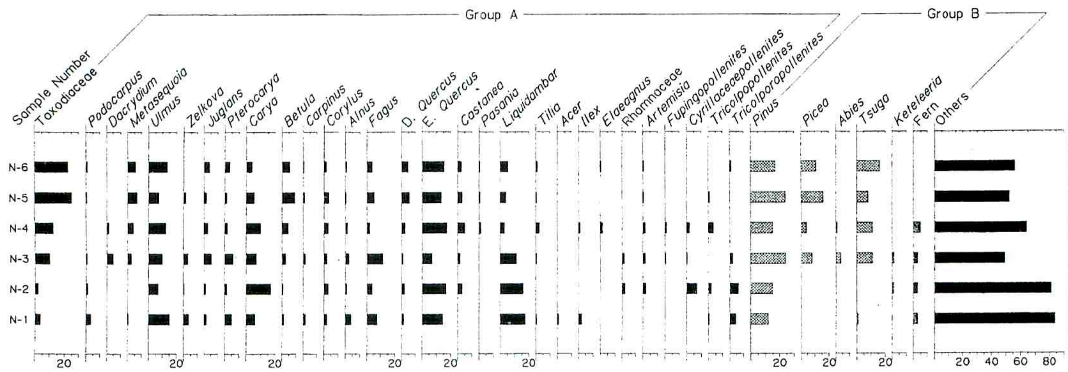

Fig. 3. Pollen diagram showing major floral components of the samples N-1, N-6 (Nishikurosawa Formation) in the northwestern coastal area. See Fig. 2 for further explanation.

Nishikurosawa Formation, i. e. higher occurrence of Taxodiaceae, *Ulmus*, Pinaceae pollen, etc. , and constantly lower appearance of *Liquidambar, Carya,* etc. (Fig. 2).

Evaluation of Current Pollen Data and Previous Studies

The pollen flora from the Shiosenomisaki Sandstone and Conglomerate Member of the Monzen Formation exhibits a recovery of the broad-leaved types upward. Its inferred climate is somewhat comparable with the Late Oligocene-Early Miocene changing process of the worldwide climate based on various approaches, such as on the marine megafauna in the Mediterranean [6], on the oxygen isotope data in the Southwest Pacific [7], and on the pollen records from the mainland of China [8, 9, 10]. The same member also yields plant fossils that have been assigned to the cool-temperate Aniai-type flora by Huzioka [11, 12]. Fission track ages are 27. 1 Ma, 31. 5 Ma [13], and 29. 8 Ma [14] from the underlying Kuguriiwa Lava Member, and 23. 7 Ma [14], 25. 3 Ma [13] and 26 Ma [15] from the overlying Shinzan Rhyolite Member. The Shinzan Rhyolite Member also holds the K-Ar age of 24. 4 Ma [16]. Therefore, the present record seems to display the floral change in the latest Oligocene-earliest Miocene.

The Daijima Formation is famous as yields the Daijima type flora which reflects warm temperate climate [11]. Plant fossils were gathered mainly from the tuffaceous mudstone and lignitic mudstone intercalated in the upper part of the formation. The present study displays a distinctive flourish of the broad-leaved pollen elements and now-extinct Tertiary types well represented in the flora from the middle part of the Daijima Formation to the lower part of the Nishikurosawa Formation. The current strata cover a most pronounced Neogene event called the "Mid-Neogene climatic optimum" in Japan around the age of 16 Ma [17]. The lower part of the Daijima Formation is poor both in the number and preservation of the pollen. However rich pollen fossils were reported by Sato [18] from the same beds. The main elements indicated by Sato are represented by many *Alnus, Carpinus, Ulmus / Zelkova* and *Betula,* together with a number of Pinaceae, *Tsuga* and spores. If this is true, pollen flora from the lower part of the formation seems to still hold some features of the Aniai-type flora.

Age of the flora mainly follows the radiometric time scale and the biochronologic framework. The fission track ages of the Hokakejima Dacite Member at the basal part of the Daijima Formation are 20 Ma [15], 22.0 Ma and 20.9 Ma [13]. The same member also reveals the K-Ar age of 18.8 Ma [16]. The planktonic foraminiferal fauna from the lower upper part of the Nishikurosawa Formation exposed on the southern coast is correlated with the Blow's planktonic foraminiferal zone [19] N.9 by Saito and Maiya [20].

The pollen flora from the upper part of the Nishikurosawa Formation and the Onnagawa Formation implies such changes as the major Tertiary types gradually declined and conifers (including Taxodiaceae, *Metasequoia*), *Ulmus, Alnus,* etc. played an increasing role upwards. The cause of the variation in the floral components may be versatile. It may be due to a possible climatic cooling or the enlargement of the transgression. In the Oga Peninsula, the Monzen and Daijima Formations are generally considered as sediments of the non-marine environment, while all other Neogene formations are of marine origin [2], though Fujioka et al. [21] once suggested that there is a possibility that the Daijima Formation could be partially of marine condition. According to our present study, dinoflagellate cysts occurred frequently in the Nishikurosawa Formation and the upper layers. There is no sample from the Daijima Formation containing marine fossil. Tsuchi once indicated that the Mid-Neogene climatic optimum is followed by an abrupt cooling begun at 15 Ma ago in central and northern Japan. This is reflected by the change in the marine fauna from the tropical-subtropical Kadonosawa type to the cold-water Shiobara-Yama fauna [17]. A change in the diatom flora of the early Middle Miocene at ca. 14 Ma ago was recognized by Yanagisawa from the high and middle latitude area in the North Pacific. This was suggested to be coincident with an abrupt cooling of the sea water temperature [22]. Consequently, the present pollen record is supposed to be largely in correspondence with the climate deterioration in spite of intensified marine environment.

An outline of the climate reflected by the current pollen data displays a major Miocene warm period in the middle Daijima to early Nishikurosawa stages. This result is not in full agreement with the one proposed by Sato. Sato [18] once suggested that there are at least two periods of cool temperate climate fluctuation in the late Daijima to early Nishikurosawa stages. We do not consider

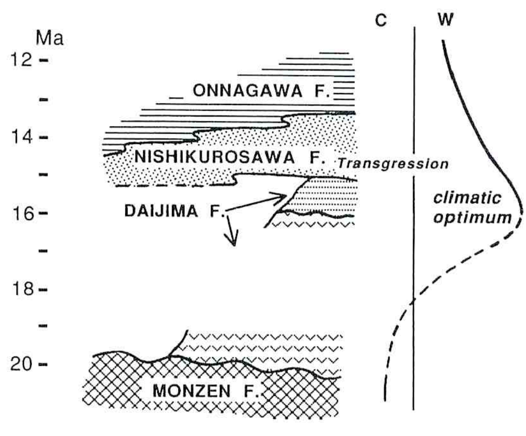

Fig. 4. An outline of changes in climate and environment in the Miocene of the Oga Peninsula.

there could be any distinctive climate cooling in the mentioned period. As we have already mentioned, the Daijima Formation consists of non-marine sediments, and the Nishikurosawa is characterized by shallow marine deposits which originated in the early Middle Miocene transgression. Sato [18] affirmed that the early Middle Miocene transgression is a widely synchronized event occurred around 16 Ma ago, while the warm pollen flora of the Daijima Formation is older than 16 Ma ago. On the contrary, Yamanoi [23] considered that the Neogene warm event (climatic optimum) took place simultaneously in a wide region, and pointed out some time discordance of the early Middle Miocene transgression among the different places. Thus, it is possible to conclude that the climatic optimum occurred in the Daijima Stage was centered at 16 Ma ago, and the early Middle Miocene transgression was expressed as a sandy deposit of the Nishikurosawa Formation happened at or later than 16 Ma ago. The transgression facies changed subsequently to the muddy deep marine deposit named as the Onnagawa Formation during 15-13.5 Ma [24] ago, which shows a climatic deterioration by the fossil evidence (Fig. 4).

A Comparison of Miocene Pollen Floras between Oga Peninsula and Northern China

The pollen flora in the first stage of the Miocene in Northern China is generally distinguished by a large number of conifer pollen, often occupying half of the total content. The angiospermous pollen are characterized by the frequent occurrence of Ulmaceae and amentiferous pollen [25, 26]. Here we cited that it is a distinctive case in the Northern China as example, the pollen record from the lignite deposit in Tianzhen region, Shanxi Province (40. 6 °N, 114.1°E). The lignite deposit in the region is intercalated in the Hannaoba basalt. The pollen flora is predominated with gymnospermous elements, mainly including *Picea, Abies, Pinus* and *Tsuga*, etc. Angiospermous pollen are relatively lower component, but many amentiferous pollen grains, such as *Juglans, Carya, Betula, Alnus, Corylus*, etc. occurred frequently. There are also a certain number of ferns in the flora [27] (Fig. 5). The age of the present flora was deduced based on the K-Ar dating of the Hannaoba basalt. The K-Ar age of the basalt in the neighboring Weichang and Wulougong areas, Hebei Province is 23. 3-23. 8 Ma, and 22. 1 Ma respectively (unpublished data from the Second Regional Geological Surveying Party of Bureau of Geology and Mineral Resources, Hebei) [26].

The pollen flora then turns into a most flourishing period with both the temperate elements, such

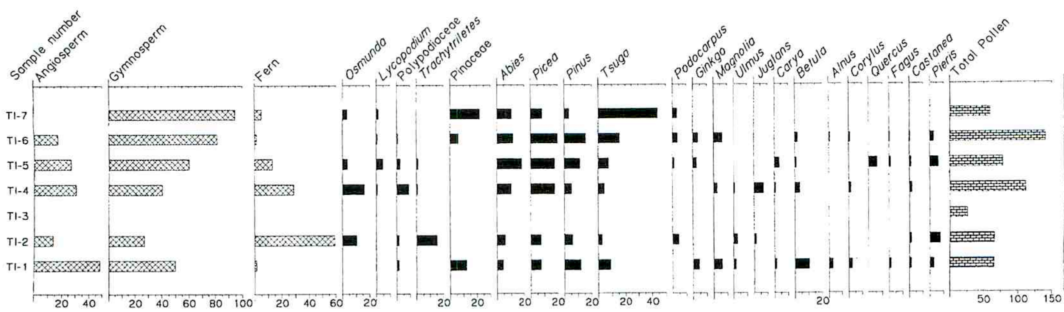

Fig. 5. Pollen diagram showing major floral components of the the lignite deposit in the Tianzhen region, Shanxi Province (datum basis after Wang, 1978).

as Betulaceae, Juglandaceae, Ulmaceae, D. *Quercus*, etc. and the subtropical types including *Castanea*, E. *Quercus*, *Liquidambar*, *Carya*, *Rhus*, Oleaceae, Meliaceae, Sterculiaceae, Lauraceae, etc. well represented, together with a number of the aquatic plants like *Trapa*, *Ceratopteris*, etc. [25]. Typical stratum including both pollen and mega-plants were found from the famous Shanwang Formation in the Linju county, Shandong Province (36. 5°N, 118. 8°E). According to the former studies [28, 29], as well as our current inspection, the prominent genera of the Shanwang pollen flora are E. *Quercus*, *Liquidambar*, *Altingia*, *Ulmus*, *Juglans*, *Carya*, *Pterocarya*, *Corylus*, *Fagus* and *Pinus*. Less common elements include *Acer*, *Celtis*, *Carpinus*, *Alnus*, *Betula*, Taxodiaceae, *Tilia*, *Ruta*, *Zelkova*, D. *Quercus*, *Salix*, *Ilex*, *Picea*, *Tsuga*, *Larix* / *Pseudotsuga*, and some form genera *Fupingopollenites*, *Tricolpites*, *Tricolpopollenites*, etc. Pollen of xerophytes and herbs are always rare. Only few *Ephedra*, Chenopodiaceae, Gramineae and Polygonaceae were found. The detailed contents of the main elements in the Shanwang Formation show in Fig. 6 based on the published datum [29]. It is generally agreed that the Shanwang flora is of the late Early Miocene-early Middle Miocene in age based on the K-Ar dating, paleomagnetic dates, as well as some biostratigraphic evidences [29, 30].

The pollen floras succeeding the Shanwang stage bear more or less resemblance to the previous one, but including less subtropical elements and more herbaceous forms. The herbs mainly represented by *Artemisia* and Chenopodiaceae especially display an extensive increase northward and westward in space, and upward in the sequence [25, 26, 30]. Our former report on the pollen flora from the interval 1348. 24-1554. 50m in depth of Core CB-20, southwest end of Bohai Sea (38. 0°N, 118. 8°E) could be taken as one of the representative cases. The flora is characterized by inherent many common features of the Shanwang flora, at the same time, distinguished by containing many herbaceous types [31].

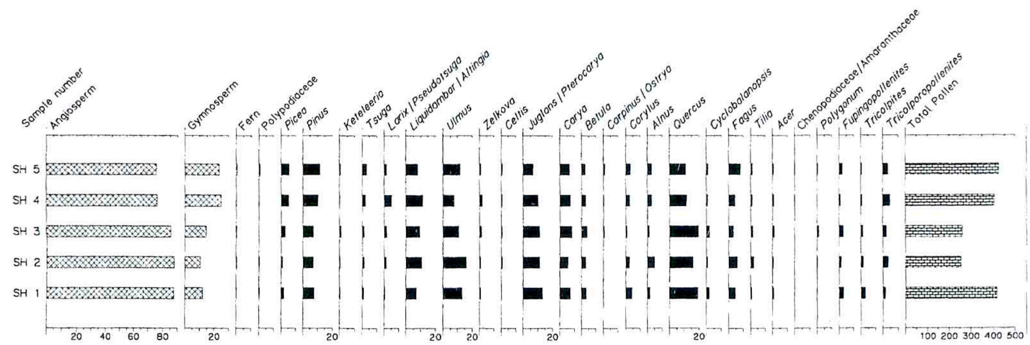

Fig. 6. Pollen diagram showing major floral components of the Shanwang Formation in Linju county, Shandong Province (datum basis after Liu and Leopold, 1992).

According to the above mentioned features, pollen floras from the Oga Peninsula and Northern China share many common points. Both the floras are typified by the high occurrence of conifer and amentiferous elements at the first stage of the Miocene, followed by a distinctive floral flourishing period at the late Early Miocene-early Middle Miocene. There are also many common taxa throughout the Miocene. However, the pollen flora from the Northern China generally contains more types including a number of herbaceous forms than that from Japan, at the same time, climate variations reflected by the Miocene pollen flora of Japan are generally more distinct than that of China. There are two climatic cooling steps recognized from the Miocene pollen flora of the Oga Peninsula : one was in the Middle Miocene as indicated by our current data, and the other more abrupt one in the Late Miocene Shinzan Diatomaceous Mudstone Member [1, 32].

Cause of the differences may be raised mostly by the opening of the Sea of Japan started at the early stage of the Miocene. It is generally assumed that the initial stage of the opening began 16 Ma ago, and the main stage of the opening was 15 Ma ago. By 14 Ma ago, the opening of the Sea of Japan had been almost completed [33]. Since the complete opening of the Sea of Japan, the Japanese Islands are surrounded by the prevailed marine environment, while the mainland of China is dominated by the continental condition, resulting in the differential development of their floras.

Conclusions

The pollen floras from the Miocene of the Oga Peninsula imply some interesting variations which are suggested to be consistent with several major environmental changes at that time, such as the opening of the Sea of Japan ; the "Mid-Neogene climatic optimum" and the following climatic deterioration. The present study also exhibits that the pollen data can be taken as one of the substantial approaches to reflect the paleoenvironment.

The Miocene floras of the Oga Peninsula of Japan and Northern China share many common points each other. However, regional development of the floras became more and more distinct as a result of the complete opening of the Sea of Japan in the Middle Miocene. Since then, the flora in Japan is under the prevailing marine climate, while the one in China still under the intensified continental condition.

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References

(1) Yamanoi, T. : Neogene pollen stratigraphy of the Oga Peninsula, Northeast Honshu, Japan (in Japanese with English abstract). *Jour. Geol. Soc. Japan,* 84, 69-86 (1978).

(2) Matoba, Y., A. Tomizawa and K. Fukasawa : Neogene and Quaternary sedimentary sequences in the Oga Peninsula. Guidebook for Field Trip No.2 of Benthos'90, the Fourth International Symposium on Benthic Foraminifera, Sedai, Japan, 62p. (1990).

(3) Chiji, M. and Japan National Working Group of IGCP-246 : Opening of the Sea of Japan, in time and space. Fifth International Congress on Pacific Neogene Stratigraphy and IGCP-246 "Pacific Neogene : Evolution and Events", Abstract Volume, Shizuoka, Japan, 14-15 (1991).

(4) Huzioka, K., T. Inoue, T. Takayasu, H. Kano, S. Honda and T. Kano : Geology of the Oga Peninsula, Akita Prefecture. Guidebook of the geological excursion at the 61st Annual Meeting of Geol. Soc. Japan, Akita (Ed. T. Inoue), 1-30 (1954).
(5) Kanaya, T. : Miocene diatom assemblages from the Onnagawa Formation and their distribution in the correlative formations in northeast Japan. *Sci. Rep., Tohoku Univ.*, 2nd Ser. (Geol.), **30**, 1-130 (1959).
(6) Demarcq, J. A. : Paleothermic evolution during the Neogene in Mediterranean through the marine megafauna. VIIIth RCMNS Congress (Abstract), 176-178 (1985).
(7) Murphy, M. G. and J. P. Kennett : Development of latitudinal thermal gradients during the Oligocene : Oxygen-isotope evidence from the Southwest Pacific. Initial Reports of Deep Sea Drilling Project, XC, 1347-1360 (1985).
(8) Zhao, Y.-N., X.-Y. Sun and D.-N. Wang : Tertiary sporopollen assemblages from Shache and Kuche Basin, Xinjiang (in Chinese with English abstract). *Bull. Inst. Geol. Chin. Acad. Geol. Sci.*, **4**, 95-116 (1982).
(9) Sun, X.-Y., Y.-N Zhao. and Z.-S. He : The Oligocene-Miocene palynological assemblages from the Xining-Minghe Basin, Qinghai Province (in Chinese with English abstract). *Geol. Rev.*, **30** : 207-216 (1984).
(10) Wang, W.-M. and D.-H. Zhang : Tertiary sporo-pollen assemblages from the Shangdou-Huade Basin, Inner Mongolia — with discussion on the formation of the steppe vegetation in China (in Chinese with English abstract). *Acta Micropalaeontologica Sinica*, **7**, 239-252 (1990).
(11) Huzioka, K. : Two Daijiman floral types in the inner zone of northeastern Japan (in Japanese abstract). *Jour. Geol. Soc. Japan*, **55**, 177 (1949).
(12) Huzioka, K. : The Aniai flora of Akita Prefecture, and the Aniai-type floras in Honshu, Japan. *Jour. Akita. Univ., Mining., Ser. A*, **3**, 1-105 (1964).
(13) Suzuki, T. : Fission track ages of the Tertiary volcanic rocks in the Oga Peninsula, northern Japan (in Japanese with English abstract). *Jour. Geol. Soc. Japan*, **86**, 441-453 (1980).
(14) Ganzawa, Y. : Fission track ages of volcanic rocks from Cretaceous to Tertiary in the inner belt of northeast Japan-Okushiri Island, Oga Peninsula and Asahi Mountains- (in Japanese with English abstract). *Jour. Geol. Soc. Japan*, **93**, 387-401 (1987).
(15) Nishimura, S. and S. Ishida. : Fission-track ages of tuffs of the Neogene Tertiary in Oga Peninsula, Akita Prefecture, Japan (in Japanese with English abstract). *Jour. Japan. Assoc. Miner. Petr. Econ. Geol.*, **67**, 166-168 (1972).
(16) Kimura, K. : Radiometric ages of the Tertiary formation in northeast Honshu, Japan (in Japanese). *Chikyu Monthly*, **8**, 370-375 (1986).
(17) Tsuchi, R. : Neogene events in Japan and southeast Asia. The Annual Technical Meeting 1989 and IGCP-246. Department of Geological Sciences, Chiang Mai University, Thailand, 169-177 (1991)
(18) Sato, S. : On the so-called "Mid-Neogene climatic optimum" in Japan (in Japanese with English abstract). *Fossil*, **53** : 7-19 (1992).
(19) Blow, W. H. : Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967, vol. 1 (Eds. P. Brönimann and H. H. Renz). E. J. Brill, Leiden, Netherlands, 199-422 (1969).
(20) Saito, T. and S. Maiya : Planktonic foraminifera of the Nishikurosawa Formation, northeast Honshu, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, **91**, 113-125 (1973).
(21) Fujioka, N., T. Ohguchi, S. Maiya, M. Usuda and K. Baba : On the sediments of Daijima-

Nishikurosawa age in the northeast inner Japan area (in Japanese with English abstract). *Journal of the Japanese Association of Petroleum Technologists,* **46**, 11-26 (1981).

(22) Yanagisawa, Y. : Evolution of Neogene diatom flora and its relation to paleoceanographic events (in Japanese with English abstract). Neogene Biotic Evolution and Related Events, Osaka Museum of Natural History, Special Publication, 17-20 (1988).

(23) Yamanoi, T. : The palyno-flora of early Middle Miocene sediments in the Pohang and Yangnam Basins, Korea. Centenary of Japanese Micropaleontology, Terra Sci. Pub. Tokyo, 473-480 (1992).

(24) Koizumi, I. and Y. Matoba : On the top of the Nishikurosawa Stage. The Memories of the Geological Society of Japan, 32, 187-195 (1989).

(25) Song, Z.-C. and W.-M. Wang : Neogene flora and its environment in Northeast Asia. Pacific Neogene Events in Time and Space, Contributions to the West Pacific (Ed. R. Tsuchi). Secretariat IGCP-246, Shizuoka University, Japan, 27-44 (1994).

(26) Liu, G.-W. : Neogene palynologycal sequence of Northern China (in Chinese with English abstract). *Acta Palaeontologica Sinica,* **27**, 75-90 (1988).

(27) Wang, H.-T. : On the discovery of the late Tertiary sporo-pollen assemblage in the brown-coal beds of Tianchen Region and its significance (in Chinese with English abstract). Acta Sci. Nat. Univ. Pekinensis, **4** : 89-110 (1978).

(28) Sung, Z.-C. : Miocene sporo-pollen complex of Shanwang, Shantung. *Acta Palaeontologica Sinica,* **7** : 99-109 (1959).

(29) Liu, G.-W. and E. B. Leopold : Paleoecology of a Miocene flora from the Shanwang Formation, Shandong Province, Northern East China. *Palynology,* **16**, 187-212 (1992).

(30) Wang, W.-M. : Synthetic analyses and climatic comparison among the Neogene palynofloras of Northern China (in Chinese with English abstract). Proceeding of the Symposium on Geological and Geochemical Records of Environments and Environmental Changes in China. Guizhou Science and Technology Publishing House, 100-103 (1990).

(31) Yamanoi, T., W.-M. Wang and J-R. Li : A middle Miocene pollen flora of core CB-20, Southwest end of Bohai Sea. *Jpn. J. Palynol.*, **39** : 103-111 (1993).

(32) Yamanoi, T. : Pollen fossils for chronostratigraphy - its application to oil prospecting - (in Japanese with English abstract). *Jour. Japanese Assoc. Petrol. Technologists,* **48**, 93-96 (1983).

(33) Chiji, M. and Japan National Working Group of IGCP-246 : Paleogeography and environments during the opening of the Sea of Japan. Pacific Neogene Events, Their Timing, Nature and Interrelationship (Ed. R. Tsuchi). University of Tokyo Press, 161-169 (1990).

男鹿半島における中新世の花粉群集に関する新知見と北部中国の花粉群集

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日本列島は新第三系の発達が良好な地域であり、とくに東北日本の男鹿半島では一連の新第三系が連続的に露出している。このことから男鹿半島は東北日本の新第三系の模式地として種々の研究がなされてきた。大型植物化石の研究では、中新世の暖温な台島型植物群の模式地として知られている。花粉化石は山野井（1978）によって一連の新第三紀の層序との関連で研究されたが、下位の地層の中新世中期の門前層、台島層、西黒沢層の花粉分析層準の数は必ずしも十分ではなかった。これを補うべく、中新統の試料を集め（Fig. 1)、花粉分析を行った。その結果は Fig. 2, 3 に示されている。これらの花粉組成を検討した結果、層序と古気温との関係は Fig. 4 にまとめたとおりである。すなわち、climatic optimum は陸成の台島層中に認められ、この時期は 16 Ma 頃と考えるのが妥当であり、その後、西黒沢層の海進期には気温が低下していく傾向が認められた。こうした結論は同層準の花粉を扱った佐藤（1992）の見解を否定するものであることにも言及した。さらに、男鹿と北部中国の花粉群集を比較した結果、中新世中期までは共通点が多いが、その後、日本海が拡大した時点では、日本の植生は海洋気候的であったのに対し、中国のそれは大陸性の気候の強まりを反映した植生となった。