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The Oligocene Noda Flora from the Yuya-wan Area of the Western End of Honshu, Japan. Part 2*

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Abstract The Noda flora of 34 species consists mainly of broad-leaved deciduous trees with an admixture of some broad-leaved evergreen trees and a conifer *Glyptostrobus*. It consists of extant genera except for *Litseaphyllum* and *Leguminosites*, and has several species recorded from the Miocene rocks in East Asia. A few species, *Berberis saseboensis*, *Populus eowightiana* and *Alnus prenepalensis*, are characteristic in Paleogene floras. The Noda flora shows a modernized aspect, being similar to the Daibo flora from the upper part of the Noda Group and also to the Daijima-type floras (late Early to earliest Middle Miocene) in its composition and components. The Ainoura flora in Kyushu, formerly referred to represent the earliest Miocene, is considered to be nearly contemporaneous with the Noda flora, although differs in dominant species and other floral features. The floral, megafaunal, micropaleontological and radiometric evidences indicate that the Noda flora is assigned to be Late Oligocene in age.

In the previous paper (TANAI and UEMURA, 1991), we described plant megafossils of the Noda flora from the Kiwado Formation in Yamaguchi Prefecture. In this Part 2, we discuss the characteristics of floral composition, relations to other fossil floras and age of the Noda flora.

Composition of the Noda Flora

We distinguished 34 species, distributed in 19 families and 27 genera, among the specimens (about 200 in number) from the Kiwado Formation. Except for one conifer, the Noda flora is composed of dicotyledonous species (Table 1).

Among the 33 dicotyledons (Magnoliopsida) the subclass Hamamelididae is dominant with 13 species. Subclasses Rosidae (9 species) and Dilleniidae (8 species) are also main components. Of the 19 families, the Fagaceae, Betulaceae and Salicaceae are predominant in having 3 species each. All the Noda genera are now growing in Japan, except for two exotic genera (*Glyptostrobus* and *Liquidambar*) and two genera (*Litseaphyllum* and *Leguminosites*).

The numerical representation of the Noda species is not available, but *Berberis saseboensis*, *Ulmus* sp. cf. *U. carpinoides*, *Quercus miovariabilis* and *Alnus prenepalensis* seem to be dominant or common representatives so far as the collection at hand is

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Table 1. Composition of the Noda Flora

- Division Coniferophyta
  - Class Coniferopsida
    - Order Taxodiales
      - Family Taxodiaceae
        - *Glyptostrobus europaeus* (BRONGNIART) HEER
- Division Magnoliophyta
  - Class Magnoliopsida
    - Subclass Magnoliidae
      - Order Laurales
        - Family Lauraceae
          - *Lindera* sp.
          - *Litseaphyllum* sp.
    - Subclass Ranunculidae
      - Order Ranunculales
        - Family Berberidaceae
          - *Berberis saseboensis* TANAI
    - Subclass Hamamelididae
      - Order Cercidiphyllales
        - Family Cercidiphyllaceae
          - *Cercidiphyllum* sp.
      - Order Hamamelidales
        - Family Hamamelidaceae
          - *Hamamelis* sp. cf. *H. protojaponica* TANAI et N. SUZUKI
          - *Liquidambar* sp. cf. *L. miosinica* HU et CHANEY
      - Order Urticales
        - Family Ulmaceae
          - *Ulmus longifolia* UNGER
          - *Ulmus* sp. cf. *U. carpinoides* GOEPPERT
      - Order Fagales
        - Family Fagaceae
          - *Lithocarpus* sp.
          - *Quercus miovariabilis* HU et CHANEY
          - *Quercus nagatoensis* TANAI et UEMURA
        - Family Betulaceae
          - *Alnus prenepalensis* HU et CHANEY
          - *Alnus* sp.
          - *Carpinus* sp.
      - Order Juglandales
        - Family Juglandaceae
          - *Pterocarya* sp.
          - *Carya* sp.
    - Subclass Dilleniidae
      - Order Theales
        - Family Theaceae
          - *Eurya* sp.
          - *Stewartia* sp.
      - Order Salicales
        - Family Salicaceae

Populus eowightiana (ENDO) TANAI et UEMURA
Populus sp. cf. *P. balsamoides* GOEPPERT
Salix sp.
Order Ericales
Family Ericaceae
Rhododendron hekiense TANAI et UEMURA
Rhododendron sp.
Order Ebenales
Family Ebenaceae
Diospyros miokaki HU et CHANEY
Subclass Rosidae
Order Rosales
Family Rosaceae
Rosa okamotoi TANAI et UEMURA
Rosa usyuensis TANAI
Order Fabales
Family Fabaceae (Leguminosae)
Leguminosites sp.
Sophora miojaponica HU et CHANEY
Order Myrtales
Family Lythraceae
Lagerstroemia imamaurae TANAI et UEMURA
Order Sapindales
Family Sapindaceae
Sapindus tanaii ONOE
Family Aceraceae
Acer rotundatum HUZIOKA
Acer sp. cf. *A. tricuspidatum* BRONN
Order Cornales
Family Alangiaceae
"*Alangium*" *aequalifolium* (GOEPPERT) KRYSHTOFOVICH et BORSUK

concerned. All the Noda species are supposed to have a woody growth habit, as presumed from the most similar living species and from the preservation of fossil leaves. The Noda specimens are represented by leaves, leaflets or foliage shoots. The absence of reproductive organs and herbaceous plants may be due to the small sample size and possibly to a taphonomic bias.

Of the 33 dicotyledons, 12 species (36%) have entire-margined leaves and at least 5 species (*Litseaphyllum* sp., *Lithocarpus* sp., *Quercus miovariabilis*, *Q. nagatoensis*, and *Eurya* sp.) have a thick (coriaceous) texture.

From the floral composition and other features noted above, the Noda flora is considered to have originated from the broad-leaved deciduous forest mixed with some evergreen broad-leaved trees. As the plant fossil bearing Kiwado Formation is largely shallow marine in origin, the broad-leaved deciduous forest appears to have covered lowland to succeeding montane slopes, where the warm-temperate climate was prevailed with moderate to ample rainfalls. The abundance of *Ulmus*, *Quercus* (*Q.*

miovariabilis) and *Alnus*, and an occurrence of *Liquidambar*, *Pterocarya*, *Carya*, *Populus*, *Salix*, and "*Alangium*" accompanied by some supposed shrubs or small trees of *Berberis*, *Rhododendron*, *Salix* and Fabaceae, indicate that the Noda flora is characterized by elements of stream/lake border and more or less open, sunny stands.

Comparison with Other Floras

Paleogene floras in Japan have been described in the late 1960's and early 1970's: MATSUO (1967, 1970, 1971 and others), ENDO (1968), TANAI (1970), HUZIOKA and TAKAHASI (1970). These floras, which were assigned by each author to be Oligocene or Eocene in age, are mostly dated the Eocene in a recent bio- and chronostratigraphic framework (for example, TANAI, 1990). Hence, up to the present the knowledge of Oligocene floras in Japan has been meager in comparison with those of Eocene and Miocene ages.

Comparison with floras in Yuya-wan area

As noted in Part 1, plant megafossils are found in three horizons of the Hioki Group in the Yuya-wan area: the assemblage from the Jyuraku Formation, Noda flora from the Kiwado Formation and Daibo flora from the Hitomaru Formation in ascending order. The comparison is made in the following lines with the previously published account for the Noda flora, and with the Daibo flora and the assemblage from the Jyuraku Formation.

The plant megafossils collected by Okamoto and Imamura from the Kiwado Formation were identified by Endo, and 50 species are listed (table 4 in OKAMOTO and IMAMURA, 1964). These are all dicotyledons distributed in 19 families and 30 genera, and include 20 taxa that were specifically determined or compared to the previously described species. Our taxonomic study based on the same collection, however, is beyond minor correction of Endo's identification; for example, 20 specific name bearing taxa identified by Endo are correlated to our revision as shown in Table 2, although some specimens are lost in the collection.

Prior to OKAMOTO and IMAMURA (1964), IMAMURA (1958) asserted that the Noda flora is of Oligocene age, because the flora contains many Paleogene species such as *Populus zadachii* HEER?, *Engelhardia* cf. *brongniartii* ETTINGSHAUSEN, *Quercus* cf. *groenlandica* HEER, *Broussonetia* cf. *imaii* ENDO, *Cercidiphyllum eojaponicum* ENDO, *Platanus aceroides* GOEPPERT, *Acer arcticum* HEER and *Viburnum nordenskioeldii* HEER?. However, we could determine only one Paleogene species, *Populus eowightiana*, which is commonly found in the Eocene Ishikari Group of Hokkaido. Although we cannot accept most of ENDO's taxonomic determination, we arrive at a same conclusion on dating for the Noda flora as that IMAMURA asserted.

The flora from the upper part of the Hioki Group is called the Daibo flora, in which HUZIOKA (1974) described 41 species in 22 families and 31 genera. The Daibo flora is clearly similar to the Noda flora in floral composition, consisting mainly of

Table 2. Status of specific revisions of the Noda flora

ENDO (in OKAMOTO and IMAMURA, 1964)	TANAI and UEMURA, 1991
Populus zadachii HEER?	*Cercidiphyllum* sp.
Engelhardia cf. *brongniartii* ETTINGSHAUSEN	(indeterminable, probably leaf fragment of *Acer*)
Juglans nigella HEER?	*Pterocarya* sp.
Juglans? sp. (Cf. *J. acuminata* BRAUN)	*Lagerstroemia imamurae* TANAI et UEMURA
Betula brongniarti ETTINGSHAUSEN?	*Ulmus carpinoides* GOEPPERT
Castanea kubinyi KOVATS	*Quercus miovariabilis* HU et CHANEY
Castanea ungeri HEER	*Quercus miovariabilis* HU et CHANEY
Fagus antipofi HEER	*Quercus miovariabilis* HU et CHANEY
Fagus? sp. (Cf. *F. antipofi* HEER)	*Carpinus* sp., *Quercus miovariabilis* HU et CHANEY
Quercus cf. *groenlandica* HEER	(missing)
Quercus lyellii HEER?	(*Litseaphyllum* sp.)
Broussonetia cf. *imaii* ENDO	*Populus ewightiana* (ENDO) TANAI et UEMURA
Ficus tiliaefolia HEER	"*Alangium*" *aequalifolium* (GOEPPERT) KRYSHTOFOVICH et BORSUK
Ficus cf. *tiliaefolia* HEER	"*Alangium*" *aequalifolium* (GOEPPERT) KRYSHTOFOVICH et BORSUK
Cercidiphyllum eojaponicum ENDO	*Cercidiphyllum* sp.
Platanus aceroides GOEPPERT	(missing)
Acer arcticum HEER	(indeterminable, probably leaf fragment of Vitaceae?)
Acer pictum THUNB.	*Acer rotundatum* HUZIOKA
Celastrophyllum cf. *crenatum* HEER	(missing)
Rhamnus cf. *rossaessleri* UNGER	(missing)
Viburnum nordenskioeldii HEER?	*Hamamelis* sp. cf. *H. protojaponica* TANAI et N. SUZUKI

broad-leaved deciduous trees mixed with some conifers and evergreen broad-leaved trees. The percentage of entire-margined dicot leaves (34%) in the Daibo flora approximates that of the Noda flora (36%). Of the 34 Noda species, the following species are common or closely similar to the Daibo taxa: *Lindera* sp., *Liquidambar* sp. cf. *L. miosinica*, *Ulmus longifolia*, *U.* sp. cf. *U. carpinoides*, *Pterocarya* sp., *Leguminosites* sp., *Acer rotundatum* and "*Alangium*" *aequalifolium*.

HUZIOKA (1974) concluded that the Daibo flora is most similar to the late Early to earliest Middle Miocene Daijima-type floras of Honshu, differing much from the "Noda flora" of OKAMOTO and IMAMURA (1964) in having many warm-temperate elements and a large number of species known from the Miocene floras. He thus suggested that a distinct break in floral sequence may be present between the Noda and Daibo floras. However, the difference between the composition of these two floras is minor as our present study reveals.

It is evident that both the Noda and Daibo floras have a modern aspect in their floral composition. Indeed, they are hardly distinguished from Miocene floras of

Japan, especially from the Daijima-type floras, so far as the genus composition is concerned. Furthermore, they contain many species that have been reported from the Miocene rocks.

Plant megafossil assemblages from the Jyuraku Formation in the lower part of the Noda Group include *Osmunda* (evergreen), *Pinus* (3-needled), *Sequoia*, *Metasequoia*, *Thuja*, *Laurophyllum*, *Zelkova*, *Quercus* (evergreen), *Comptonia*, *Engelhardia* (TANAI and UEMURA, 1983), *Leguminosites*, *Acer*, and others. The assemblage, although small in sample size, is characterized by many coniferous taxa and relative abundance of *Pinus* and evergreen *Quercus*. Compared with the Noda and Daibo floras, the assemblage from the Jyuraku Formation commonly contains evergreen plants indicating more warmer climate.

Comparison with the Ainoura flora

In the Sasebo and Karatsu coal fields of Northwest Kyushu, the coal-bearing Sasebo Group conformably overlies the Kishima Group which yields the Ashiya molluscan fauna. The Ainoura flora is from the Ainoura Formation, the lowest part of the Sasebo Group. The Ainoura flora of the Sasebo coal field consists principally of Miocene temperate species, including some warmer elements and Paleogene species of *Nelumbo nipponica*, "*Acer*" *arcticum* and *Alangium basiobliquum* (=*Plafkeria basiobliqua*); it has been regarded to represent the earliest Miocene flora (TANAI and ONOE, 1956; TANAI, 1961).

Followed the recent scheme of Tertiary chronostratigraphy, we reinterpret the Ainoura flora to be Late Oligocene in age: 1) the Ainoura flora contains "Paleogene" species noted above, 2) *Taxodium* remains in Japan is confined to the Paleogene as reviewed by UEMURA (1990), 3) judging from the floral composition and component, the Ainoura flora is older than the early Early Miocene Aniai-type flora and younger than the Late Eocene or earliest Oligocene Kishima flora (MATSUO, 1971) in the Karatsu coal field, 4) fission track age (29.4 Ma) for the Ainoura Formation (KIMURA and TSUJI, 1990) indicates early Late Oligocene age, and 5) biostratigraphic evidence of planktonic formainifers and nannofossils for the underlying and overlying marine rocks (SAKAI *et al.*, 1990; OKADA, 1991) is consistent with the above interpretation.

The floral composition of the Noda flora differs from that of the Ainoura flora, although these two floras might be expected to be contemporaneous. The Ainoura flora represents a less diverse, lowland vegetation which occupied just behind the coal-forming basin, as evidenced by the dominance of *Alnus*, together with *Glyptostrobus* and *Taxodium*. According to the floral list by the senior author (TANAI, 1961), the Ainoura flora lacks evergreen representatives and is composed mainly of temperate elements. Relatively low representation of entire-margined dicots (24%) also supports the temperate aspect of the flora. However, the common occurrence of *Alnus preneplaensis* and *Berberis saseboensis* in the Noda flora is noteworthy, because these two species were only known from the Ainoura Formation in Japan. *Alnus prenepalensis* was first recorded from the Miocene Shanwang flora in China, but no

subsequent record has been known from the Miocene rocks in Japan.

Both the Noda and Ainoura floras show a younger or modernized aspect in their floral compositions and components, consisting of extant genera except for some genera such as *Litseaphyllum* and *Leguminosites*. A common association of "Miocene" species is also characteristic to both the floras. As the floral difference between the two floras is due in part to depositional and ecological factors, we interpret that both the floras are nearly contemporaneous within the Late Oligocene.

Comparison with other Paleogene floras

The Late Ecoene or earliest Oligocene floras are known in Northwest Kyushu by several authors: the Sakito flora in the Sakito-Matsushima coal field and the Kishima flora in the Karatsu coal field. These floras consist typically of Paleogene type species of woody dicots such as *Zelkova kushiroensis* ("*Z. serrata* MAKINO *fossilis*"), *Liquidambar* sp. ("*L. formosana* HANCE") and others (species in parentheses are those of MATSUO, 1970, 1971), including commonly Paleogene species such as *Nelumbo nipponica* (ENDO, 1934; MATSUO, 1970, 1971), *Musophyllum nipponicum* (ENDO, 1931) and *Sabalites nipponicus* (YAMASAKI, 1952; ENDO, 1953). Although these two floras need to reinvestigate by a further much collection and taxonomic revision, they are apparently distinguishable from the Noda flora in having many older taxa and warmer floral composition.

The Oligocene floras which contain *Engelhardia* and *Quercus ussuriensis* have been known from Hokkaido, North Korea and Primorye; these floras have a temperate composition including a number of Miocene relatives. In our previous paper describing *Engelhardia* (TANAI and UEMURA, 1983), these *Engelhardia*-bearing floras were assigned to be Late Oligocene in age, but they are recently assignable, if not all, to the Early Oligocene (see TANAI, 1990, for the Wakamatsuzawa flora in Hokkaido). A comparison of the Noda flora with these Oligocene *Engelhardia*-bearing floras is requisite to understand the history of the modernized Oligocene floras and vegetations in East Asia; it is, however, premature because taxonomic investigation for Oligocene floras have been incomplete.

TAKAHASHI (1961, 1963a, b) classified the Paleogene and "Early Miocene" palynofloras into five zones in North Kyushu and western end of Honshu. The youngest zone, the Sasebo pollenflora, includes the assemblages from the Hioki, Ashiya and Kishima (excluding lowermost part, the Kishima Formation) groups. He states that a major change in palynomorph component and composition is recognized between the Sasebo and the underlying four pollenfloras. The palynological fact is consistent with our result that Oligocene floras such as the Noda and Ainoura floras show the modernized aspect in composition and components. In other word, the "Neogene-type" floras appeared in the Oligocene, differing much from the Eocene floras.

In the preceding discussion, it is evident that the Noda flora is closely similar to the Daibo flora in the floral composition. These two floras show the modern aspect, resembling Neogene floras in genus or some species composition. Except for some

components such as *Alnus prenepalensis*, *Populus eowightiana*, *Berberis saseboensis* and others, the overall similarity to the Daijima-type floras of late Early to earliest Middle Miocene is noteworthy. Although somewhat different in floral composition, the Noda flora is also related to the Late Oligocene Ainoura flora in Kyushu.

Geologic Age

Beside the floral evidence, some age discussions are followed below by megafaunal, micropaleontologic and radiometric evidences. The plant bearing Kiwado and overlying Taoyama formations yield the Ashiya molluscan fauna (OKAMOTO, 1965, and others). Controversial opinions have been shared as to the age of the Ashiya molluscan fauna: some regarded as the Late Oligocene and others as the Early Miocene. Recent micropaleontologic works indicate, however, that the Ashiya Group containing the type Ashiya fauna is confined to the Oligocene: the Group is correlative with the planktonic formainifer zone P21 (latest Early Oligocene; TSUCHI *et al.*, 1987) and nannofossil zone CP19 (latest Early Oligocene to Late Oligocene; OKADA, 1991). Moreover, it becomes evident that the Ashiya type fauna is not wholly synchronous, tending to indicate older ages toward the west in Kyushu (OKADA, 1991). Planktonic microfossils from the Noda Group have not been studied in detail, but FUSE and KOTAKA (1986) reported a nannofossil *Dictyoccocites bisectus* from the Taoyama Formation, indicating the late Paleogene.

Fission track ages for the Kiwado Formation of the Noda Group were obtained by MURAKAMI *et al.* (1989) and KIMURA and TSUJI (1990): 27.2 Ma and 24.5 Ma, respectively. These dates are within the Late Oligocene according to the time scale of BERGGREN *et al.* (1985).

From these evidences, we refer the Noda flora of the Kiwado Formation to be Late Oligocene in age, though the precise age within it is open to the future works. Except for plants and brackish water molluscs, there is no age-indicating evidence for the Daibo flora from the Hitomaru Formation. It is suggested, however, that the Daibo flora is not far from the age of the Noda flora, judging from the closely similar composition.

Conclusion

The Noda flora is preserved in the Kiwado Formation of the Noda Group, which is largely shallow marine in origin and contains rich molluscan fossils called the Ashiya fauna. The Noda flora is made up of 34 species in 19 families and 27 genera. The majority of the Noda genera is extant, except for *Litseaphyllum* and *Leguminosites*. The Noda flora has several species recorded from Miocene floras in East Asia, and is especially similar to the late Early to earliest Middle Miocene Daijima type floras in Japan in its composition and components. While a few species, *Berberis saseboensis*, *Populus eowightiana* and *Alnus prenepalensis*, are characteristic in Paleogene floras.

Of the 33 dicotyledons, 12 species (36%) have entire-margined leaves. The Noda flora is considered to have originated from the broad-leaved deciduous forest mixed with evergreen broad-leaved trees. The modernized aspect of the Noda flora in the composition and components is common to the Daibo and Ainoura floras; these three floras probably represent Late Oligocene floras.

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Appendix

HUZIOKA (1974) indicated the depository of the registered specimens of the Daibo flora in the Institute of Mining Geology, Mining College, Akita University, Akita (AKMG). These specimens removed to keep under the collection of the Institute of Geology, Faculty of Science, Hiroshima University, Hiroshima (IGSH-Dib).