

Plant megafossils from the Pliocene Toki Sand and Gravel Formation in and around Ena City, Gifu Prefecture, central Japan

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岐阜県恵那市周辺の土岐砂礫層から産出する鮮新世の大型植物化石

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抄録：岐阜県恵那市周辺の土岐砂礫層から産出する大型植物化石群集を記載した。この大型植物化石群集は、19科、26属、30種からなり、7種の針葉樹と23種の双子葉植物から構成される。また、多くの外地生種や暖温帯から亜熱帯に分布する温暖な要素を含み、絶滅属を含まないことから、鮮新世の大型植物化石群集と考えられる。

Abstract: Plant megafossils from the Pliocene Toki Sand and Gravel Formation in and around Ena City in central Japan are described. The plant megafossil assemblages from this Formation are composed of 7 coniferous species and 23 dicotyledonous species, distributed among 19 families and 26 genera. These plant megafossil assemblages include both exotic and warm elements, but no extinct genera. The age of the assemblages can be assigned to the Pliocene.

Key Words: Plant megafossil; Pliocene; Toki Sand and Gravel Formation; Gifu Prefecture.

Introduction

The upper Cenozoic Tokai Group is one representative of fluvio-lacustrine sedimentation in Japan, and is distributed around Ise Bay. The Tokai Group generally contains abundant plant megafossils, but the upper formation of the group in Gifu Prefecture has almost no plant megafossils. We report and describe new plant megafossil occurrences from this formation (named the Toki Sand and Gravel Formation). In addition, we show that the plant megafossil assemblages contain both exotic and warm elements which disappeared during the Late Miocene to Pliocene in Japan, but no extinct genera.

The Tokai Group is geographically divided into three "Groups", "The Seto Group" in the northeastern coastal area of Ise Bay, "the Tokoname Group" of the Chita Peninsula, and "the Age Group" in the western coastal area of Ise Bay. The Seto Group is divided into the Seto Porcelain Clay Formation and the overlying Yadagawa Formation in Aichi Prefecture. "The Seto Group" in Gifu Prefecture consists of the lower Tokiguchi Porcelain Clay Formation and the upper Toki Sand and Gravel Formation. The Seto Porcelain Clay Formation and the Yadagawa Formation are

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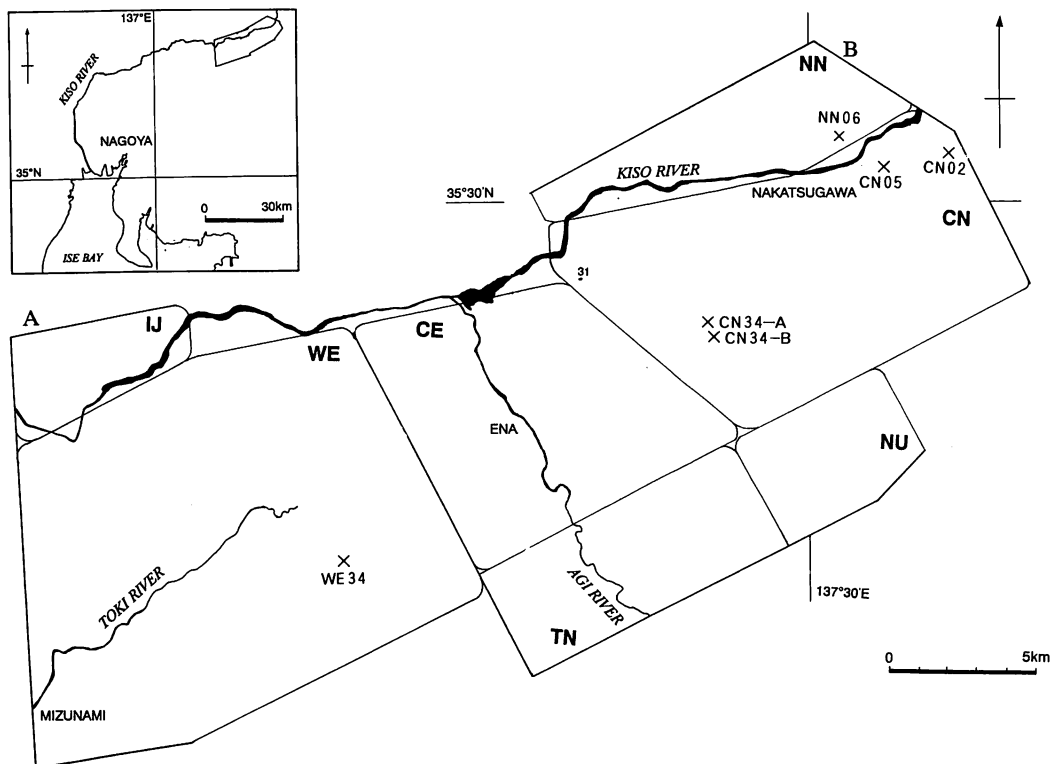


Fig. 1. Plant megafossil localities. NN, Northern Nakatsugawa area; CN, Central Nakatsugawa area; NU, Nenoue plateau area; CE, Central Ena area; TN, Tono Grassland area; WE, Western Ena area; IJ, Iiji plateau area.

correlated with the Tokiguchi Porcelain Clay Formation and the Toki Sand and Gravel Formation, respectively.

Both porcelain clay formations contain numerous plant megafossils (Miki, 1939, 1941, 1963; Ozaki, 1991). Miki (1941) named these porcelain clay formations as "*Pinus trifolia* bed", and assigned them to Pliocene age. Tanai (1961) and Kokawa (1961) called the flora from the *Pinus trifolia* bed as "*Pinus trifolia* flora", and Tanai (1961) assigned the flora to indicate the Late Miocene to Early Pliocene. Regardless of age, the *Pinus trifolia* flora is the oldest one of the Tokai Group (Kokawa, 1961; Nasu, 1972; Onishi, 1978; Ozaki, 1991). In spite of many reports and descriptions on the plant megafossils from the lower Seto and Tokiguchi Porcelain Clay Formations, there have been few megafossils studied from the upper Toki Sand and Gravel Formation, because the upper formation is composed mainly of gravel beds, and has few lensoid bodies or thin beds of fine clastics containing plant megafossils. Tsukagoshi (1992b) summarized the available data on the stratigraphic distribution of plant megafossils from the Tokai Group, and pointed out that the flora overlying *Pinus trifolia* flora was still poorly known.

Geological outline

The Seto Group in and around Ena City is the Toki Sand and Gravel Formation without the Tokiguchi Porcelain Clay Formation. The Group overlies bedrock composed of granitic rocks,

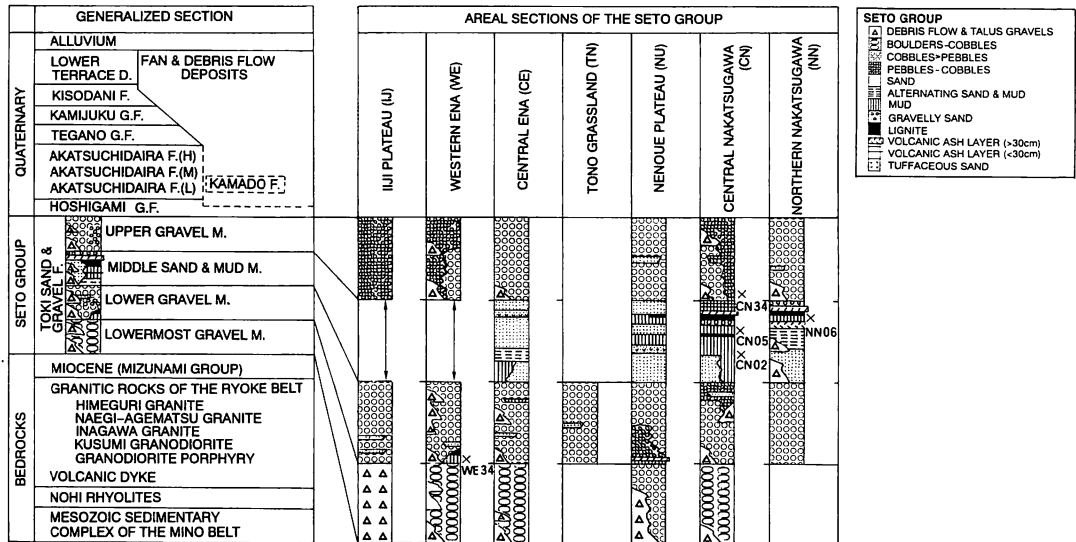


Fig. 2. Generalized geologic section of the Seto Group in and around Ena City and localities of plant megafossils (modified from Todo Collaborative Research Group, 1994). F, Formation; M, Member; D, Deposit.

rhyolitic rocks, Mesozoic sedimentary complexes, and Early to Middle Miocene of shallow marine deposits. The Seto Group is, in turn, overlain by Quaternary deposits.

The Todo Collaborative Research Group (1985, 1994) established the lithostratigraphy of the Toki Sand and Gravel Formation in and around Ena City. The formation is fluvial in origin, and is divided into the Lowermost Gravel, Lower Gravel, Middle Sand and Mud, and Upper Gravel Members in ascending order. The formation attains to 150 m in thickness, and contains several intercalation of volcanic ash layers. The remarkable Nakatsugawa I & II volcanic ash layer is intercalated in the upper part of the Middle Sand and Mud member. The Nakatsugawa I & II volcanic ash layer, whose fission track age is 3.3 ± 0.4 Ma (Todo Collaborative Research Group, 1985), has been correlated with the Ohtani and Togo volcanic ash layers distributed around the coastal area of Ise Bay (Nakayama *et al.*, 1994).

Localities of plant megafossils

We collected plant megafossils at 6 localities shown in Fig. 1, Fig. 2, Fig. 3 & Appendix. In this paper we follow locality numbers of Todo Collaborative Research Group (1994).

Loc. WE34: Lower Gravel Member. Outcrop locates on the riverside along the tributary of the Toki River at Sasaragi, Ena City. The outcrop is composed mainly of mud beds with intercalations of gravel and sand.

Loc. CN02: Middle Sand and Mud Member. Mud and lignite beds in roadside cliff at Ochiai, Nakatsugawa City.

Loc. CN05: Middle Sand and Mud Member. Outcrop is behind a house at Sangosawa, Nakatsugawa City. The outcrop consists of mud beds associated with gravel and lignite beds.

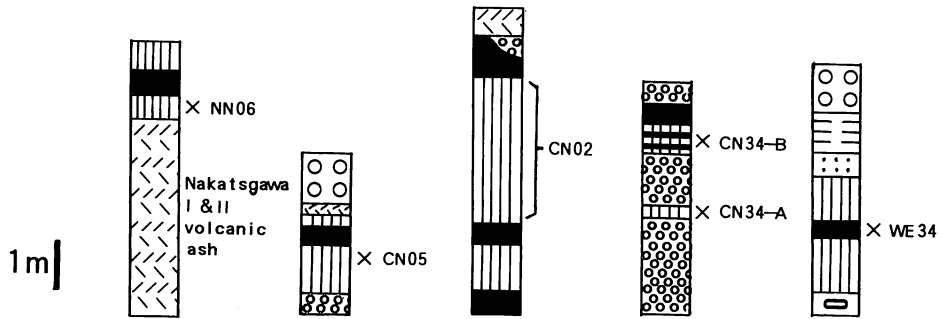


Fig. 3. Columnar section of plant megafossil locality. See the lithologic key in Fig. 2.

Loc. NN06: Middle Sand and Mud Member. Former mine of porcelain clay at Itabashi, Nakatsugawa City. Mud, lignite and Nakatsugawa I & II volcanic ash beds are exposed.

Loc. CN34: Upper Gravel Member. The cliff, comprising mainly gravel beds, is on the tributary of the Kiso River at Fukasawa, Nakatsugawa City. CN34-A is a mud lens in the lower part of cliff, and CN34-B is intercalation of alternating sand and mud beds in the upper part of the cliff.

All localities, apart from NN06, are new occurrences of plant megafossils. Miki (1956) described *Nyssa pachycarpa*, *Nyssa rugosa* and *Cunninghamia* sp. from NN06. Yamada and Murayama (1958) found *Sequoia sempervirens*, *Fagus* sp., *Fagara ailanthoides*, *Stewartia* cf. *monadelphica* and *Styrax microcarpa* at NN06. Onishi (1978) reported the occurrence of fossil pollen in this area. Three localities, SK-1, SK-2 and SK-3 of Onishi (1978), are located under the Nakatsugawa I & II volcanic ash layer. The pollen assemblages of these localities are characterized by abundance of *Taxodiaceae*, *Alnus*, *Fagus*, *Liquidambar* and *Nyssa*.

Compositional analysis

Plant megafossils from this area comprise 30 species, distributed throughout 19 families and 26 genera (Table 1). They are represented by 7 conifers and 23 dicotyledons. Loc. NN06 contains the greatest number of species and specimens (Table 1). This flora includes exotic and warm elements, associated with marsh plants (Table 2). An exotic element is a plant which disappeared from Japan and is extant in another country. A plant of warm element is distributed in warm-temperate to subtropical zones of East Asia. Stratigraphic changes of floras have not been determined because of the sparse occurrence of plant megafossil apart from Loc. NN06.

Exotic element: *Pseudolarix amabilis*, *Cunninghamia* sp., *Glyptostrobus pensilis*, *Metasequoia glyptostroboides*, *Liquidambar formosana*, *Fortunearia sinensis*, *Cyclocarya paliurus*, *Nyssa aspratilis*, *Nyssa pachycarpa*.

Warm element: *Glyptostrobus pensilis*, *Quercus gilva*, *Choerospondias axillaris*.

Marsh plant: *Glyptostrobus pensilis*, *Alnus japonica*, *Nyssa aspratilis*, *Nyssa pachycarpa*.

Table 1. Systematic list and occurrence of plant megafossils from the Toki Sand and Gravel Formation in and around Ena City.

Family	Species	WE34	CN02	CN05	NN06	CN34-A	CN34-B
Pinaceae	<i>Pseudolarix amabilis</i> (Nels.) Rheder (Cone scale)	×					
	<i>Pseudotsuga japonica</i> (Shirasawa) Beissner (Cone)					×	
	<i>Tsuga</i> sp. (Leaf)					×	
Taxodiaceae	<i>Cunninghamia</i> sp. (shoot)					×	
	(Leaf)					×	
	<i>Glyptostrobus pensilis</i> (Stout.) K.Koch (Cone)				×	(×)	
	<i>Metasequoia glyptostroboids</i> Hu et Cheng (Cone)						×
	(Shoot)	×					
Cupressaceae	<i>Thuja protojaponica</i> Miki (Shoot)					×	
Magnoliaceae	<i>Magnolia obovata</i> Thunb. (Endotesta)				×		
Hamamelidaceae	<i>Fortunearia sinensis</i> Rhed. et Wils. (Seed)		×				
	<i>Liquidambar formosana</i> Hance (Leaf)	×					
	(Fruit)				×		
Buxaceae	<i>Buxus microphylla</i> Sieb. et Zucc.						
	var. <i>japonica</i> (Muell.Arg.) Rhed. et Wils. (Leaf)					×	
Ulmaceae	<i>Zelkova ungeri</i> (Ettings.) Kovats (Leaf)	×					
Fagaceae	<i>Fagus microcarpa</i> Miki (Cupule)		×	×	×		
	(Fruit)			(×)	(×)		
	<i>Quercus gilva</i> Blume (Leaf)	×					
Betulaceae	<i>Alnus japonica</i> (Thunb.) Steud. (Infructescence)				×		
Juglandaceae	<i>Cyclocarya paliurus</i> (Batal.) Iljinsk. (Endocarp)				×		
Theaceae	<i>Stewartia monadelpha</i> Sieb. et Zucc. (Capsule)			×	×		
Styracaceae	<i>Styrax japonica</i> Sieb. et Zucc. (Seed)				×		
	<i>Styrax rugosa</i> Miki (Seed)				×		
	<i>Styrax</i> sp. A (Seed)				×		
	<i>Styrax</i> sp. B (Seed)		×		×		
Symplocaceae	<i>Symplocos myrtacea</i> Sieb. et Zucc. (Endocarp)	×					
Rutaceae	<i>Fagara ailanthoides</i> (Sieb. et Zucc.) Engler (Mesotesta)						×
Anacardiaceae	<i>Choerospondias axillalis</i>						
	(Roxb.) B.L.Burt et A.W.Hill (Endocarp)				×		
Staphyleaceae	<i>Euscaphis japonica</i> (Thunb.) Kanitz. (Mesotesta)				×		
Sabiaceae	<i>Meliosma</i> sp. cf. <i>M. rigida</i> Sieb. et Zucc. (Endocarp)				×		
	<i>Sabia japonica</i> Maxim. (Mesocarp)				×		
	<i>Nyssa aspratilis</i> Eyde et Barghoorn (Endocarp)				×		
Nyssaceae	<i>Nyssa pachycarpa</i> Miki (Endocarp)		×		×		
Vitaceae	<i>Vitis</i> sp. (Seed)	×			×		
	Total	7	4	2	17	5	2

Correlation

Tsukagoshi (1992b) reviewed the stratigraphic distribution of plant fossils from the Tokai Group (Fig.4) which can be divided into four compositions: Late Miocene (Loc. A), Late Miocene to Pliocene (Locs. B to E), Late Pliocene (Locs. F and G), and Late Pliocene to Pleistocene (Loc. H). Fossil flora from Loc. A is distinctive because of the occurrences of the extinct genera *Protosequoia*, *Distylopsis*, *Eotrapsa*, *Eoeuryale* and *Hemitrapsa*, the exotic element *Pinus trifolia* and *Melliodendron*, and the warm element *Lithocarpus*. This flora is the same as *Pinus trifolia* flora. Fossil floras from Locs. B to E are characterized by the disappearance of the extinct genera (apart from *Protosequoia*), exotic elements and warm elements of Loc. A. These floras are further characterized by the occurrences of the Late Miocene elements *Protosequoia*, *Paliurus protonipponicus* and *Liquidambar protopalmata*. Fossil floras from Locs. F and G. are characterized by the occurrences of the exotic elements *Nyssa*, *Sequoia*, *Pseudolarix* and *Liquidambar*, and the absence of *Protosequoia*, *Paliurus protonipponicus* and *Liquidambar protopalmata*. Characteristics of fossil flora from Loc. H are the disappearance of the exotic elements *Nyssa*, *Pseudolarix* and *Liquidambar*, and the occurrence of the cool-temperate element *Picea maximowiczii*.

Table 2. Geographical distribution and habitat of allied living species of plant megafossil from the Toki Sand and Grave Formation in and around Ena City

Fossil	Allied living species	Geographical distribution						Forest Zone ×: Japan △: East Asia				Habitat	Growth habit
		Japan					*Other area	Subalpine	Cool-temperate	Warm-temperate	Subtropical		
		Hokkaido	Honshu										
			North	Central	South	Shikoku							
<i>Pseudolarix amabilis</i> (Nels.) Rheder	<i>P. amabilis</i>						C						
<i>Pseudotsuga japonica</i> (Shirasawa) Beissner	<i>P. japonica</i>				×	×		×	×		Sl	t	
<i>Tsuga</i> sp.	?											t	
<i>Cunninghamia</i> sp.	<i>C. konishii</i> ,						T			△	Sl	t	
	<i>C. lanceolata</i>						C			△	Sl	t	
<i>Glyptostrobus pensilis</i> (Stout.) K. Koch.	<i>G. pensilis</i>						C			△	Ma	t	
<i>Metasequoia glyptostroboides</i> Hu et Cheng	<i>M. glyptostroboides</i>						C			△	Sl	t	
<i>Thuja protojaponica</i> Miki	?											t	
<i>Magnolia obovata</i> Thunb.	<i>M. obovata</i>		×	×	×	×		×	×		Sl	t	
<i>Fortunearia sinensis</i> Rehd. et Wils.	<i>F. sinensis</i>						C			△	Sl	t	
<i>Liquidambar formosana</i> Hance	<i>L. formosana</i>						C, T			△	Sl	t	
<i>Buxus microphylla</i> S. et Z. var. <i>japonica</i>	<i>B. microphylla</i> v. <i>japonica</i>			×	×	×	T	×	×		Sl	t	
<i>Zelkova ungeri</i> (Ettings.) Kovats	<i>Z. serrata</i>		×	×	×	×	C, T	×	×		Sl	t	
<i>Fagus microcarpa</i> Miki	?											t	
<i>Quercus gilva</i> Blume	<i>Q. gilva</i>				×	×	C, T		×		Sl	t	
<i>Alnus japonica</i> (Thunb.) Steud.	<i>A. japonica</i>	×	×	×	×	×	C, KO, U, T	×	×	×	Ma	t	
<i>Cyclocarya paliurus</i> (Batal.) Iljinsk.	<i>C. paliurus</i>						C			△	Sl	t	
<i>Stewartia monadelpha</i> Sieb. et Zucc.	<i>S. monadelpha</i>				×	×		×			Sl	t	
<i>Styrax japonica</i> Sieb. et Zucc.	<i>S. japonica</i>	×	×	×	×	×	KO	×	×	×	Sl	t	
<i>Styrax rugosa</i> Miki	?											t	
<i>Styrax</i> sp. A	?											t	
<i>Styrax</i> sp. B	?											t	
<i>Symplocos myrtacea</i> Sieb. et Zucc.	<i>S. myrtacea</i>				×	×			×		Sl	t	
<i>Fagara ailanthoides</i> (S. et Z.) Engler	<i>F. ailanthoides</i>			×	×	×	KO, C, T	×	×		Sl	t	
<i>Choerospondias axillaris</i> (Roxb.) Burt et Hill	<i>C. axillaris</i>					×	Tha, Him	×	×		Sl	t	
<i>Euscaphis japonica</i> (Thunb.) Kanitz.	<i>E. japonica</i>			×	×	×	T, C	×			Sl	t	
<i>Meliosma</i> sp. cf. <i>M. rigida</i> Sieb. et Zucc.	<i>M. rigida</i>			×	×	×	T, C				Sl	t	
<i>Sabia japonica</i> Maxim.	<i>S. japonica</i>					×	C	×			Sl	vs	
<i>Nyssa aspratilis</i> Eyde et Barghoorn	?						C, Him, Mal, NA			△	Ma	t	
<i>Nyssa pachycarpa</i> Miki	?						C, Him, Mal, NA			△	Ma	t	
<i>Vitis</i> sp.	?											vs	

*Other area: C, China; T, Taiwan; KO, Korea; U, Ussuri; M, Manchuria; Tha, Thailand; Him, Himalaya; Mal, Malaysia; NA, North America. Habitat: Sl, Slope; Ma, Marsh. Growth habit: t, tree; vs, viny shrub.

The plant megafossil assemblages from the Toki Sand and Gravel Formation in and around Ena City are characterized as follows: (1) Extinct genera such as *Eotrapa*, *Distylopsis*, *Eoeuryale*, *Hemitrapa* and *Pinus trifolia* do not occur. (2) There are many exotic elements of Locs. B to G. (3) *Picea maximowiczii*, characteristic of Loc. H, has not been found. The Nakatsugawa I & II volcanic ash layer is correlative with the Togo and Ohtani volcanic ash layers. Some plant megafossils e.g. *Liquidambar protopalmeta* and *Paliurus protonipponicus* at Loc. D of the Ohtani volcanic ash have not been discovered from the Toki Sand and Gravel Formation in the study area. Above these, the plant megafossil assemblages from the Toki Sand and Gravel Formation in and around Ena City are assigned to the Pliocene. Detailed correlation, however, is still impossible because floral changes in the Tokai Group have not been sufficiently clarified.

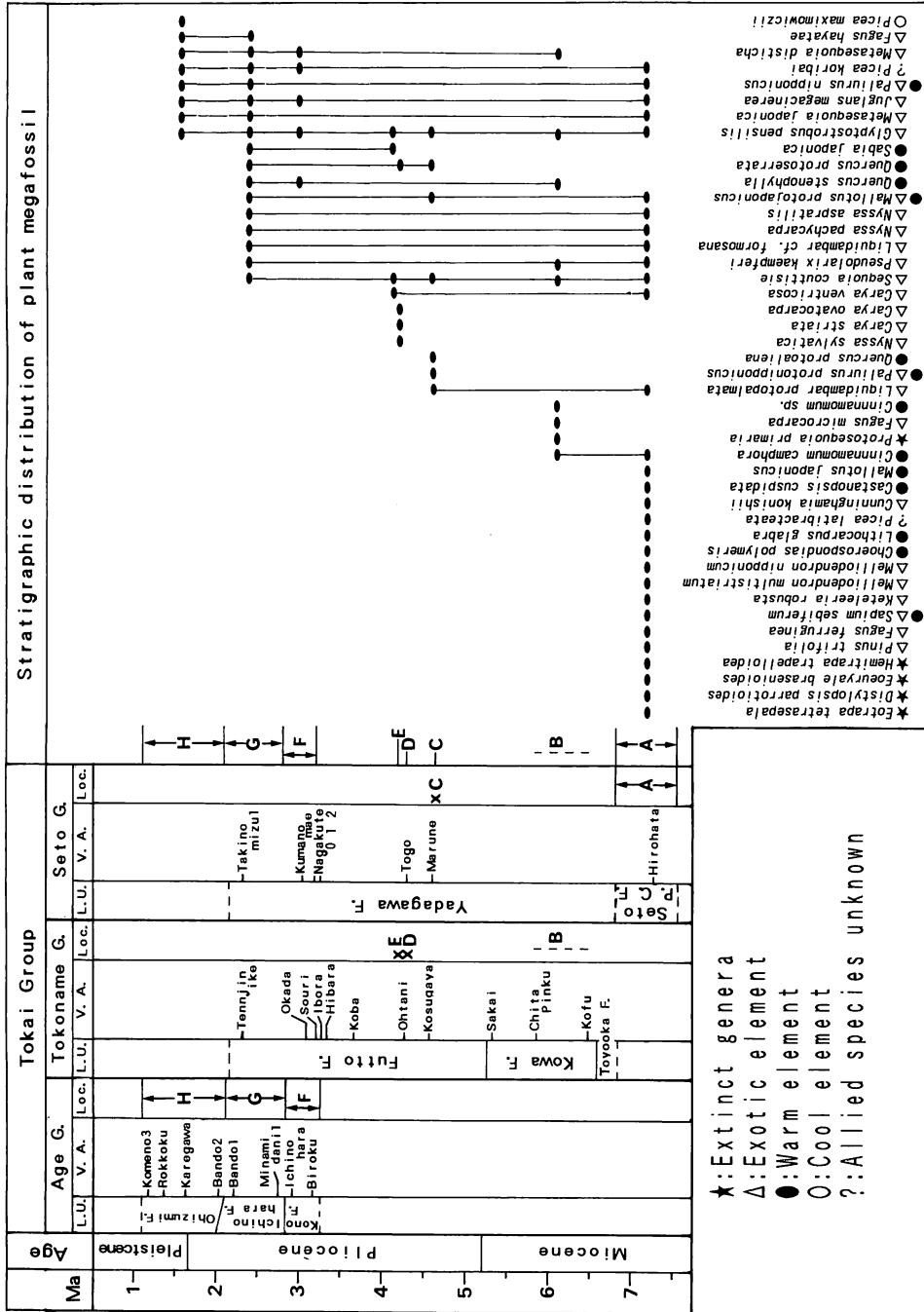


Fig. 4. Stratigraphic distribution of selected plant megafossil from the Tokai Group (Tsukagoshi, 1992b). F, Formation; Seto P.C.F., Seto Porcelain Clay Formation; L.U., Local unit; V.A., Volcanic ash; Loc., Locality. Loc.A, Total of nineteen localities (Miki, 1963); B, Loc.80(Miki, 1948); Loc.C, Loc.KM01 (Tsukagoshi,1992a); Loc.D, Loc.1 and Loc.2 (Onoe *et al.*,1986); Loc. E, Loc.81 (Miki,1948); Loc.F, Localities of Kono Formation; Loc.G, Localities of Ichinohara Formation; Loc.H, Localities of Ohizumi Formation; Loc. F, G and H, after Table 4 in Yoshida *et al.* (1991) and Fig.17 in Yoshida(1990).

Conclusion

Plant megafossil assemblages from the Toki Sand and Gravel Formation in and around Ena City include many exotic elements and some warm elements which survived from the Late Miocene. However extinct genera, some Late Miocene exotic elements and Quaternary cool-temperate elements have not been discovered. These plant megafossil assemblages are assigned to the Pliocene.

Systematic description

The family name and its arrangement of angiosperm are based on Takhtajan (1980). The specific name of an extant plant is based on Kitamura and Murata (1971, 1976). The original description and some literature citation are shown if necessary. Plant megafossils described in this paper are preserved in the Herbarium Osaka Museum of Natural History (OSA).

Family Pinaceae

***Pseudolarix amabilis* (Nels.) Rheder** (Pl. 1, fig. 2)

Pseudolarix kaempferi Gord. —Miki, 1941a, p. 255, pl. 4, fig. C; text-fig. 6, A.

Description: Cone scales having bract, deltoid in shape, base cordate, 2.2 cm long, 1.4 mm wide.

Occurrence and collection: Loc. WE34, OSA-QB 655, 713.

***Pseudotsuga japonica* (Shirasawa) Beissner** (Pl. 1, fig. 1)

Pseudotsuga japonica (Shirasawa) Beissner —Miki, 1948, pl. 2, fig. G; text-fig. 4, Aa-c. —Miki, 1957, p. 257, pl. 9, fig. Ha-b.

Description: Cones elliptic, 4.0 cm long, 2.4 cm wide. This species is characterized by having less number of oblique row and basal cone scale without hump-like thickness.

Occurrence and collection: Loc. CN34-A, OSA-QB 654.

***Tsuga* sp.** (Pl. 1, figs. 3-5)

Description: Leaves linear, 8-9 mm long, apex emerginate. Petiole curved, separate face of petiole not expanded.

Occurrence and collection: Loc. CN-34A, OSA-QB 709-711.

Family Taxodiaceae

***Cunninghamia* sp.** (Pl. 1, figs. 8-12)

Description: Leaves spiral arrangement, decurrent on stem, linear in shape, 2.0-2.7 mm wide. Margin having minute serration. Two ranked stomatal zone on under surface of leaf.

Occurrence and collection: Loc. CN34, OSA-QB 656, 700.

***Glyptostrobus pensilis* (Stout.) K.Koch** (Pl. 1, figs. 15, 16)

Glyptostrobus pensilis Koch —Miki, 1941a, p. 259, pl. 5, figs. Ha-b, text-fig. 7C.

Description: Cones obovate, 19-21 mm long, 13 mm wide. Cone scales arranged spirally. Bract scale at the upper part separated from seminiferous scale.

Occurrence and collection: Loc. NN06, OSA-QB 657, 658.

***Metasequoia glyptostroboides* Hu et Cheng** (Pl. 1, figs. 13, 14, 18)

Description: Cone scales decussate arrangement. Shoots having linear leaf and decussate leaf scar.

Occurrence and collection: Loc. WE34, OSA-QB 672; Loc. CN34-B, OSA-QB 659.

Family Cupressaceae

***Thuja protojaponica* Miki** (Pl. 1, fig. 6, 7)

Thuja protojaponica Miki —Miki, 1941b, p. 380, fig.2, Ca-b. —Miki, 1956a, pl. 13, fig. Ib. —Miki, 1958, p. 134, pl. 1, fig.E.

Description: Shoots 2-3 mm wide, with four leafed node. This genus is distinguished from *Thujopsis* by small leaf and shallow stomatal band.

Occurrence and collection: Loc. CN34-A, OSA-QB 701, 702.

Family Magnoliaceae

***Magnolia obovata* Thunb.** (Pl. 4, figs. 13-15)

Magnolia obovata Thunb. —Miki, 1937, p. 315, text-figs. 4, a-d. —Miki, 1941a, p. 274, text-figs. 13, Aa-e.

Description: Seeds compressed, oblong to obovate in shape, 8-9 mm long, 7-8 mm wide, exo- and mesotesta not preserved. Endotesta woody, having large chalaza and striation.

Occurrence and collection: Loc. NN06, OSA-QB 660, 661.

Family Hamamelidaceae

***Fortunearia sinensis* Rehd. et. Wilis.** (Pl. 1, figs. 21, 22)

Fortunearia sinensis Rehd. et. Wils. —Miki, 1941a, p. 275, pl. 6, fig. Fb; text-fig. 14, Dc.

Description: Seed lustrous, oblong in shape, 8-11 mm long and 5 - 6 mm wide, apex acute and base obtuse. Hilum large and hollow.

Occurrence and collection: Loc. CN02, OSA-QB 662.

***Liquidambar formosana* Hance** (Pl. 1, figs. 20, 23; pl. 2, figs. 18, 20, 21)

Liquidambar formosana Hance —Miki, 1941a, p. 275, pl. 6, fig. B; text-figs. 14, Ba-c.

Description: Leaves, palmately three lobed, estimated 10 cm wide, base truncate. Venation, perfect marginal actinodromous, primary veins originated from the top of petiole. Lateral primaries diverging at 40-50 degree, weakly curved outward. Margin serrate. Tooth bowed inside, apex round with gland. Texture thick. Petiole stout, more than 2.4 cm long, 1.5 mm wide in flattened state. Fruit composed of many capsule, 17 mm in diameter.

Occurrence and collection: Loc. WE34, OSA-QB 677, 707; NN06, OSA-QB 663.

Family Buxaceae

***Buxus microphylla* Sieb. et Zucc. var. *japonica* (Muell. Arg.) Rehd. et Wils.**

(Pl. 1, fig. 19; pl. 2, fig. 19)

Buxus japonica Muell —Miki, 1937, text-figs. 7, Aa-f. —Miki, 1941a, text-figs. 16, Da-c.

Description: Leaves, apex emarginate, base acute, 5-8 mm wide. Primary vein stout. Fimbriated

marginal vein from petiole to apex. Secondary vein, dichotomously ramified, curving up near margin, fused into fimbriated vein. Tertiary vein, diverging acute angle. Areolation lacking. Margin entire. Texture coriaceous.

Occurrence and collection: Loc. CN34-A, OSA-QB 703, 704.

Family Ulmaceae

***Zelkova ungeri* (Ettings.) Kovats** (Pl. 1, fig. 17)

Zelkova ungeri (Ettings.) Kovats —Kovats, 1856, p. 27, pl. 5 figs. 1-12; pl. 6, figs. 1-6(not seen). —Miki, 1937, pl. 9, fig. O; text-figs. 3, Da-e. —Miki, 1941, p.272, text-figs. 12, Ia-c. —Tanai, 1961, p. 322, pl. 18, figs. 1-3, 6-9, 11. —Huzioka et Uemura, 1974, p. 352, pl.6, figs. 2-3.

Planera ungeri Ettingshausen —Ettingshausen, 1851, p. 14, pl. 2, figs. 5-18(not seen).

Description: Leaves ovate, 17-19 mm long, 7 mm wide. Apex acute, base asymmetrical. Venation craspedodromous. Secondary veins, 7 - 8 pairs, curved up near margin. Bifurcate near margin, upper vein running into tooth, curved outside in tooth, lower vein running in the sinus. Upper secondary vein diverging at more acute angle than lower. Intersecondary vein sometimes present. Tertiary vein percurrent. Quaternary venation forming areole. Areole pentagonal to polygonal. Veinlet branched. Margin serrate. Tooth, apical side straight to convex, basal side concave to straight, angle of tooth apex nearly 90 degree, sinus shallow. Texture chartaceous. *Zelkova serrata* (Thunb.) Makino is distinguished from these leaves by acuminate tooth.

Occurrence and collection: Loc. WE34, OSA-QB 705, 708.

Family Fagaceae

***Fagus microcarpa* Miki** (Pl. 2, figs. 1-13, 16, 17)

Fagus microcarpa Miki —Miki, 1933a, p.8, pl. 2, fig. F, text-fig. 3, N. —Miki, 1933b, p. 621, pl. 1, fig. G; text-figs.1, L-M. —Miki, 1937, p. 313, pl. 8, fig. G; text-figs. 3, K-L. —Uemura, 1980, p.36, figs.1-10, 14-16.

Description: Cupules with stalk, cup body ellipsoidal, 7-13 mm long, 6-9 mm wide in flattened state. Base truncate to round, apex dehiscent into four valves. Surface rough. Prickles scaly, 1.5 mm long, recurving, with pointed apex. More prickles at upper half to one third. Stalk 4-6 mm long. Fruits as long as cup body, two fruits in one cupule (pl. 2, fig. 13), ovate in shape, having three winged angles, adherent plane triangle (pl. 2, fig. 16). These cupules are somewhat different from cupules of *F. microcarpa* listed as synonym by sparse and recurved prickles.

Occurrence and collection: Loc. CN02, OSA-QB 670; Loc. CN05, OSA-QB 669, 673; Loc. NN06, OSA-QB 664-668,671,674,699.

***Quercus gilva* Blume** (Pl. 3, fig. 17)

Description: Leaves oblanceolate in outline, apex weakly acuminate. Venation craspedodromous. Midvein concave on upper surface, convex on under surface. Secondary vein convex on under surface. Serration present on upper half. These leaves are distinguished from *Q. salicina* by oblanceolate shape.

Occurrence and collection: Loc. WE34, OSA-QB 706.

Family Betulaceae

***Alnus japonica* (Thunb.) Steud.** (Pl. 2, figs. 14, 15)

Description: Infructescence elliptic, 9-15 mm long, 9 mm wide. Scales 5 mm wide, having one bract and four bracteoles.

Occurrence and collection: Loc. NN06, OSA-QB 675.

Family Juglandaceae

***Cyclocarya paliurus* (Batal.) Iljinsk.** (Pl. 3, figs. 1, 2)

Pterocarya multistriata Miki —Miki, 1948, p. 132, pl. 6, fig. G. —Miki, 1955, pl. 3, Ba-b.

Description: Nut napiform, apex acuminate, 5 mm in diameter, 4 mm high. Surface with radiated striation (17 striations in pl.3, fig.1, 2). Striations having minute projection along encircled line.

Occurrence and collection: Loc. NN06, OSA-QB 678.

Family Theaceae

***Stewartia monadelpha* Sieb. et Zucc.** (Pl. 4, figs. 18, 19, 23)

Stewartia monadelpha Sieb. et Zucc. —Miki, 1937, p. 324, text-fig. 8K.

Stewartia pseudocamelia Max. —Miki, 1938, text-fig. 6K.

Stewartia monadelpha Sieb. et Zucc. —Miki, 1941a, p.288, text-figs. 18Ga-e.

Description: Capsules ovate, apex acuminate, 13 mm long and 11 mm wide in maximum, splitting to 5-7 woody valves.

Occurrence and collection: Loc. CN05, OSA-QB 680; Loc. NN06, OSA-QB 679, 681.

Family Styracaceae

***Styrax japonica* Sieb. et Zucc.** (Pl. 3, figs. 9-12)

Description: Seeds elliptic in shape, 9 mm long, 5.5 mm wide. Hilum large. Three ridges between pericarp constriction reach apex of seed. Testa densely foveolate.

Occurrence and collection: Loc. NN06, OSA-QB 683.

***Styrax rugosa* Miki** (Pl. 3, figs. 5-8)

Styrax rugosa Miki —Miki, 1941, p. 295, pl. 7, figs. Ha; text-figs. 20, Dc-b.

Description: Seed elliptic, 6 mm long, 4 mm wide. Testa densely foveolate with tuberculation. No ridge between pericarp constrictions.

Occurrence and collection: Loc. NN06, OSA-QB 684.

***Styrax* sp. A** (Pl. 3, figs. 3, 4)

Description: Seed elliptic, 1.7 cm long, 1.3 cm wide. Hilum large. Three ridges between pericarp constrictions reach apex of seed. Testa densely foveolate. This specimen is characterized by large size.

Occurrence and collection: Loc. NN06, OSA-QB 682.

***Styrax* sp. B** (Pl. 3, figs. 13-16)

Description: Seeds, 3.4 mm long, 2.4 mm wide. Testa reticulate. These specimens are characterized by small size.

Occurrence and collection: Loc. CN02, OSA-QB 685.

Family Symplocaceae

***Symplocos myrtacea* Sieb. et Zucc.** (Pl. 4, figs. 9, 10)

Symplocos myrtacea Sieb. et Zucc. —Miki, 1941, p. 293, pl. 7, fig. I; text-fig. 20, Ia-b.

Description: Endocarp ampullaceous, base truncate, 3.5 mm long, 2.5 mm wide, surface having reticulation.

Occurrence and collection: Loc. WE34, OSA-QB 688.

Family Rutaceae

***Fagara ailanthoides* (Sieb. et Zucc.) Engler** (Pl. 4, figs. 4, 5)

Fagara ailanthoides (Sieb. et Zucc.) Engler —Miki, 1937, p. 318, text-figs. 7, Ca-c. —Miki, 1941, p. 279, text-fig. 16, E.

Description: Seeds, obovate, 4 mm long and 3 mm wide, palisadal exotesta not preserved. Mesotesta with reticulate surface.

Occurrence and collection: Loc. CN34-B, OSA-QB 687.

Family Anacardiaceae

***Choerospondias axillalis* (Roxb.) B.L.Burt et A.W.Hill** (Pl. 4, figs. 1, 2)

Spondias axillalis Roxb. —Miki, 1941, p. 281, pl.6, fig. Ib; text-figs. 16, Jc-e.

Description: Endocarp, 17 mm long, 13 mm in diameter, apex round with five germ pore at apical part, base mucronate with five small pits.

Occurrence and collection: Loc. NN06, OSA-QB 686.

Family Staphyleaceae

***Euscaphis japonica* (Thunb.) Kanitz.** (Pl. 3, figs. 18, 19)

Euscaphis japonica Pax —Miki, 1941a, p. 282, text-fig. 16, H.

Description: Seeds compressed, orbicular in shape, hilar region truncate, 5 mm wide, 5 mm high, 3 mm thick, palisadal exotesta not preserved. Hilum grooved, mesotesta woody with rugose surface.

Occurrence and collection: Loc. NN06, OSA-QB 697.

Family Sabiaceae

***Meliosma* sp. cf. *M. rigida* Sieb. et Zucc.** (Pl. 4, figs. 3, 6-8)

Meliosma cf. *rigida* Sieb. et Zucc. —Miki, 1941a, p. 283, text-fig. 16, H.

Description: Endocarp, spherical with keel, 3-5 mm in diameter. Lateral surface with sparse rugosity.

Occurrence and collection: Loc. NN06, OSA-QB 690, 698.

***Sabia japonica* Maxim.** (Pl. 3, figs. 20-22)

Sabia japonica Maxim. —Miki, 1941, p. 283, text-fig. 17, Da-c.

Description: Mesocarp compressed, obovate, 5.3 mm wide, 3.7 mm high. Lateral surface with reticulation.

Occurrence and collection: Loc. NN06, OSA-QB 689.

Family Nyssaceae

***Nyssa aspratilis* Eyde et Barghoorn** (Pl. 4, 17, 22)

Nyssa aspratilis Eyde et Barghoorn —Eyde and Barghoorn, 1963, p. 357, Fig. 11.

Nyssa rugosa Miki —Miki, 1956b, p. 287, pl. 1, figs. Da-d; text-fig. 5, A-F.

Description: Endocarp, elliptic, apex round, base acute, 18 mm long, 12 mm wide, bilocular. Surface rugose with 10-13 sharp ridge.

Occurrence and collection: Loc. NN06, OSA-QB 692, 694, 696.

***Nyssa pachycarpa* Miki** (Pl. 4, figs. 16, 20, 21)

Nyssa pachycarpa Miki —Miki, 1941a, p. 292, pl. 7, fig. Ka; text-fig. 19E. —Miki, 1956b, p. 288, pl. 1, fig. Ca-d; text-fig. 5, G-N.

Description: Endocarp, elliptic, apex pointed, base acute, 21 mm long, 12 mm wide bilocular. Surface with 7-10 round ridge.

Occurrence and collection: Loc. NN06, OSA-QB 692, 693, 695; Loc. CN02, OSA-QB 714.

Family Vitaceae

***Vitis* sp.** (Pl. 4, figs. 11, 12)

Description: Seed compressed obovoid, 6.3 mm long, 5.4 mm wide. Two furrows on both side of sutural line not reach both ends. Chalaza elliptic in shape.

Occurrence and collection: Loc. WE34, OSA-QB 712; Loc. NN06, OSA-QB 691.

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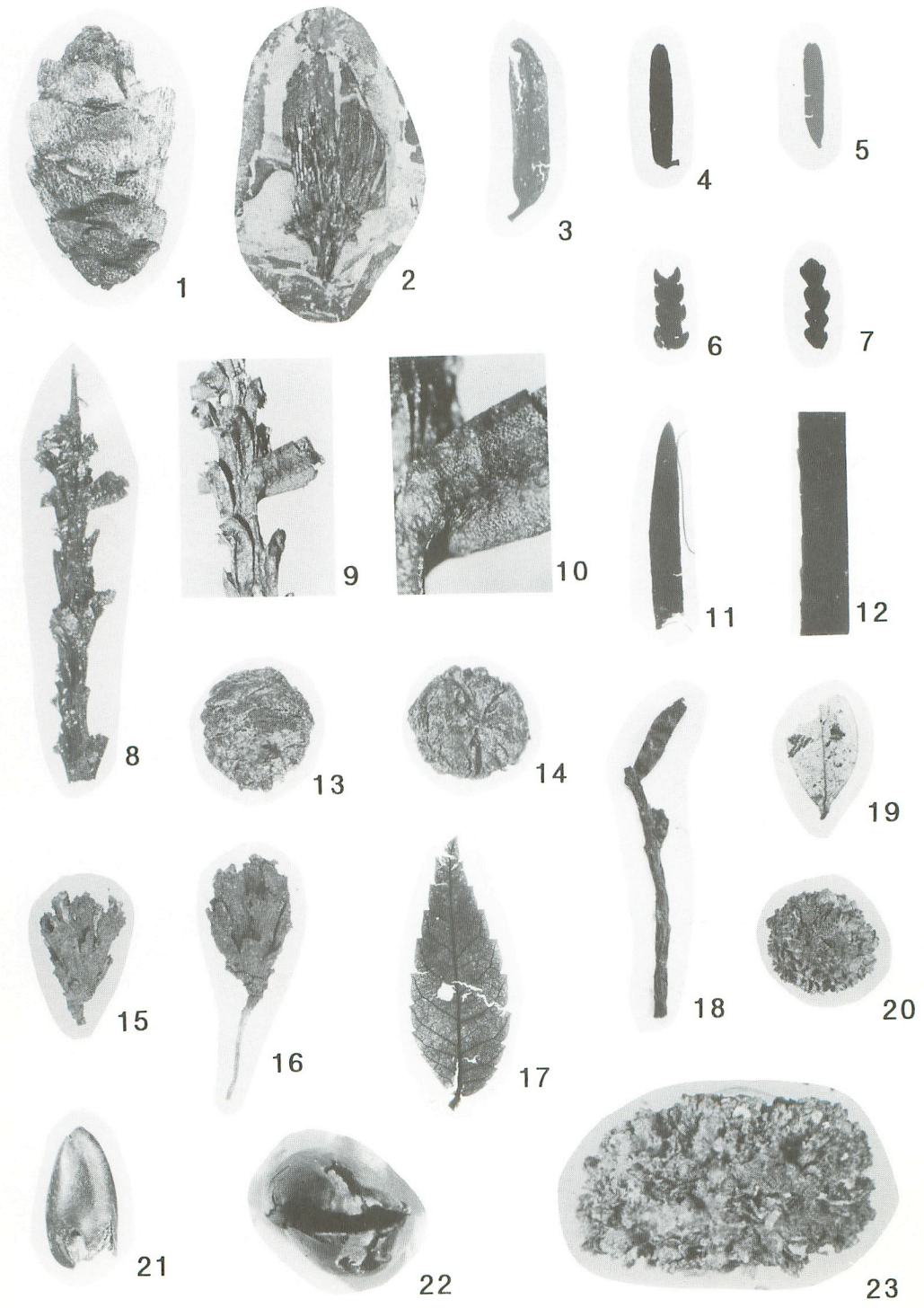
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The Todo Collaborative Research Group (“Todo” means porcelain clay in Japanese)

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Explanation of Plate 1

- Fig. 1. *Pseudotsuga japonica* (Shirasawa) Beissner (cone) $\times 1$, Loc. CN34-A, OSA-QB 654.
Fig. 2. *Pseudolarix amabilis* (Nels.) Rheder (cone scale) $\times 1.5$, Loc. WE34, OSA-QB 655.
Figs. 3-5. *Tsuga* sp. (leaf) Loc. CN34-A.
 Fig. 3, $\times 4$, OSA-QB 710. Fig. 4, $\times 2$, OSA-QB 709. Fig. 5, $\times 2$, OSA-QB 711.
Figs. 6, 7. *Thuja protojaponica* Miki (shoot) $\times 2$.
 Fig. 6, Loc. CN34-A, OSA-QB 701. Fig. 7, Loc. CN34-A, OSA-QB 702.
Figs. 8-10. *Cunninghamia* sp. (shoot) Loc. CN34-A, OSA-QB 656.
 Fig. 8, $\times 2$. Fig. 9, $\times 2.9$, enlarged Fig. 6. Fig. 10, $\times 8$.
Figs. 11, 12. *Cunninghamia* sp. (leaf) Loc. CN34-A, OSA-QB 700.
 Fig. 11, $\times 2$. Fig. 12, $\times 8$, enlarged marginal serration of Fig. 11.
Figs. 13, 14. *Metasequoia glyptostroboides* Hu et Cheng (cone) Loc. CN34-B, OSA-QB 659.
 Fig. 13, $\times 1$. Fig. 14, $\times 1$, section of Fig. 13.
Fig. 15, 16. *Glyptostrobus pensilis* (Stout.) K. Koch (cone) $\times 1$.
 Fig. 15, Loc. NN06, OSA-QB 658. Fig. 16, Loc. NN06, OSA-QB 657.
Fig. 17. *Zelkova ungeri* (Ettings.) Kovats (leaf) $\times 2$, Loc. WE34, OSA-QB 705.
Fig. 18. *Metasequoia* sp. (shoot) $\times 3$, Loc. WE34, OSA-QB 672.
Fig. 19. *Buxus microphylla* Sieb. et Zucc. var. *japonica* (Muell. Arg.) Rehd. et Wils. (leaf) $\times 2$, Loc. CN34-A, OSA-QB 704.
Figs. 20, 23. *Liquidambar formosana* Hance (fruit) Loc. NN06, OSA-QB 663.
 Fig. 20, $\times 1$. Fig. 23, $\times 3$, enlarged lateral view of Fig. 20.
Figs. 21, 22. *Fortunearia sinensis* Rhed. et Wils. (seed) Loc. CN02, OSA-QB 662.
 Fig. 21, $\times 2$. Fig. 22, $\times 4$, view from hilar side of Fig. 21.



Explanation of Plate 2

Figs. 1-13, 16, 17. *Fagus microcarpa* Miki

Fig. 1-6. (cupule) $\times 2$, Loc. NN06, OSA-QB 664-668, 676, 699.

Fig. 7. (cupule) $\times 2$, Loc. CN05, OSA-QB 669.

Fig. 8. (cupule) $\times 2$, Loc. CN02, OSA-QB 670.

Fig. 9. (cupule) $\times 5$, enlarged Fig. 4.

Fig. 10. (fruit) $\times 3.3$, Loc. NN06, OSA-QB 671.

Fig. 11. (fruit) $\times 3.3$, Loc. NN06, OSA-QB 674.

Fig. 12. (fruit) $\times 3.3$, Loc. CN05, OSA-QB 673.

Fig. 13. (cupule) $\times 4.5$, apical view of Fig. 4.

Fig. 16. (fruit) $\times 4$, enlarged basal view of Fig. 10.

Fig. 17. (cupule) $\times 4.3$, enlarged Fig. 4.

Figs. 14, 15. *Alnus japonica* (Thunb.) Steud. (infructescence), Loc. NN06, OSA-QB 675.

Fig. 14, $\times 2$. Fig. 15, $\times 4.4$, enlarged scale of Fig. 14.

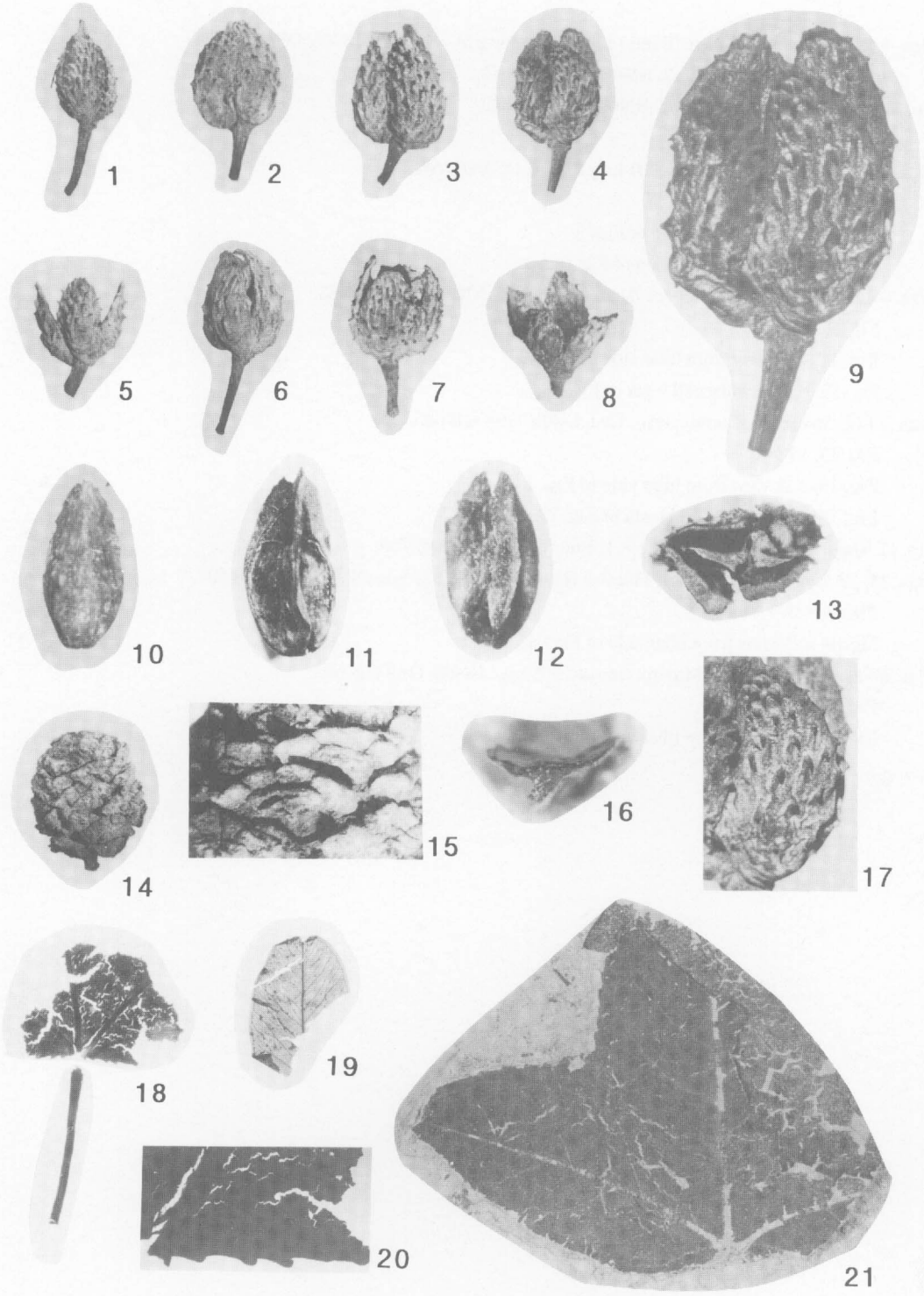
Figs. 18, 20, 21. *Liquidambar formosana* Hance (leaf)

Fig. 18, $\times 1$, Loc. WE34, OSA-QB 707.

Fig. 20, $\times 3.8$, enlarged basal part of Fig. 18.

Fig. 21, $\times 1$, Loc. WE34, OSA-QB 677.

Fig. 19. *Buxus microphylla* Sieb. et Zucc. var. *japonica* (Muell. Arg.) Rehd. et Wils. (leaf) $\times 2$, Loc. CN34-A, OSA-QB 703.



Explanation of Plate 3

Figs. 1, 2. *Cyclocarya paliurus* (Batal.) Iljinsk. (endocarp) $\times 3$, Loc. NN06, OSA-QB 678.

Fig. 1, apical view. Fig. 2, lateral view of Fig. 1.

Fig. 3, 4. *Styrax* sp. A (seed), Loc. NN06, OSA-QB 682.

Fig. 3, $\times 1.5$. Fig. 4, $\times 2$.

Figs. 5-8. *Styrax rugosa* Miki (seed) Loc. NN06, OSA-QB 684.

Fig. 5, 6, $\times 3$.

Fig. 7, view from hilar side of Fig. 5.

Fig. 8, $\times 10.8$, enlarged testa of Fig. 5.

Figs. 9-12. *Styrax japonica* Sieb. et Zucc. (seed) Loc. NN06, OSA-QB 683.

Fig. 9, 10, $\times 3$.

Fig. 11, $\times 3$, view from hilar side of Fig. 9.

Fig. 12, $\times 12.5$, enlarged testa of Fig. 9.

Figs. 13-16. *Styrax* sp. B (endocarp), Loc. CN02, OSA-QB 685.

Fig. 13, 14, $\times 5$.

Fig. 15, $\times 5$, view from hilar side of Fig. 13.

Fig. 16. $\times 10.8$, enlarged testa of Fig. 13.

Fig. 17. *Quercus gilva* Blume (leaf) $\times 1$, Loc. WE34, OSA-QB 706.

Figs. 18, 19. *Euscaphis japonica* (Thunb.) Kanitz. (endotesta) Loc. NN06, OSA-QB 697.

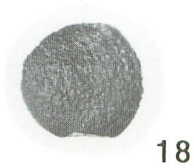
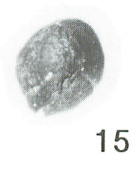
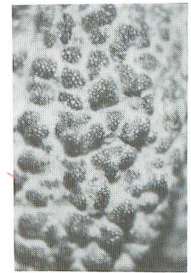
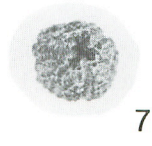
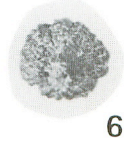
Fig. 18, $\times 3$.

Fig. 19, $\times 3$, view from hilar side of Fig. 18.

Figs. 20-22. *Sabia japonica* Maxim. (mesocarp) Loc. NN06, OSA-QB 689.

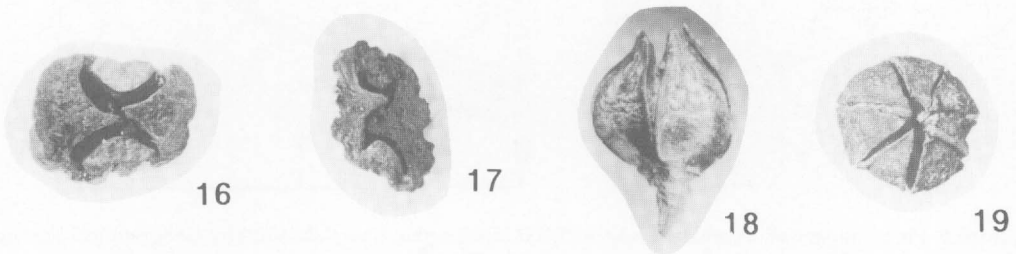
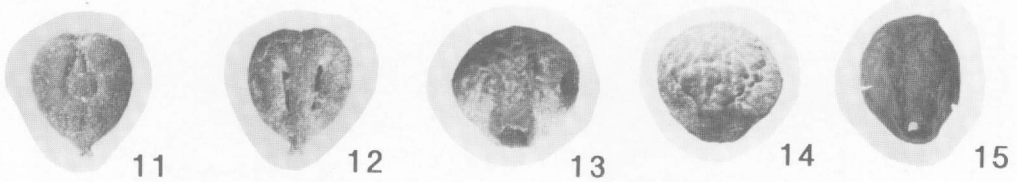
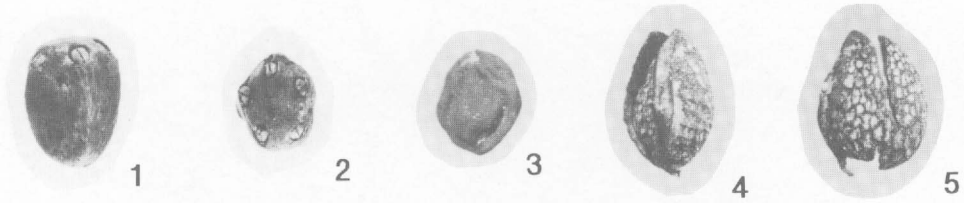
Fig. 20, 22, $\times 3$.

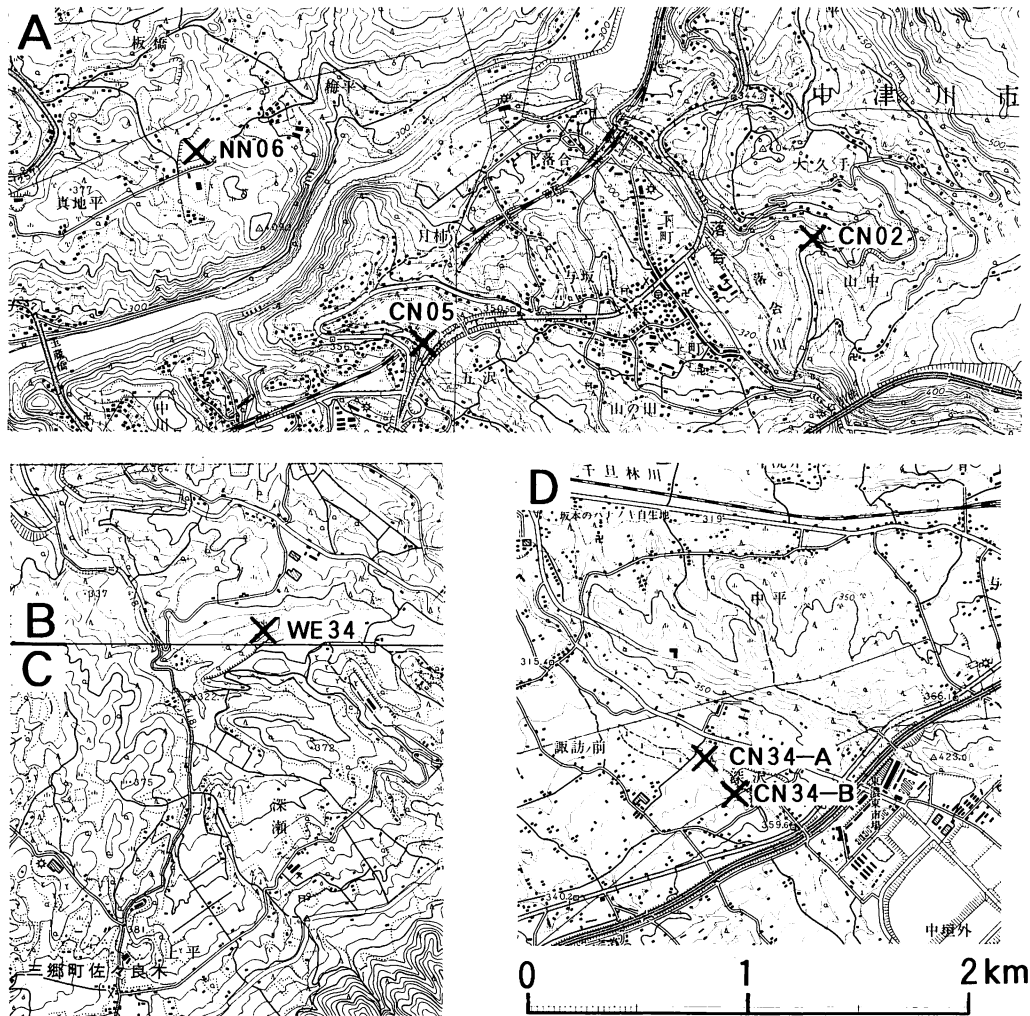
Fig. 21, $\times 3$, view from hilar side of Fig. 20.



Explanation of Plate 4

- Fig. 1, 2. *Choerospondias axillalis* (Roxb.) B.L.Burt et A.W.Hill (endocarp) $\times 1$, Loc. NN06, OSA-QB 686.
Fig. 2, apical view of Fig. 1.
- Figs. 3, 6-8. *Meliosma* sp. cf. *M. rigida* Sieb. et Zucc. (endocarp)
Fig. 3, $\times 4.5$, Loc. NN06, OSA-QB 690.
Figs. 6-8, $\times 3$, Loc. NN06, OSA-QB 698.
Fig. 7, basal view of Fig. 6.
- Fig. 4, 5. *Fagara ailanthoides* (Sieb. et Zucc.) Engler (endotesta) $\times 4.6$, Loc. CN34-B, OSA-QB 687.
- Figs. 9, 10. *Symplocos myrtacea* Sieb. et Zucc. (endocarp) Loc. WE34, OSA-QB 688.
Fig. 9, $\times 4$. Fig. 10, $\times 8$, basal view of Fig. 9.
- Figs. 11, 12. *Vitis* sp. (seed) $\times 2.6$, Loc. NN06, OSA-QB 691.
- Fig. 13-15. *Magnolia obovata* Thunb. (endotesta) $\times 2$, Loc. NN06.
Fig. 13, view from chalazal side, OSA-QB 661.
Fig. 14, view from raphe side of Fig. 21.
Fig. 15, view from chalazal side, OSA-QB 660.
- Fig. 16, 20, 21. *Nyssa pachycarpa* Miki (endocarp) $\times 2$.
Fig. 16, cross section, Loc. NN06, OSA-QB 695.
Fig. 20, Loc. NN06, OSA-QB 692.
Fig. 21, Loc. NN06, OSA-QB 693.
- Figs. 17, 22. *Nyssa aspratilis* Eyde et Barghoorn (endocarp) $\times 2$.
Fig. 17, cross section, Loc. NN06, OSA-QB 696.
Fig. 22, Loc. NN06, OSA-QB 694.
- Figs. 18, 19, 23. *Stewartia monadelpha* Sieb. et Zucc. (capsule)
Fig. 18, $\times 2$, Loc. CN05, OSA-QB 680.
Fig. 19, $\times 1.9$, Loc. NN06, OSA-QB 681.
Fig. 23, $\times 2$, Loc. NN06, OSA-QB 679.





Appendix. Plant megafossil localities. From 1:25,000 topographic map published by Geographical Survey Institute of Japan. A, Tsumago; B, Takenami; C, Mizunami; D, Ena.