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ARTICLE

REVISION OF THE NARIWA FLORA AND ITS IMPLICATIONS IN TERRESTRIAL CLIMATE CHANGES DURING THE LATE TRIASSIC IN EAST ASIA

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ABSTRACT

The Nariwa Group is well-known for the distinctive Late Triassic Nariwa flora and fossil marine bivalves characterized by the presence of *Monotis ochotica*. Based on the recently proposed stratigraphic scheme of the Nariwa Group, localities of the previously known Nariwa flora are assigned to the lower and upper terrestrial horizons that are intercalated by a marine deposit that yields *Monotis ochotica* and rich in plant fossils. In this study, we re-examine the previously collected specimens of the Nariwa flora based on the new stratigraphic scheme and erect two distinct floristic assemblages within the Nariwa Group, namely Niga and Hina-Hinabata floristic assemblages. The lower plant fossil assemblage, the Niga Floristic Assemblage, from the Niga Formation is characterized by a greater diversity of Dipteridaceae and cycadophytes, while the upper Hina-Hinabata Floristic Assemblage from the Hina and Hinabata Formations is characterized by the increase of Ginkgoales and cycadophytes remains with the lower abundance of Dipteridaceae. The ages of the Niga and Hina-Hinabata floristic assemblages are inferred to be the Norian and the Norian-Rhaetian?, respectively, based on the floristic correlation. The floral changes recognized in the Nariwa Group may imply the changes in the climate conditions from subtropical to warm temperate with increased seasonality in eastern Eurasia during the latest Triassic.

Key words: Nariwa Group, Late Triassic, Norian, Rhaetian, Floristic assemblage, Paleoclimate

湯川弘一・孫 革・鈴木茂之・今井拓哉（2020）成羽植物群の再検討と東アジアでの後期三畳紀の陸上気候変化における意義．福井県立恐竜博物館紀要 19：89–104.

成羽層群は特徴的な後期三畳紀の成羽植物群と，モノチスに代表される海生二枚貝化石でよく知られている．近年の成羽層群の層序学的研究では，モノチスを産する海成層を挟んで，上下共に植物化石を多産する陸成層が存在することが確認された．そこで本研究では，新しい層序を基に，先行研究で報告されていた産地および植物化石を見直し，２つの植物化石群集（仁賀植物化石群集と日名－日名畑植物化石群集）を認めた．仁賀植物化石群集は，地頭層の下位に位置する仁賀層から産出する植物化石からなり，ヤブレガサウラボシ科のシダ植物やベネチテス類，ソテツ類などの裸子植物の多様性が高いことで特徴付けられる．一方，日名－日名畑植物化石群集は，地頭層の上位に位置する日名層及び日名畑層から産出する植物化石からなり，仁賀植物化石群集に比べてイチョウ類やベネチテス類，ソテツ類の多様性の増加，およびヤブレガサウラボシ科のシダ植物の多様性の減少が示される．植物化石の対比により，仁賀植物化石群集と日名－日名畑植物化石群集は，それぞれ Norian および Norian-Rhaetian? と示唆される．また，両植物化石群集における構成の変化から，三畳紀末期にかけて東ユーラシアでは亜熱帯から暖温帯の気候へと変化していたことが示唆される．

INTRODUCTION

Nariwa flora is a Late Triassic plant-fossil assemblage unique to the Nariwa Group distributed in western Okayama of Honshu Island, Japan (Fig. 1). The group has been extensively studied for its paleobotanical record since the preliminary report by Yokoyama in 1905 (Oishi, 1932; 1940; Oishi and Huzioka, 1938; Huzioka, 1970; Kimura and Ohana, 2000).

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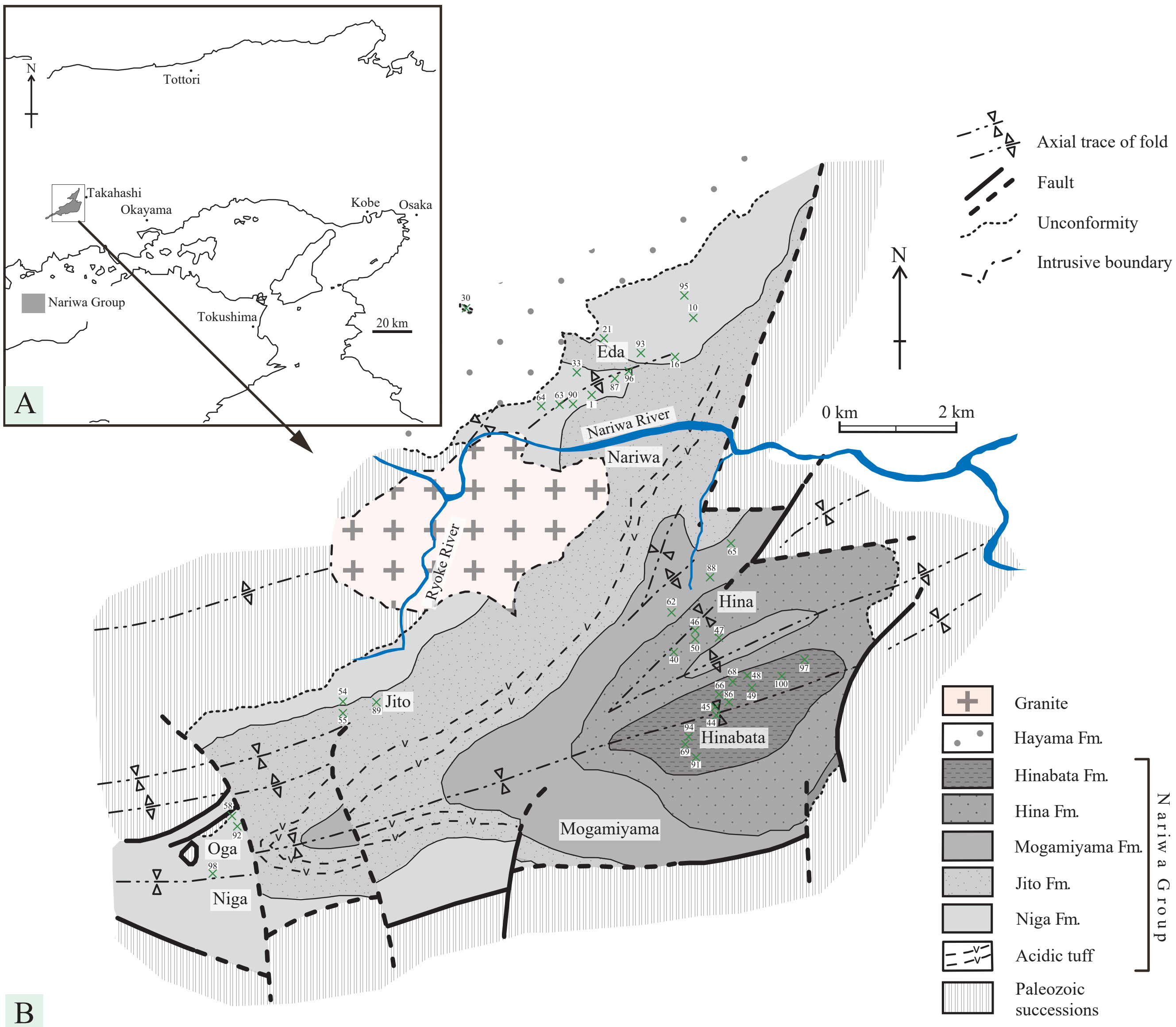

FIGURE 1. **A**, Location of the Nariwa Group; **B**, geological map of the Nariwa Group, modified from Suzuki and Asiedu (1995) and localities of the plant fossils of the group. See Table 1 for the references of each locality.

Based on the compositional similarity to the Rhaetic floras of Sweden (Nathorst, 1878), Greenland (Harris, 1931) and Vietnam (Zeiller, 1903), the age of the Nariwa flora has been assigned to the Rhaetian (Oishi, 1932; 1940). On the other hand, Kobayashi et al. (1937) argues for its Norian age based on the occurrence of fossil bivalve *Monotis ochotica* (Keyserling, 1848) in the uppermost horizon of the Nariwa Group. Teraoka (1959) defines the formations of the Nariwa Group as the Mogamiyama, Hinabata and Jito Formations in ascending order. Based on the occurrence of *M. ochotica* in the Jito Formation, Teraoka (1959) assigns the Nariwa Group to the Norian. This assignment has been widely accepted, and the Nariwa flora has served as a representative flora for the Norian in East Asia (Kimura, 1987; Sun, 1993; Dobruskina, 1994; Sun et al., 1995; Shorokhova et al., 2009; Kustatscher et al., 2018).

Suzuki and Asiedu (1995) challenges the traditional stratigraphic scheme of the Nariwa Group and re-defines it as the Niga, Jito, Mogamiyama, Hina, and Hinabata formations in ascending order (Fig. 2). Suzuki and Asiedu (1995) further suggests that the Nariwa flora can be stratigraphically divided into the lower and the upper units. Notably, it has been suggested that the floristic assemblage of the Nariwa Group

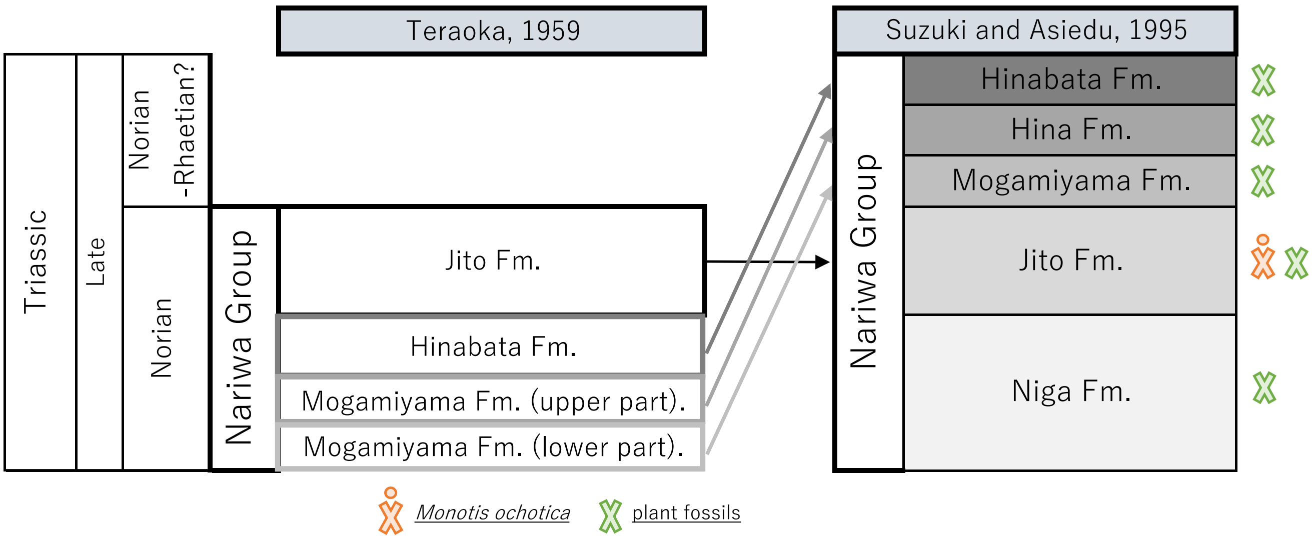

FIGURE 2. Stratigraphy of the Nariwa Group after Suzuki and Asiedu (1995).

differs from those typical for the Norian (Oishi, 1932; 1940), and re-evaluation of the Nariwa flora and its age is in order.

Here, we re-examine the stratigraphic positions for previously collected specimens of the Nariwa flora in light of the new stratigraphic scheme (Suzuki and Asiedu, 1995). Clarifying their occurrences within the group reveals that the Nariwa flora is in fact composed of two distinct floristic assemblages. These floristic assemblages allow constraining the depositional age of the formations within the Nariwa Group and help paleoclimatic reconstruction of eastern Eurasia during the Late Triassic.

GEOLOGICAL SETTING

The Nariwa Group represents a shallow-marine to terrestrial sedimentary sequence that crops out in western Okayama, Honshu Island, Japan (Fig. 1). The Paleozoic strata, which are composed of the complexly folded Carboniferous to Permian sediments, underly the Nariwa Group unconformably to the east and west. The Nariwa Group is unconformably overlain by the Lower Cretaceous Hayama Formation characterized by the reddish mudstone and conglomerates. The intrusion of the granitic rocks is present in the northern outcrops of the Nariwa Group, which likely occurred during the Late Cretaceous based on the thermal metamorphism observed in the Early Cretaceous Hayama Formation. Since the preliminary report of the Nariwa Group by Yokoyama in 1905, its fossil assemblages and stratigraphy have been extensively studied for wealth of paleoenvironmental and paleobotanical data for the Triassic of East Asia. (Yokoyama, 1905; Oishi, 1932; 1940; Oishi and Huzioka, 1938; Huzioka, 1970; Kimura and Ohana, 2000). Here, we provide a brief overview of the study history and previous understanding about the stratigraphy and depositional environment of the Nariwa Group.

History of the geological study of the Nariwa Group

The first geological study of the Nariwa Group was conducted in Fukatawa, Nariwa, in 1888, in which fossil marine bivalve *Monotis ochotica* was reported (Hiramatsu, 1992) and the Nariwa Group was assigned to the Triassic (Otsuka, 1896). Following the earliest study, Akagi (1925) and Kobayashi et al. (1937) argue that the horizons yielding plant remains corresponded to the lower part, and the horizon yielding *M. ochotica* to the upper part of the group. Teraoka (1959) proceeds the stratigraphic study of the Nariwa Group and defines the terrestrial Mogamiyama and Hinabata formations, and the marine Jito Formation in ascending order within the Group. On the contrary, Otoh (1985) suggests that the Jito Formation in fact underlies the Mogamiyama and Hinabata Formations. In support of Otoh (1985), Suzuki and Asiedu (1995) proposes a stratigraphic subdivision of the Nariwa Group: the Niga, Jito, Mogamiyama, Hina, and Hinabata formations in ascending order (Figs. 1, 2). The present study follows the stratigraphic definition of Suzuki and Asiedu (1995).

Stratigraphy

Otoh (1985) proposes a set of acidic tuff horizons in the Jito Formation as the key bed for the Nariwa Group. Suzuki and Asiedu (1995) clarifies the stratigraphic relationship of the Jito Formation and other formations within the group, and the revised stratigraphy places the marine Jito Formation overlying the non-marine Niga Formation and underlying the non-marine Mogamiyama, Hina and Hinabata formations (Fig. 2). The stratigraphy of the Nariwa Group was most recently reviewed by Suzuki (2009) which generally follows Suzuki and Asiedu

TABLE 1. List of the localities of plant fossils from the Nariwa Group with references. The stratigraphic definitions follow Suzuki and Asiedu (1995).

Paleobotanical works	Niga Fm.	Jito Fm.	Mogamiyama Fm.	Hina Fm.	Hinabata Fm.
Oishi, 1931				46	
Oishi, 1932	1, 10, 16, 21, 30, 33, 54, 58, 63, 64	55	62, 65	40, 46, 47, 50	44, 45, 48, 49, 66, 68, 69
Oishi, 1940	1, 10, 16, 21, 30, 33, 54, 58, 63, 64, 85, 87, 90, 95	55, 89	62, 65, 88	40, 46, 47, 50	44, 45, 48, 49, 66, 68, 69, 86, 91, 94
Oishi and Yamasita, 1935					44
Oishi and Huzioka, 1938	1, 10, 16, 21, 30, 33, 54, 58, 63, 64, 85, 87, 90, 92, 93, 95	55, 89	62, 65, 88	40, 46, 47, 50	44, 45, 48, 49, 66, 68, 69, 86, 91, 94
Kon'no, 1962					49
Huzioka, 1970	96				
Numano and Tsuchiya, 1990					97
Numano and Tsuchiya, 1991					
Kimura and Ohana, 2000	98				
Kobatake, 1954	99				
Yukawa et al., 2012					100

(1995). We adopt Suzuki (2009) and herein provide a brief description of the formations comprising the group.

The Niga Formation is composed of fluvial deposits and represented by fining-upward successions of coarse-grained sandstone, alternating sandstone and mudstone, and coaly mudstone. Each succession measures about 10 m thick. The coaly mudstone produces well-preserved plant remains.

The Jito Formation represents as shallow to offshore marine deposits. It includes weakly stratified, well-sorted coarse-grained sandstone, muddy fine-grained sandstone, and turbiditic sandstone and mudstone, with intermittent horizons of acidic tuff measuring up to 20 cm thick. The mudstone yields abundant remains of *Monotis ochotica*, and plant remains are occasionally present throughout the formation. This formation is equivalent to the Jito Formation in Teraoka (1959).

The fluvial Mogamiyama Formation is characterized by fining-upward successions of conglomerate, sandstone, alternation of sandstone and mudstone, and coaly mudstone. The thickness of successions is approximately 10 m. Plant remains are present in the coaly mudstone layers. This formation is equivalent to the lower part of the Mogamiyama Formation in Teraoka (1959).

The Hina Formation is composed of conglomerate dominated fluvial deposits, which is characterized by fining-upward successions of conglomerate and sandstone with a thin mudstone horizon at the top. The formation contains fragmentary plant fossils. It is equivalent to the upper part of the Mogamiyama Formation in Teraoka (1959).

The Hinabata Formation is a mudstone-dominated floodplain deposit. It is represented by the fining-upward successions of coarse-grained sandstone, alternation of sandstone and mudstone, and mudstone. The formation yields well-preserved, numerous plant remains. It is equivalent to the Hinabata Formation in Teraoka (1959).

Depositional environment

The channel deposits observed in the Niga Formation contain medium- to coarse-grained sandstone, exhibit a distinct lower contact and cut into the underlying mudstone. The floodplain deposits of the Niga Formation are composed of the overbank mudstone horizons and a single sandstone horizon likely representing a crevasse splay deposit (Suzuki, 2009) within a meandering fluvial system. The floodplain was probably extensive, as indicated by the coal and coaly mudstone horizons at the top of the fining-upward sequence occasionally present in the formation. The depositional environment of the Jito Formation transitioned from the shallow marine to offshore, and back to shallow marine through the time (Suzuki et al., 2013; Masaoka and Suzuki, 2015). The Mogamiyama Formation exhibits the deposits resembling those of the Niga Formation, indicating that these two formations were deposited under a similar sedimentary environment. The Mogamiyama Formation differs from the Niga Formation in presence of conglomerates within the channel deposits and in lesser abundance of mudstone horizons with an upward-fining sequence (Suzuki, 2009). The Hina Formation exhibits conglomerates and sandstone predominantly without associated mudstone, suggesting well-developed meandering channels. The Hinabata Formation is composed largely of mudstone with upward-fining sequence that sometimes lacks channel deposits (Suzuki, 2009), indicating the predominance of the floodplain in a meandering fluvial system.

RESULTS

Stratigraphic assignments of the fossil localities

We verified the previously-reported plant fossil localities and assigned them to appropriate formations following the stratigraphic definition of Suzuki and Asiedu (1995) and the geological map in this study (Fig. 1). These are summarized in Tables 1 and 2.

The plant fossil localities of each formations are as follows (Table 1): The Niga Formation, locs. 1, 10, 16, 21, 30, 33, 54, 58, 63, 64, 85, 87, 90, 92, 93, 95, 96, 98, 99; the Jito Formation, locs. 55, 89; the Mogamiyama Formation, locs. 62, 65, 88; the Hina Formation, locs. 40, 46, 47, 50; the Hinabata Formation, locs. 44, 45, 48, 49, 66, 68, 69, 86, 91, 94, 97, 100. Localities 1–96 were reported by Oishi (1931; 1932; 1940), Oishi and Yamasita (1935), Oishi and Huzioka (1938), Kon'no (1962) and Huzioka (1970). Localities 97, 98, 99 and 100 were reported by Numano and Tsuchiya (1990; 1991), Kimura and Ohana (2000), Kobatake (1954) and Yukawa et al. (2012), respectively.

Floristic assemblages

Based on the revised stratigraphy of the Nariwa Group (Suzuki and Asiedu, 1995) and stratigraphic assignments of the localities in the present study, the Nariwa flora can be stratigraphically divided into two parts, floristic assemblages of which are distinct from one to the other: the Niga Floristic Assemblage (Niga FA) of the Niga Formation and Hina-Hinabata Floristic Assemblage (Hina-Hinabata FA) of the Hina and Hinabata Formations.

Niga FA—The Niga FA consists of 54 species belonging to 27 genera, including Equisetales (ca. 9.3%), Filicopsida (ca. 35.2%), Caytonales (ca. 3.7%), Bennettitales (ca. 5.5%), Cycadales (ca. 7.4%), cycadophytes incertae sedis (ca. 9.3%), Czekanowskiales (ca. 3.7%), Ginkgoales (ca. 7.4%) and Coniferales (ca. 18.5%) (Table 3). The taxa present only in this assemblage include *Annulariopsis inopinata*? Zeiller, 1903, *Pseudolobatannularia densifolia* Kobatake, 1954, *Clathropteris elegans* Oishi, 1940, *Dictyophyllum spectabile* Nathorst, 1906, *Hausmannia* (*Protorhipis*) *crenata* (Nathorst) Moeller, 1902, *H.* (*P.*) *dentata* Oishi, 1932, *H.* (*P.*) *nariwaensis* Oishi, 1930, *Thaumatopteris nipponica* Oishi, 1932, *T. pusilla* (Nathorst) Oishi et Yamasita, 1936, *Cladophlebis nariwaensis* Oishi et Huzioka, 1938, *Sagenopteris nariwaensis* Huzioka, 1970, *S. nilssoniana* (Brongniart) Ward, 1900, *Pterophyllum serratum* Oishi et Huzioka, 1938, *Taeniopteris leclerei* Zeiller, 1903, *T. minensis* Oishi, 1932, *T. richthofeni* (Schenk) Sze, 1933, *T. stenophylla* Kryshtofovich, 1910, *Baiera guilhaumati* Zeiller, 1903, *Cycadocarpidium binerivium* Kimura et Ohana, 2000, *Elatocladus plana* (Feistmantel) Seward, 1919, *Nageiopsis rhaetica* Oishi, 1932, *Podozamites concinnus* Oishi et Huzioka, 1938, *P. schenki* Heer, 1876 and *Stenorachis elegans* Oishi, 1932.

Hina-Hinabata FA—The Hina-Hinabata FA consists of 78 species belonging to 35 genera, including Equisetales (ca. 9.0%), Filicopsida (ca. 33.3%), Bennettitales (ca. 11.5%), Cycadales (ca. 12.8%), cycadophytes incertae sedis (ca. 5.2%), Czekanowskiales (ca. 2.6%), Ginkgoales (ca. 12.8%), Coniferales (ca. 12.8%) and gymnosperms incertae sedis (ca. 1.3%) (Table 3). The taxa present only in this assemblage including *Equisetites nariwensis* Kon'no, 1962, *Lobatannularia nampoensis* (Kawasaki) Kawasaki, 1927, *Neocalamites hoerensis* (Schimper) Halle, 1908, *Phyllotheca* sp., *Asterotheca okafujii* Kimura et Ohana, 1980, *Todites princeps* (Presl) Gothan, 1914, *T. williamsoni* (Brongniart) Seward, 1900, *Gleichenites*? sp., *Coniopteris*? sp., *Clathropteris obovata* Oishi, 1932, *Cladophlebidium*? *okayamaensis* Oishi et Huzioka, 1938, *Cladophlebis bitchuensis* Oishi, 1932, *C. gigantea* Oishi, 1932, *C. pseudodelicatula* Oishi, 1932, *C.* (*Osmundopsis*?) *subplectrophora* Oishi et Huzioka, 1938, *C. tenue* Oishi et Huzioka, 1938, *Sphenopteris gracilis* Oishi, 1932, *Otozamites huzisawae* Oishi et Huzioka, 1938, *O. lancifolius* Oishi, 1932, *O. molinianus* Zigno, 1852, *Pterophyllum aequale* (Brongniart) Nathorst, 1878, *P. ctenoides* Oishi, 1932, *Yabeiella* sp., *Ctenis takamiana* Oishi et Huzioka, 1938, *C. yabei* Oishi, 1932, *Nilssonia japonica* Kimura et Tsujii, 1983, *N. splendens* Sun, 1993, cfr. *N. tenuicaulis* (Phillips) Fox-Strangways, 1892, *Ptilozamites tenuis* Oishi, 1932, *Taeniopteris lanceolata* Oishi, 1932, *Baiera elegans* Oishi, 1932, *B. furcata* Heer, 1877, *B. paucipartita* Nathorst, 1886, *B. taeniata* Braun, 1843, *Ginkgoites digitata* (Brongniart) Seward, 1919 var. *huttoni* Seward, 1919, *Glossophyllum*? sp., *Podozamites distans* (Presl) Braun, 1843, *Stenorachis bitchuensis* Oishi, 1932, *S.* (*Ixostrobus*?) *konianus* Oishi et Huzioka, 1938, cfr. *Storgaardia spectabilis* Harris, 1935, *Swedenborgia cryptomerioides* Nathorst, 1876 and *S. major* Harris, 1935.

The taxa common in both the Niga and Hina-Hinabata floristic assemblages include: *Equisetites multidentatus* Oishi, 1932, *Neocalamites carrerei* (Zeiller) Halle, 1908, *Todites fukutomii* Kimura et Ohana, 1980, *T. goeppertianus* (Muenster) Krasser, 1922, *Clathropteris meniscoides* (Brongniart) Brongniart, 1828, *Dictyophyllum muensteri* (Goeppert) Nathorst, 1875, *D. nilssoni* (Brongniart) Goeppert, 1846, *Thaumatopteris elongata* Oishi, 1932, *Cladophlebis denticulata* (Brongniart) Fontaine, 1889, *C. haiburnensis* (Lindley et Hutton) Brongniart, 1849, *Pterophyllum schenki* (Zeiller) Zeiller, 1903, *Ctenis japonica* Oishi, 1932, *Nilssonia acuminata* (Presl) Goeppert, 1844, *N. muensteri* (Presl) Schimper, 1880, *N. simplex* Oishi, 1932, *Taeniopteris nabaensis* Oishi, 1932, *Czekanowskia rigida* Heer, 1876, *Phoenicopsis* sp., *Baiera filiformis* Oishi, 1932, *Ginkgoites sibirica* (Heer) Seward, 1919, *Elatocladus tenerrima* (Feistmantel) Sahni, 1928, *Pityophyllum longifolium* (Nathorst) Moeller, 1903 and *Podozamites lanceolatus* (Lindley et Hutton) Braun, 1843.

Additionally, the Jito Formation contains six species of five genera. Among them, *Pterophyllum angustum* (Braun) Gothan, 1914 is absent in the Niga and Hina-Hinabata floristic assemblages (Table 2). The Mogamiyama Formation contains 15 species of 13 genera. The following taxa occur only in this formation: *Goeppertella varida* Oishi et Huzioka, 1938, cfr. *Pterophyllum distans* Morris, 1862 (in Oldham and Morris, 1862), *Nillsonia brevis* Brongniart, 1825, *Ptilozamites nilssoni*

TABLE 2. List of the fossil plants from the Nariwa Group with the locality numbers.

Plant groups	Classes	Orders	Families		Genera and species	Niga Fm.	Jito Fm.	Mogamiyama Fm.	Hina Fm.	Hinabata Fm.
Pteridophytes	Equisetopsida	Equisetales		1	*Annulariopsis inopinata*? Zeiller	1, 16				
				2	*Equisetites multidentatus* Oishi	1				49
				3	*E. nariwensis* Kon'no					49
				4	*E.* sp.	1, 16, 30, 33			46	44, 49
				5	*Lobatannularia nampoensis* (Kawasaki) Kawasaki					97
				6	*Neocalamites carrerei* (Zeiller) Halle	10, 54, 58			50	49, 97
				7	*N. hoerensis* (Schimper) Halle					45, 48
				8	*Phyllotheca* sp.					69
				9	*Pseudolobatannularia densifolia* Kobatake	99				
	Filicopsida	Marattiales		10	*Asterotheca okafujii* Kimura et Ohana				47	44, 48, 49, 97
				11	*Marattia asiatica* (Kawasaki) Harris	90				44, 49, 97
		Filicales	Osmundaceae	12	*Todites fukutomii* Kimura et Ohana	1, 33, 96	55	62		44, 69, 94, 97
				13	*T. goeppertianus* (Muenster) Krasser	33			47	48, 97
				14	*T. princeps* (Presl) Gothan					49
				15	*T. williamsoni* (Brongniart) Seward					44, 49, 66, 97
			Gleicheniaceae	16	*Gleichenites*? sp.					97
			Cyatheaceae	17	*Coniopteris*? sp.					97
			Dipteridaceae	18	*Clathropteris elegans* Oishi	1, 63				
				19	*C. meniscoides* (Brongniart) Brongniart	1, 63, 96				97
				20	*C. obovata* Oishi			62		44, 45, 49, 69, 97
				21	*Dictyophyllum muensteri* (Goeppert) Nathorst	63				49, 86
				22	*D. nilssoni* (Brongniart) Goeppert	30, 64, 87				49
				23	*D. spectabile* Nathorst	30				
				24	*Goeppertella varida* Oishi et Huzioka			88		
				25	*Hausmannia* (*Protorhipis*) *crenata* (Nathorst) Moeller	1				
				26	*H.* (*P.*) *dentata* Oishi	1				
				27	*H.* (*P.*) *nariwaensis* Oishi	1, 63, 64, 90				
				28	*Thaumatopteris elongata* Oishi	30		88		48, 49, 69
				29	*T. kochibei* (Yokoyama) Oishi et Yamasita	63		88		
				30	*T. nipponica* Oishi	1				
				31	*T. pusilla* (Nathorst) Oishi et Yamasita	1, 63				
		Filicales incertae sedis		32	*Cladophlebidium*? *okayamaensis* Oishi et Huzioka					91
				33	*Cladophlebis bitchuensis* Oishi					44, 97
				34	*C. denticulata* (Brongniart) Fontaine	10, 16, 30, 63, 85, 96		88	47, 50	49, 69, 94, 97
				35	*C. gigantea* Oishi					44, 97
				36	*C. haiburnensis* (Lindley et Hutton) Brongniart	87, 90		88	40, 50	44, 48, 97
				37	*C. nariwaensis* Oishi et Huzioka	92				
				38	*C. pseudodelicatula* Oishi					44, 97
				39	*C.* (*Osmundopsis*?) *subplectrophora* Oishi et Huzioka					44
				40	*C. tenue* Oishi et Huzioka					44, 97
				41	*C.* sp. a				47, 50	
				42	*C.* sp. b					97
				43	*C.* sp. c					97
				44	*Sphenopteris gracilis* Oishi					44
				45	*S.* sp.	63				
				46	*Spiropteris* sp.					49

TABLE 2 (continued).

Plant groups	Classes	Orders	Families		Genera and species	Niga Fm.	Jito Fm.	Mogamiyama Fm.	Hina Fm.	Hinabata Fm.
Gymnosperms	Caytoniopsida	Caytonales		47	*Sagenopteris nariwaensis* Huzioka	96				
				48	*S. nilssoniana* (Brongniart) Ward	90				
	Bennettitopsida	Bennettitales		49	*Otozamites huzisawae* Oishi et Huzioka				47	
				50	*O. lancifolius* Oishi				47	
				51	*O. molinianus* Zigno				47	
				52	*Pterophyllum aequale* (Brongniart) Nathorst				47, 50	
				53	*P. angustum* (Braun) Gothan		89			
				54	*P. ctenoides* Oishi				46	97
				55	Cfr. *P.distans* Morris			62		
				56	*P. jaegeri* Brongniart				47, 50	44, 97
				57	*P. schenki* (Zeiller) Zeiller	1, 63	55			97
				58	*P. serratum* Oishi et Huzioka	63				
				59	*P.* sp. a	1				
				60	*P.* sp. b					49
				61	*Yabeiella* sp.				46	
	Cycadopsida	Cycadales		62	*Ctenis japonica* Oishi	21, 30				97
				63	*C. takamiana* Oishi et Huzioka				50	
				64	*C. yabei* Oishi				50	
				65	*Nilssonia acuminata* (Presl) Goeppert	21				66, 97
				66	*N. brevis* Brongniart			88		
				67	*N. densinerve* (Fontaine) Berry					97
				68	*N. japonica* Kimura et Tsujii					44
				69	*N. muensteri* (Presl) Schimper	33			50	48, 49, 97
				70	*N. simplex* Oishi	1				97
				71	*N. splendens* Sun					100
				72	Cfr. *N. tenuicaulis* (Phillips) Fox-Strangways					44
	Cycadophytes incertae sedis			73	*Ptilozamites nilssoni* Nathorst			62		
				74	*P. tenuis* Oishi				50	
				75	*Taeniopteris lanceolata* Oishi				40, 50	97
				76	*T. leclerei* Zeiller	64				
				77	*T. minensis* Oishi	21, 96				
				78	*T. nabaensis* Oishi	21, 63				44
				79	*T. richthofeni* (Schenk) Sze	1, 21				
				80	*T. stenophylla* Kryshtofovich	58	89			
				81	*T.* ? sp. a					49
				82	*T.* ? sp. b			65		
	Czekanowskiopsida	Czekanowskiales		83	*Czekanowskia rigida* Heer	1, 21			47	44, 48, 69, 97, 100
				84	*Phoenicopsis* sp.	90	89	88		44, 49, 94, 97
	Ginkgopsida	Ginkgoales		85	*Baiera elegans* Oishi				47, 50	
				86	*B. filiformis* Oishi	21, 33, 58, 93				97
				87	*B. furcata* Heer				47	
				88	*B. guilhaumati* Zeiller	33				
				89	*B. minuta* Nathorst	1, 16			50	
				90	*B. paucipartita* Nathorst					44
				91	*B. taeniata* Braun					66
				92	*B*. sp.					69
				93	*Ginkgoites sibirica* (Heer) Seward	21				44, 49
				94	*G. digitata* (Brongniart) Seward var. *huttoni* Seward					66
				95	*Glossophyllum*? sp.					100
	Coniferopsida	Coniferales		96	*Cycadocarpidium binerivium* Kimura et Ohana	98				
				97	*Elatocladus plana* (Feistmantel) Seward	1				
				98	*E. tenerrima* (Feistmantel) Sahni	1			46	
				99	*E*. sp.	1				
				100	*Nageiopsis rhaetica* Oishi	1				
				101	*Pityophyllum longifolium* (Nathorst) Moeller	1, 21		88	40, 46, 50	44, 49, 69, 97
				102	*Podozamites concinnus* Oishi et Huzioka	63				
				103	*P. distans* (Presl) Braun					100
				104	*P. lanceolatus* (Lindley et Hutton) Braun	1, 16, 21, 30, 33, 58, 63, 85, 96	55, 89	65	46, 50	44, 45, 49, 69, 97, 100
				105	*P. schenki* Heer	1, 10, 63				
				106	*Stenorachis bitchuensis* Oishi				46	
				107	*S. elegans* Oishi	63				
				108	*S.* (*Ixostrobus*?) *konianus* Oishi et Huzioka				50	
				109	Cfr. *Storgaardia spectabilis* Harris					91, 97
				110	*Swedenborgia cryptomerioides* Nathorst					44, 97
				111	*S. major* Harris					44
Gymnosperms incertae sedis				112	*Campylophyllum hoermanni*? Gothan			62		
				113	*Carpolithus* sp.					44, 68

Nathorst, 1878 and *Campylophyllum hoermanni*? Gothan, 1914 (Table 2).

DISCUSSION

Features of the Niga and Hina-Hinabata floristic assemblages

The floristic composition of the Niga FA is characterized as following:

1. Filicopsida (ca. 35.2%) is predominant. In particular, Dipteridaceae is highly diverse (ca. 22.2%) with occurrence of *Clathropteris elegans*, *C. meniscioides*, *Dictyophyllum muensteri*, *D. nilssoni*, *D. spectabile*, *Hausmannia* (*Protorhipis*) *crenata*, *H.* (*P.*) *dentata*, *H.* (*P.*) *nariwaensis*, *Thaumatopteris elongata*, *T. kochibei* (Yokoyama) Oishi et Yamasita, 1936, *T. nipponica*, and *T. pusilla*.
2. Cycadophytes (Bennettitales and Cycadales) occupies ca. 22.2% in composition. Bennetitales exhibits a low diversity with occurrence of only *Pterophyllum schenki*, *P. serratum*, and *P.* sp. a. On the other hand, *Taeniopteris* is common (ca. 9.2%) with *Teniopteris leclerei*, *T. minensis*, *T. nabaensis*, *T. richthofeni*, and *T. stenophylla*.
3. Coniferales is the third-most abundant (ca. 18.5%) with *Cycadocarpidium*, *Elatocladus*, *Nageiopsis*, *Pityophyllum*, *Podozamites*, and *Stenorachis* present.
4. In addition to the above taxa, Caytonales (*Sagenopteris*), and Czekanowskiales (*Czekanowskia* and *Phoenicopsis*) are recognized.

The floristic composition of the Hina-Hinabata FA is characterized as following:

1. Filicopsida (ca. 33.3%) is the most abundant; numerous species of *Cladophlebis* (ca. 12.8%) are present. Dipteridaceae is common (ca. 6.4%) and composed of *Clathropteris obovata*, *C. meniscoides*, *Dictyophyllum muensteri*, *D. nilssoni*, and *Thaumatopteris elongata*, while lacking *Hausmannia*. Marattiales and Osmundaceae are present in most of the localities (Table 2).
2. Cycadophytes is the second most abundant (ca. 29.5%). Among them, Bennettitales is diverse (ca.11.5%) and includes *Otozamites*. Similarly, Cycadales (ca.12.8%) includes various species of *Nilssonia* (*N. acuminata*, *N. densinerve* (Fontaine) Berry, 1911, *N. japonica*, *N. muensteri*, *N. simplex*, *N. splendens*, and cfr. *N. tenuicaulis*) and *Ctenis*.
3. Ginkgoales (ca. 12.8%) contains diverse species of *Baiera* (*B. elegans*, *B. filiformis*, *B. furcata*, *B. minuta* Nathorst, 1878, *B. paucipartita*, *B. taeniata*) and *Ginkgoites* (*G. sibirica*, *G. digitata* var. *huttoni*), with notable occurrence of *Glossophyllum*.
4. *Czekanowskia rigida* and *Phoenicopsis* sp. (Czekanowskiales) are found in many localities (Table 2).
5. *Cycadocarpidium* is absent, while *Swedenborgia* and *Storgaardia* are present.

The Niga and Hina-Hinabata floristic assemblages commonly contain Filicopsida as the most abundant component of the assemblages, while Filicopisda compositions differ between these assemblages in which Dipteridaceae is more dominant in the Niga FA. The Niga and Hina-Hinabata floristic assemblages are also similar in containing cycadophytes as the second most abundant component; however, the Bennettitales are more diverse in the Hina-Hinabata FA than in the Niga FA. Coniferales are notably abundant in the Niga FA. In contrast, Ginkgoales are well represented and Czekanowskiales are common in the Hina-Hinabata FA.

Comparison and the age assignments of the Niga and Hina-Hinabata floristic assemblages

The Late Triassic Niga FA is paleogeographically comparable with the Sadgorod Floral Assemblage (late Carnian) and the Amba Floral Assemblage (middle Norian) of the Mongugai flora of Primorye in Russia, the Mine flora of Yamaguchi in Japan (early–middle Carnian and Carnian–Norian) and the Tianqiaoling flora of Jilin in China (Norian). Similarly, the Hina-Hinabata FA can be compared with the Daedong flora of the Korean Peninsula and the Tonkin flora of Vietnam (Norian–Rhaetian).

Niga FA—The Sadgorod Floral Assemblage from the Sadgorod Formation consists of 43 species belonging to 25 genera (Shorokhova et al., 2009), while the Amba Floral Assemblage from the Amba Formation consists of 86 species belonging to 37 genera (Shorokhova et al., 2009). The Mine flora is found in the Mine Group of Omine Region (lower–middle Carnian) (Maeda and Oyama, 2019) and of Asa Region (Carnian–Norian) (Nishimura, 2012) of Yamaguchi, and composed of 40 genera and 92 species (Naito, 2000). The Tianqiaoling flora consists of 79 species belonging to 31 genera, which is inferred as the Norian based on the plant fossil assemblage (Sun, 1993) (Tables 3, 4).

The Niga FA exhibits some degree of similarity with the Sadgorod Floral Assemblage and Mine flora, in which dipteridaceous ferns are predominant, *Taenopteris* is common, and the genera *Czekanowskia*, *Phoenicopsis* and *Cycadocarpidium* are present. However, the Niga FA differs from them in the lower diversity of Conifelaes (particularly *Podozamites* and *Cycadocarpidium*). Rather, the Niga FA is better comparable with the Amba Floral Assemblage and the Tianqiaoling flora. They are commonly characterized by equally abundant ferns, namely Dipteridaceae (*Clathropteris* and *Dictyophyllum*) and cycadophytes (*Pterophyllum*, *Ctenis*, *Nilssonia* and *Taeniopteris*), with Conifelaes (*Podozamites*, *Cycadocarpidium* and *Elatocladus*) being next abundant. However, the Niga FA differs from the Amba Floral Assemblage and the Tianqiaoling flora in the lower diversity of Conifelaes (particularly *Podozamites* and *Cycadocarpidium*) and the presence of Marattiales and the genus *Thaumatopteris*. The Niga FA also contains *Czekanowskia* and *Phoenicopsis*, which are absent in the Amba Floral Assemblage.

Hina-Hinabata FA—The Daedong flora consists of 70 species belonging to 39 genera (Kimura and Kim, 1984), which is roughly dated as the Late Triassic (Kustatscher et al., 2018). The Tonkin flora is composed of 38 genera and 70 species

TABLE 3. Comparison of floristic assemblages of the Mine flora, the Nariwa flora (the Niga and Hina-Hinabata floristic assemblages) and the Kuruma-type flora.

Plant groups	Orders	Nariwa flora						Mine flora						Kuruma-type flora		
		Late Triassic						Late Triassic						Early Jurassic		
		Norian			Norian—Rhaetian?			lower—middle Carnian			Carnian-Norian			Pliensbachian—Toarcian		
		Niga FA			Hina—Hinabata FA			Omine Region			Asa Region					
		Genera	Species	%	Genera	Species	%	Genera	Species	%	Genera	Species	%	Genera	Species	%
Bryophytes		0	0	0	0	0	0	1	1	1.2	0	0	0	0	0	0
Pteridophytes	Equisetales	4	5	9.3	4	7	9	6	13	16.2	2	7	17.1	2	7	9.5
	Filicopsida	8	19	35.2	12	26	33.3	9	22	27.5	6	12	29.3	12	24	32.4
	(Dipteridaceae)	(4)	(12)	(22.2)	(3)	(5)	(6.4)	(4)	(6)	(7.5)	(4)	(6)	(14.6)	(4)	(4)	(5.4)
Gymnosperms	Caytonales	1	2	3.7	0	0	0	0	0	0	1	1	2.4	1	1	1.3
	Bennettitales	1	3	5.5	3	9	11.5	2	2	2.5	1	2	4.9	4	12	16.2
	Cycadales	2	4	7.4	2	10	12.8	2	3	3.8	1	2	4.9	3	9	12.2
	Cycadophytes incertae sedis	1	5	9.3	2	4	5.2	1	2	2.5	1	2	4.9	1	6	8.1
	Czekanowskiales	2	2	3.7	2	2	2.6	3	3	3.8	3	3	7.3	2	2	2.7
	Ginkgoales	2	4	7.4	3	10	12.8	2	7	8.8	1	1	2.4	3	5	6.8
	Coniferales	6	10	18.5	6	9	11.5	11	27	33.7	4	11	26.8	4	8	10.8
Gymnosperms incertae sedis		0	0	0	1	1	1.3	0	0	0	0	0	0	0	0	0
Total		27	54	100	35	78	100	37	80	100	20	41	100	32	74	100

(Dobruskina, 1994) (Tables 3, 4). It has been originally suggested the Rhaetian (Zeiller, 1903). However, subsequent analyses by Akagi (1954) raise a possibly of its Norian-Rhaetian age, and Kustatscher et al. (2018), while assigning the flora to the Rhaetian, mentions the difficulty in distinguishing between the Norian and the Rhaetian ages by floral composition. Considering these disputes and the lack of definitive evidence to refute the Norian age of the flora, we concur with Akagi (1954) and consider that the Tonkin flora is the Norian-Rhaetian (Table 4).

The Hina-Hinabata FA and the Daedong flora are characterized by abundance of ferns, namely the genera *Todites* and *Cladophlebis*, and cycadophytes (*Otozamites*, *Pterophyllum*, *Ctenis* and *Nilssonia*), in addition to the occurrences of the genera *Czekanowskia* and *Phoenicopsis*. On the other hand, in the Hina-Hinabata FA, *Taeniopteris* is less abundant and *Cycadocarpidium* is absent. The Hina-Hinabata FA and the Tonkin flora are characterized by abundant ferns (*Clathropteris*, *Dictyophyllum*, *Cladophlebis*, *Asterotheca* and *Sphenopteris*) and cycadophytes (*Otozamites* and *Pterophyllum*), low diversity of *Podozamites*, and the absence of *Cycadocarpidium*. The Hina-Hinabata FA differs from the Tonkin flora in containing Czekanowskiales and higher diversity of Ginkgoales.

Age of the Niga and Hina-Hinabata floristic assemblages— By the presence of *Monotis ochotica*, an index fossil of the late Norian (Gavrilova et al., 2006), the age of the Jito Formation is suggested the late Norian. The contacts of the Jito Formation with the underlying Niga Formation is unclear, nor is the overlying Hinabata Formation. Therefore, the Niga FA is likely late Norian and/or older, while the Hina-Hinabata FA late Norian and/or younger.

Floristic comparisons of the Niga FA and the Hina-Hinabata FA with other floras of known ages allow age-constraint of these assemblages. In the Niga FA, cycadophytes and Filicopsida are predominant, while in the Sadgorod Floral Assemblage (late Carnian) and Mine flora (early–middle Carnian in Omine Region), Coniferales and Filicopsida are the most common. Furthermore, the diversity of Equisetales is lower in Niga FA than in the Mine flora. These differences in floristic compositions among the Niga FA, the Sadgorod FA and the Mine flora suggest that the Niga FA is not assignable to the Carnian. Additionally, the Niga Formation underlies the Jito Formation conformably (Masaoka and Suzuki, 2015), eliminating the possibility that there is a hiatus between these Formations. These lines of evidence indicate that the Niga FA is at least younger than the Carnian. On the other hand, cycadophytes and ferns, the plants that became prominent in the Norian-Rhaetian, are present in the Niga FA as in the Amba Floral Assemblage and the Tianqiaoling flora. Because the upper Norian Jito Formation caps the Niga Formation, it is concluded that the Niga FA is assignable to the Norian.

The Hina-Hinabata FA is comparable to the Norian–Rhaetian Tonkin flora (Akagi, 1954; Kustatscher et al., 2018) in the low diversity of *Podozamites* and absence of *Cycadocapidium*, which is in contrast to the Norian Amba Floral Assemblage and the Tianqiaoling flora with moderately-diverse *Podozamites* and

TABLE 4. Comparison of floristic assemblages of the Sadgorod Floral Assemblage and the Amba Floral Assemblage of the Mongugai flora, the Tianqiaoling flora, the Daedong flora, and the Tonkin flora.

Plant groups	Orders	Mongugai flora						Tianqiaoling flora			Daedong flora			Tonkin flora		
		Late Triassic						Late Triassic			Late Triassic			Late Triassic		
		upper Carnian			middle Norian			Norian						Norian–Rhaetian		
		Sadgorod FA			Amba FA											
		Genera	Species	%	Genera	Species	%	Genera	Species	%	Genera	Species	%	Genera	Species	%
Bryophytes		1	1	2.3	1	2	2.3	0	0	0	0	0	0	0	0	0
Pteridophytes	Lycopodiales	1	1	2.3	2	2	2.3	0	0	0	0	0	0	0	0	0
	Equisetales	2	3	7	3	6	7	3	6	7.6	4	7	9.6	3	3	4.7
	Filicopsida	5	7	16.2	6	14	16.3	7	12	15.2	10	18	24.7	16	27	42.1
	(Dipteridaceae)	(3)	(4)	(7.5)	(3)	(7)	(8.1)	(3)	(4)	(5.1)	(3)	(3)	(4.1)	(2)	(7)	(10.9)
Gymnosperms	Caytonales	0	0	0	3	5	5.8	1	2	2.5	1	1	1.4	2	2	3.1
	Bennettitales	2	2	4.7	3	12	13.9	1	1	1.3	5	12	16.4	4	13	20.3
	Cycadales	2	2	4.7	2	6	7	3	8	10.1	5	7	9.6	1	4	6.3
	Cycadophytes incertae sedis	3	3	7	1	5	5.8	1	4	5.1	2	7	9.6	2	8	12.5
	Czekanowskiales	2	5	11.6	1	1	1.2	2	4	5.1	2	3	4.1	0	0	0
	Ginkgoales	3	4	9.3	4	6	7	3	9	11.4	4	6	8.2	1	1	1.6
	Coniferales	3	11	25.6	7	18	20.9	7	23	29.1	6	12	16.4	3	4	6.3
Gymnosperms incertae sedis		1	4	9.3	4	9	10.5	3	10	12.6	0	0	0	2	2	3.1
Total		25	43	100	37	86	100	31	79	100	39	73	100	34	64	100

the common occurrence of *Cycadocarpidium*. Therefore, the Hina-Hinabata FA is at least assignable to the late Norian to Rhaetian. Notably, the Hina-Hinabata FA exhibits a partial similarity with the Early Jurassic Kuruma-type flora. The Kuruma-type flora in the Kuruma Group, central Honshu Island is composed of 32 genera and 74 species of fossil plants (Kimura et al., 1988), and is assigned to Pliensbachian–Toarcian (Takeuchi et al., 2017). Both the Kuruma-type flora and the Hina-Hinabata FA are characterized by abundant cycadophytes in which *Otozamites* is present and *Nilssonia* is diverse, and by the occurrence of Czekanowskiales (*Czekanowskia* and *Phoenicopsis*) and Coniferales (*Storgaardia* and *Swedenborgia*), leaving a possibility that the age of the Hina-Hinabata FA is younger than the Rhaetian.

Paleoclimate inferred from the Niga and Hina-Hinabata floristic assemblages

The Niga Formation that yields the Niga FA and Hina and Hinabata Formations that yield the Hina-Hinabata FA were presumably deposited in meandering fluvial systems. Based on the suggested depositional environments of the Niga Formation, the Niga FA likely represents the fossil plants that inhabited near the channels and floodplain environment. Similarly, the Hina-Hinabata FA is constituted by the fossil plants that inhabited near the channels and floodplain environment during the time of the Hina and Hinabata Formations, respectively. Therefore, the habitats of these floristic assemblages were probably not largely different.

Dipteridaceae is more abundant in the Niga FA than in the Hina-Hinabata FA. On the other hand, the diversity of cycadophytes, particularly Bennettitales, increases from the Niga FA to the Hina-Hinabata FA. This is also true for Ginkgoales. Additionally, *Czekanowskia rigida* and *Phoenicopsis* sp. (Czekanowskiales) are less common in the Niga FA than in the Hina-Hinabata FA. The predominance of thermophilous and hygrophilous Dipteridaceae and cycadophytes (Sun, 1993; Volynets and Shorokhova, 2007) in both the Niga and Hina-Hinabata floristic assemblages is consistent with a warm and humid, tropical to subtropical setting, while the abundance of the Czekanowskiales in the Hina-Hinabata FA indicates warm and humid, warm-temperate climate (Vachrameev, 1991). This difference in the floristic compositions between the Norian Niga FA and the Norian-Rhaetian? Hina-Hinabata FA indicates that the paleoclimate of eastern Eurasia generally transitioned from subtropical to warm-temperate. Additionally, mixed presence of thermophilous Dipteridaceae and cycadophytes and non-thermophilous Czekanowskiales in the Hina-Hinabata FA may suggest more pronounced seasonality during the latest Triassic.

CONCLUSIONS

1. Based on the revised stratigraphic relationship of the formations within the Nariwa Group (Suzuki and Asiedu, 1995) and comparison with coeval floras in eastern Eurasia, the Nariwa flora can be assigned to two distinct floristic assemblages, the Norian Niga FA and the Norian-Rhaetian? Hina-Hinabata FA.
2. The Niga FA is characterized by abundance of Dipteridaceous ferns (*Clathropteris*, *Dictyophyllum*, *Thaumatopteris* and *Hausmannia*) and cycadophytes (*Pterophyllum* and *Taeniopteris*), and the occurrence of genera *Sagenopteris*, *Cycadocarpidium* and *Nageiopsis*. This floristic composition of the Niga FA likely represents a warm and humid subtropical climatic condition during the Norian.
3. The Hina-Hinabata FA is characterized by abundant ferns (*Cladophlebis*, *Todites*, *Marattia*, *Asterotheca* and *Clathropteris*), cycadophytes (*Otozamites*, *Pterophyllum*, *Ctenis*, *Nilssonia*) and Czekanowskiales (*Czekanowskia* and *Phoenicopsis*), and the occurrence with genera *Glossophyllum*, *Storgaardia* and *Swedenborgia*. This floristic composition of the Hina-Hinabata FA reflects a shift to a warm-temperate condition with more pronounced seasonality toward the latest Triassic in eastern Eurasia.

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*	: in Japanese with English abstract
**	: in Japanese
***	: English translation from the original title written in Japanese
****	: in Russian and English
*****	: in Chinese and English
******	: in Russian
*******	: in Swedish
********	: in French
*********	: in Germany
**********	: in Italian

< 地名・地層名 >

Asa ………………………………… 厚狭
Fukatawa ………………………… 深屾
Hina Formation ………………… 日名層
Hinabata Formation ………… 日名畑層
Jito Formation …………………… 地頭層
Kuruma Group ……………… 来馬層群
Mine Group ………………… 美祢層群
Mogamiyama Formation ……… 最上山層
Nariwa Group ……………… 成羽層群
Niga Formation ………………… 仁賀層
Omine ……………………………… 大嶺

APPENDIX. List of the fossil plants from the Nariwa Group based on published papers: Huzioka (1970), Kimura and Tsujii (1980), Kimura and Ohana (1980), Kimura and Tsujii (1983), Numano and Tsuchiya (1990), Numano and Tsuchiya (1991), Kimura and Ohana (2000) and Yukawa et al. (2012). The classification of the plant taxa in the table follows Nishida (2017). While Huzioka (1970) reports three types of *Pterophyllum* sp., we follow Oishi and Huzioka (1938) and recognize two types of *Pterophyllum* sp.

Plant groups	Classes	Orders	Families		Genera and speices	References	Previous works
Pteridophytes	Equisetopsida	Equisetales		1	*Annulariopsis inopinata*? Zeiller	Oishi, 1930	
				2	*Equisetites multidentatus* Oishi	Oishi, 1932	
				3	*E. nariwensis* Kon’no	Kon’no, 1962	
				4	*E.* sp.	Oishi (1932), p. 267, pl. 20 (2), figs. 3-6	
				5	*Lobatannularia nampoensis* (Kawasaki) Kawasaki	Numano and Tsuchiya (1990), Numano and Tsuchiya (1991)	
				6	*Neocalamites carrerei* (Zeiller) Halle	Oishi, 1932	
				7	*N. hoerensis* (Schimper) Halle	Oishi, 1932	
				8	*Phyllotheca* sp.	Oishi, 1932	
				9	*Pseudolobatannularia densifolia* Kobatake	Kobatake, 1954	
	Filicopsida	Marattiales		10	*Asterotheca okafujii* Kimura et Ohana	Kimura and Ohana, 1980	*Cladophlebis raciborskii* Zeiller: Oishi, 1932 *Cladophlebis raciborskii* forma *integra* Oishi et Takahasi: Oishi and Huzioka, 1938
				11	*Marattia asiatica* (Kawasaki) Harris	Kimura and Tsujii, 1980	*Marattiopsis muensteri* (Goeppert) Schimper: Oishi, 1932
		Filicales	Osmundaceae	12	*Todites fukutomii* Kimura et Ohana	Kimura and Ohana, 1980	*Cladophlebis nebbensis* (Brongniart) Nathorst: Oishi, 1932
				13	*T. goeppertianus* (Muenster) Krasser	Oishi and Huzioka, 1938	*T. Roesserti* Zeiller (non Presl): Oishi, 1932
				14	*T. princeps* (Presl) Gothan	Oishi, 1932	
				15	*T. williamsoni* (Brongniart) Seward	Oishi, 1932	
			Gleicheniaceae	16	*Gleichenites*? sp.	Numano and Tsuchiya (1990), Numano and Tsuchiya (1991)	
			Cyatheaceae	17	*Coniopteris*? sp.	Numano and Tsuchiya (1990), Numano and Tsuchiya (1991)	
			Dipteridaceae	18	*Clathropteris elegans* Oishi	Oishi, 1940	*Clathropteris meniscoides* var. *elegans* Oishi: Oishi, 1932
				19	*C. meniscoides* (Brongniart) Brongniart	Oishi and Huzioka, 1938	
				20	*C. obovata* Oishi	Oishi, 1932	
				21	*Dictyophyllum muensteri* (Goeppert) Nathorst	Oishi, 1932	
				22	*D. nilssoni* (Brongniart) Goeppert	Oishi, 1932	
				23	*D. spectabile* Nathorst	Oihsi, 1932	
				24	*Goeppertella varida* Oishi et Huzioka	Oishi, 1940	
				25	*Hausmannia* (*Protorhipis*) *crenata* (Nathorst) Moeller	Oishi and Yamasita, 1936	*Hausmannia crenata* Nathorst: Oishi, 1932
				26	*H.* (*P.*) *dentata* Oishi	Oishi and Yamasita, 1936	*Hausmannia dentata* Oishi: Oishi, 1932
				27	*H.* (*P.*) *nariwaensis* Oishi	Oishi and Yamasita, 1936	*Hausmannia nariwaensis* Oishi: Oishi, 1930
				28	*Thaumatopteris elongata* Oishi	Oishi (1932), Oishi (1940)	Cfr. *Thaumatopteris brauniana* Popp: Oishi, 1932 *T. schenki* Nathorst: Oishi, 1932
				29	*T. kochibei* (Yokoyama) Oishi et Yamasita	Oishi and Yamasita, 1936	
				30	*T. nipponica* Oishi	Oishi, 1932	
				31	*T. pusilla* (Nathorst) Oishi et Yamasita	Oishi and Yamasita, 1936	
		Filicales incertae sedis		32	*Cladophlebidium*? *okayamaensis* Oishi et Huzioka	Oishi and Huzioka, 1938	
				33	*Cladophlebis bitchuensis* Oishi	Oishi, 1932	
				34	*C. denticulata* (Brongniart) Fontaine	Oishi, 1932	
				35	*C. gigantea* Oishi	Oishi, 1932	
				36	*C. haiburnensis* (Lindley et Hutton) Brongniart	Oishi, 1932	
				37	*C. nariwaensis* Oishi et Huzioka	Oishi and Huzioka, 1938	
				38	*C. pseudodelicatula* Oishi	Oishi, 1932	
				39	*C.* (*Osmundopsis*?) *subplectrophora* Oishi et Huzioka	Oishi and Huzioka, 1938	
				40	*C. tenue* Oishi et Huzioka	Oishi and Huzioka, 1938	
				41	*C.* sp. a	Oishi and Huzioka (1938), p. 77, pl. 8 (2), fig. 3	
				42	*C.* sp. b	Numano and Tsuchiya (1990), pl. 7, fig. 1 Numano and Tsuchiya (1991), p. 57, fig. 18b	
				43	*C.* sp. c	Numano and Tsuchiya (1990), pl. 7, fig. 2, pl. 8, fig. 1 Numano and Tsuchiya (1991), p. 57, fig. 19b	
				44	*Sphenopteris gracilis* Oishi	Oishi, 1932	
				45	*S.* sp.	Oishi and Huzioka (1938), p. 84, pl. 12 (6), fig. 1	
				46	*Spiropteris* sp.	Oishi, 1932	

APPENDIX (continued).

Plant groups	Classes	Orders	Families		Genera and speices	References	Previous works
Gymnosperms	Caytoniopsida	Caytonales		47	*Sagenopteris nariwaensis* Huzioka	Huzioka, 1970	
				48	*S. nilssoniana* (Brongniart) Ward	Oishi, 1940	
	Bennettitopsida	Bennettitales		49	*Otozamites huzisawae* Oishi et Huzioka	Oishi and Huzioka, 1938	
				50	*O. lancifolius* Oishi	Oishi, 1932	
				51	*O. molinianus* Zigno	Oishi, 1940	*O. indosinensis* Zeiller: Oishi, 1932
				52	*Pterophyllum aequale* (Brongniart) Nathorst	Oishi and Huzioka, 1938	
				53	*P. angustum* (Braun) Gothan	Oishi and Huzioka, 1938	
				54	*P. ctenoides* Oishi	Oishi, 1932	
				55	Cfr. *P.distans* Morris	Oishi, 1932	
				56	*P. jaegeri* Brongniart	Oishi, 1932	
				57	*P. schenki* (Zeiller) Zeiller	Oishi, 1932	
				58	*P. serratum* Oishi et Huzioka	Oishi and Huzioka, 1938	
				59	*P.* sp. a	Oishi and Huzioka (1938), p. 87, pl. 10 (4), fig. 7	
				60	*P.* sp. b	Oishi and Huzioka (1938), p. 84, pl. 10 (4), figs. 2, 2a	
				61	*Yabeiella* sp.	Oishi, 1931	
	Cycadopsida	Cycadales		62	*Ctenis japonica* Oishi	Oishi, 1932	
				63	*C. takamiana* Oishi et Huzioka	Oishi and Huzioka, 1938	
				64	*C. yabei* Oishi	Oishi, 1932	
				65	*Nilssonia acuminata* (Presl) Goeppert	Oishi, 1932	
				66	*N. brevis* Brongniart	Oishi and Huzioka, 1938	
				67	*N. densinerve* (Fontaine) Berry	Numano and Tsuchiya (1990), Numano and Tsuchiya (1991)	
				68	*N. japonica* Kimura et Tsujii	Kimura and Tsujii, 1983	*N. orientalis* Heer: Oishi, 1932
				69	*N. muensteri* (Presl) Schimper	Oishi, 1932	
				70	*N. simplex* Oishi	Oishi, 1932	
				71	*N. splendens* Sun	Yukawa et al., 2012	
				72	Cfr. *N. tenuicaulis* (Phillips) Fox-Strangways	Oishi, 1940	*Pterophyllum*? sp. aff. *N. tenuicaulis* (Phillips) Fox-Strangways: Oishi and Huzioka, 1938
	Cycadophytes incertae sedis			73	*Ptilozamites nilssoni* Nathorst	Oishi, 1932	
				74	*P. tenuis* Oishi	Oishi, 1932	
				75	*Taeniopteris lanceolata* Oishi	Oishi, 1932	
				76	*T. leclerei* Zeiller	Oishi, 1940	*T.* cfr. *leclerei* Zeiller: Oishi, 1932
				77	*T. minensis* Oishi	Oishi, 1940	Cfr. *T. minensis* Oishi: Oishi and Huzioka, 1938
				78	*T. nabaensis* Oishi	Oishi, 1932	
				79	*T. richthofeni* (Schenk) Sze	Oishi, 1940	*T.* cfr. *carruthersi* Tenison-Woods: Oishi, 1932
				80	*T. stenophylla* Kryshtofovich	Oishi, 1940	*T.* cfr. *stenophylla* Kryshtofovich: Oishi, 1932
				81	*T.* ? sp. a	Oishi (1932), p. 333, pl. 44 (26), figs. 5, 5a	
				82	*T.* ? sp. b	Oishi (1932), p. 333, pl. 44 (26), fig. 6A-B	
	Czekanowskiopsida	Czekanowskiales		83	*Czekanowskia rigida* Heer	Oishi, 1932	
				84	*Phoenicopsis* sp.	Oishi, 1932	
	Ginkgopsida	Ginkgoales		85	*Baiera elegans* Oishi	Oishi, 1932	
				86	*B. filiformis* Oishi	Oishi, 1932	
				87	*B. furcata* Heer	Oishi (1932), Oishi (1940)	
				88	*B. guilhaumati* Zeiller	Oishi, 1940	*B. guilhaumati*? Zeiller: Oishi, 1932
				89	*B. minuta* Nathorst	Oishi, 1940	*B. muensteriana* (Presl) Heer: Oishi, 1932
				90	*B. paucipartita* Nathorst	Oishi, 1932	
				91	*B. taeniata* Braun	Oishi, 1932	
				92	*B*. sp.	Oishi (1932), p. 354, pl. 50 (32), fig. 7	
				93	*Ginkgoites sibirica* (Heer) Seward	Oishi, 1932	
				94	*G. digitata* (Brongniart) Seward var. *huttoni* Seward	Oishi and Huzioka, 1938	
				95	*Glossophyllum*? sp.	Yukawa et al., 2012	
	Coniferopsida	Coniferales		96	*Cycadocarpidium binerivium* Kimura et Ohana	Kimura and Ohana, 2000	
				97	*Elatocladus plana* (Feistmantel) Seward	Oishi, 1932	
				98	*E. tenerrima* (Feistmantel) Sahni	Oishi, 1932	
				99	*E*. sp.	Oishi (1932), p. 361, pl. 51 (33), fig. 11	
				100	*Nageiopsis rhaetica* Oishi	Oishi, 1932	
				101	*Pityophyllum longifolium* (Nathorst) Moeller	Oishi, 1932	
				102	*Podozamites concinnus* Oishi et Huzioka	Oishi and Huzioka, 1938	
				103	*P. distans* (Presl) Braun	Yukawa et al., 2012	
				104	*P. lanceolatus* (Lindley et Hutton) Braun	Oishi, 1932	
				105	*P. schenki* Heer	Oishi, 1932	
				106	*Stenorachis bitchuensis* Oishi	Oishi, 1932	
				107	*S. elegans* Oishi	Oishi, 1932	
				108	*S.* (*Ixostrobus*?) *konianus* Oishi et Huzioka	Oishi and Huzioka, 1938	
				109	Cfr. *Storgaardia spectabilis* Harris	Oishi and Huzioka, 1938	
				110	*Swedenborgia cryptomerioides* Nathorst	Oishi and Yamasita, 1935	
				111	*S. major* Harris	Oishi and Yamasita, 1935	
Gymnosperms incertae sedis				112	*Campylophyllum hoermanni*? Gothan	Oishi, 1940	*Campylophyllum hoermanni* Gothan: Oishi, 1932
				113	*Carpolithus* sp.	Oishi and Huzioka, 1938	

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