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Miocene Floras of Taiwan: an Overview in Comparison with Those of Southwestern End of Japan

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Abstract. Miocene megafossil floras in Taiwan are reviewed, and floral characteristics for the Shihti flora (Early Miocene) in the northern part of Taiwan and Lilongshan flora (Late Miocene) in the southern part are briefly discussed. In particular, the comparison is made with the Early to Middle Miocene floras from the Yaeyama Group in Yonaguni-jima and Iriomote-jima, southwestern end of Japan. The Shihti and Lilongshan floras, together with the flora from Yonaguni-jima, show the feature of oak-laurel forest in the warm-temperate to subtropical regions. The flora from Iriomote-jima is characterized by wetland and more temperate elements. These floras in Taiwan and Yonaguni-jima and Iriomote-jima in Japan provide evidence of Miocene floras in the low-latitudes where little is known up to the present.

Key words : Miocene, megafossil flora, Taiwan, Yonaguni-jima, Iriomote-jima.

Introduction

In Taiwan, Tertiary sediments are widely distributed throughout the island. Miocene sediments crop out in the western mountainous and hilly lands along the Central Mountain Ranges made up mainly of the Paleogene rocks. These Miocene sediments are conformably overlain by Pliocene sediments. More limited Miocene distributions are also known in the southern and eastern coastal areas. These Miocene sediments are mostly marine in origin. In the northern and east central parts, littoral and non-marine coal-bearing sediments are intercalated at three horizons: the Lower, Middle, and Upper coals (Chang, 1967; Ho, 1988).

Although many palynological and geological works for Miocene sediments have been made, our knowledge on the Miocene floras is still insufficient. Clearly, studies on the Miocene floras in Taiwan are important, because the Miocene sequence is more complete than that of the Mainland China and is well constraint biostratigraphically by abundant marine invertebrates and microfossils (Huang & Huang, 1984; and others). Furthermore, since Miocene floras of Taiwan represent one of the low-latitude floras, these provide evidence of the latitudinal gradient of the Miocene floras in the eastern maritime areas of the Eurasian Continent. In this paper, we briefly show the outline of the Miocene floras in Taiwan and compare these with the Miocene floras in the southwestern end of Japan (Fig. 1).

Overview of the Miocene Floras in Taiwan

Miocene plant megafossils have been recorded since Deguchi (1912) listed plant megafossils in the explanatory text of the geological and mineralogical map of Taiwan. Subsequently, many Japanese geologists noted the occurrence of plant megafossils from the Miocene rocks, mostly associated sediments with workable coal seams (see Hayasaka, 1939). Tan (1940) cited S. Endo's unpublished data and listed such plants as *Ficus tiliaefolia* Heer (="*Alangium*" *aequalifolium* (Goeppert) Kryshtofovich et Borsuk), *Ficus* ? sp., *Cinnamomum* cf. *vera* Berry, and *Podogoni-*

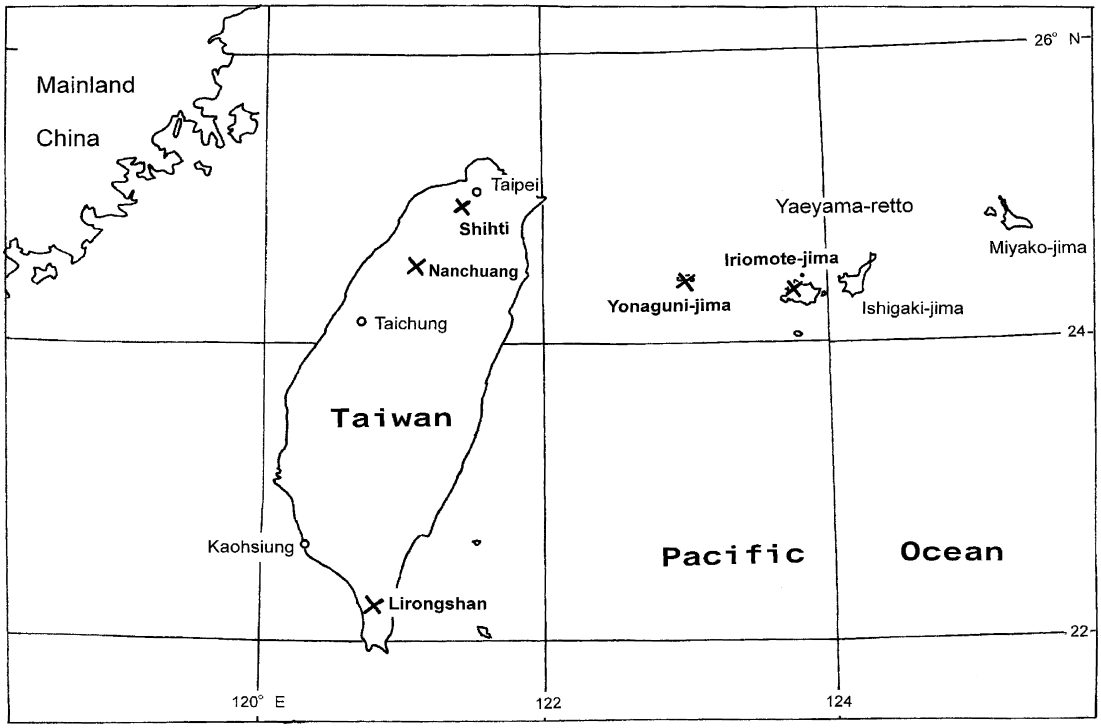

Fig. 1. Index map showing plant megafossil localities in Taiwan and Yaeyama-retto, Japan.

um sp. from the "Lower Coal" in the northern part of Taiwan (see also Tan, 1971). However, these plant megafossils have only listed without any illustration or description of the plants.

After the World War II, Chaney and Chuang (1968) published the "Middle" Miocene flora from the Shihti Formation in the northeastern part of Taiwan. Subsequently, Canright (1972) reported the occurrence of *Metasequoia* from the same formation. This Shihti flora has been the only well-studied megafossil flora, though any illustration and description of the floral components had not been given except for three new species. In recent bio- and chronostratigraphy, the Shihti Formation is the late Early Miocene older than the age of the N8 zone in the planktonic foraminifer zonation.

Plant megafossils from the Upper Coal horizon have been unknown until Cheng and Tang (1974) reported *in situ* cycadean trunks from the Nanchuang Formation in Nanchuang area, northern Taiwan.

Very recently, Li (2000) studied Miocene plant megafossils (Lilongshan flora) from the Lilongshan Formation (Late Miocene: Chen *et al.*, 1985; Sung, 1990) in the southern part of Taiwan, and described 32 leaf and seed species. He also described petrified woods from the Kungkuan Tuff in Taoyuan, northern part of Taiwan: *Taxodioxylon sequoianum* Gothan, *Bischofia javanoxyla* Li *et al.*, and *Camellia kueishanensis* Li *et al.* (Li, 2000; Li *et al.*, 1999, 2003). The Kungkuan Tuff is of Early Miocene below the Shihti Formation or the Middle Coal. Additionally, Li (2000) restudied the cycadean fossil forest reported by Cheng and Tang (1974) in Nanchuang.

Apart from plant megafossils, palynological studies were made by Ling (1965), Canright (1974), Mei and Shaw (1983), and Huang and his co-authors (Huang, 1978–1992; Chaw & Huang, 1981; Hsieh & Huang, 1985; Shaw & Huang,

1983; Hsieh *et al.*, 1985). These studies will provide a basis for the palynostratigraphic synthesis in the Miocene of Taiwan, together with the comparison with that of East China Sea (Hu & Sarjeant, 1992; Iwata & Oshima, 2001).

Shihti and Lilongshan Floras

As noted above, the Shihti flora in the northern part of Taiwan and the Lilongshan flora in the southern part are relatively well-studied fossil floras in their floral composition. The Shihti flora is of late Early Miocene, and the Lilongshan flora is of Late Miocene.

Chaney and Chuang (1968) listed 22 species, in 19 genera and 13 families, of the Shihti flora. The flora is characterized by evergreen members of the Lauraceae, associated by evergreen fagaceous members. Monocots of bambusoid and Palmae members are also charactersitic (Table 1). As they pointed out, the Shihti flora shows the resemblance with evergreen sclerophyll broad-

Table 1. List of leaf remains of the Miocene Shihti and Lirongshan floras.

Genera and species	Shihti[1]	Lilongshan[2]
Coniogramme devoli Chaney et Chuang	×	–
Pseudodrynaria sp.	–	×
Metaseuoia occidentalis (Newb.) Chaney	×	–
Actinodaphne nipponica Tanai	×	–
Cinnamomum sp.	×	× (2 species)
Machilus sp.	×	×
Neolitsea sp.	×	–
Neolitsea sp. cf. *N. aciculata* (Bl.) Koidzumi	–	×
Lindera sp.	–	× (2 species)
Phoebe mioformosana Tanai	–	×
Castanopsis miocuspidata Matsuo	×	–
Castanopsis sp.	–	× (3 species)
Cyclobalanopsis praegilva Kryshtofovich	–	×
Fagus protolongipetiolata Huzioka	–	×
Quercus sp.	–	× (2 species)
Pasania spp.	× (2 species)	–
Juglans sp.	–	×
Cleyera sp.	×	–
Diospyros sp.	×	–
Ardisia sp.	×	–
Mallotus sp.	×	–
Photinia sp.	×	–
Pongamia sp.	–	×
Leguminosae indet.	×	–
Sapindus sp.	–	×
Acer juani Chaney et Chuang	×	–
Alangium sp.	×	–
Aucuba sp.	–	×
Celastrus sp.	×	–
Gymnosporia sp.	–	×
Microtropis sp. cf. *C. protojaponica* Murai	×	–
Perrottetia miocenica Chaney et Chuang	×	–
Dicots indet.	–	× (4 species)
Smilax sp. cf. *S. trinervis* Morita	–	×
Smilax sp.	–	×
Bambusa sp.	×	–
Phyllostachys sp.	×	–
Rhapis sp.	×	–

[1] Shihti flora after Chaney & Chuang (1968) and Canright (1972).

[2] Lilongshan flora after Li (2000); seed records of *Cephalotaxus*, *Luffa*, *Nyssa*, *Diospyros*, *Ctrus*, *Ipomoea*, and *Sapindus* are excluded in this table.

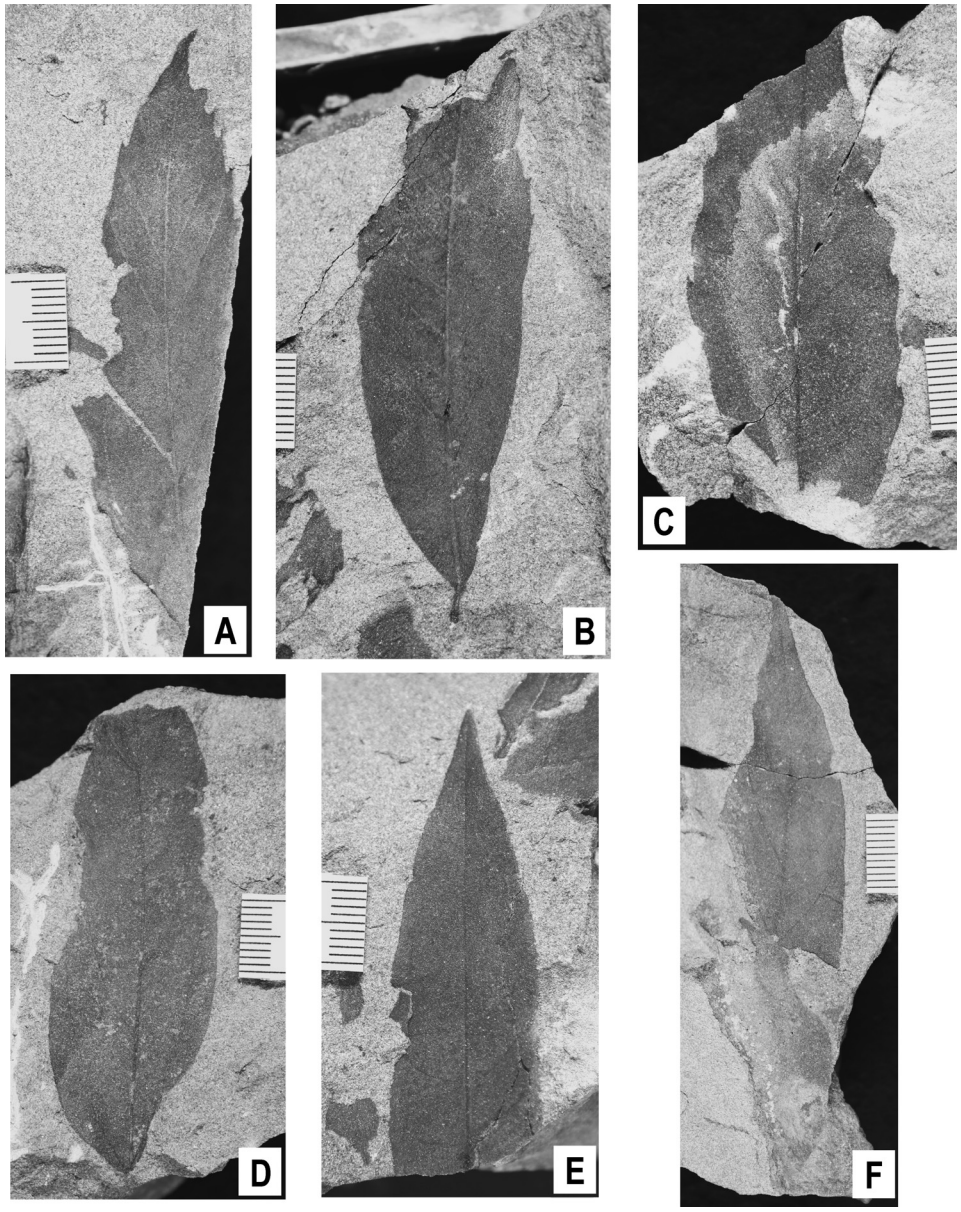

Fig. 2. Selected plant megafossils from the Lilongshan Formation (Late Miocene). A, *Cyclobalanopsis mandraliscae* (Gaudin) Tanai, NSM-PP 11551; B, *C. praegilva* Kryshtofovich, NSM-PP 11552; C, *C.* sp. cf. *C. nathorstii* (Kryshtofovich) Huzioka, NSM-PP 11553; D, *Cinnamomum* sp., NSM-PP 11554; E, Dicot indet. cf. Apocynaceae, NSM-PP 11556; F, Lauraceae cf. *Actinodaphne*, NSM-PP 11555. Scales: 10 mm.

leaved forests distributed at altitudes of 500 to 2000 m of the present-day Taiwan. The presence of the deciduous members of *Acer* and possibly *Alangium* are noteworthy. Although taxonomic status of Chaney and Chuangs' *Alangium* is uncertain, it may represent an extinct genus of the Sterculiaceae or Tiliaceae (see Tanai, 1989).

Li (2000) recognized 26 leaf species of the Lilongshang flora (Table 1). This flora is evidently allochthonous accumulated in a shallow marine basin. Although taphonomic factors must take into the consideration, an overall feature of the

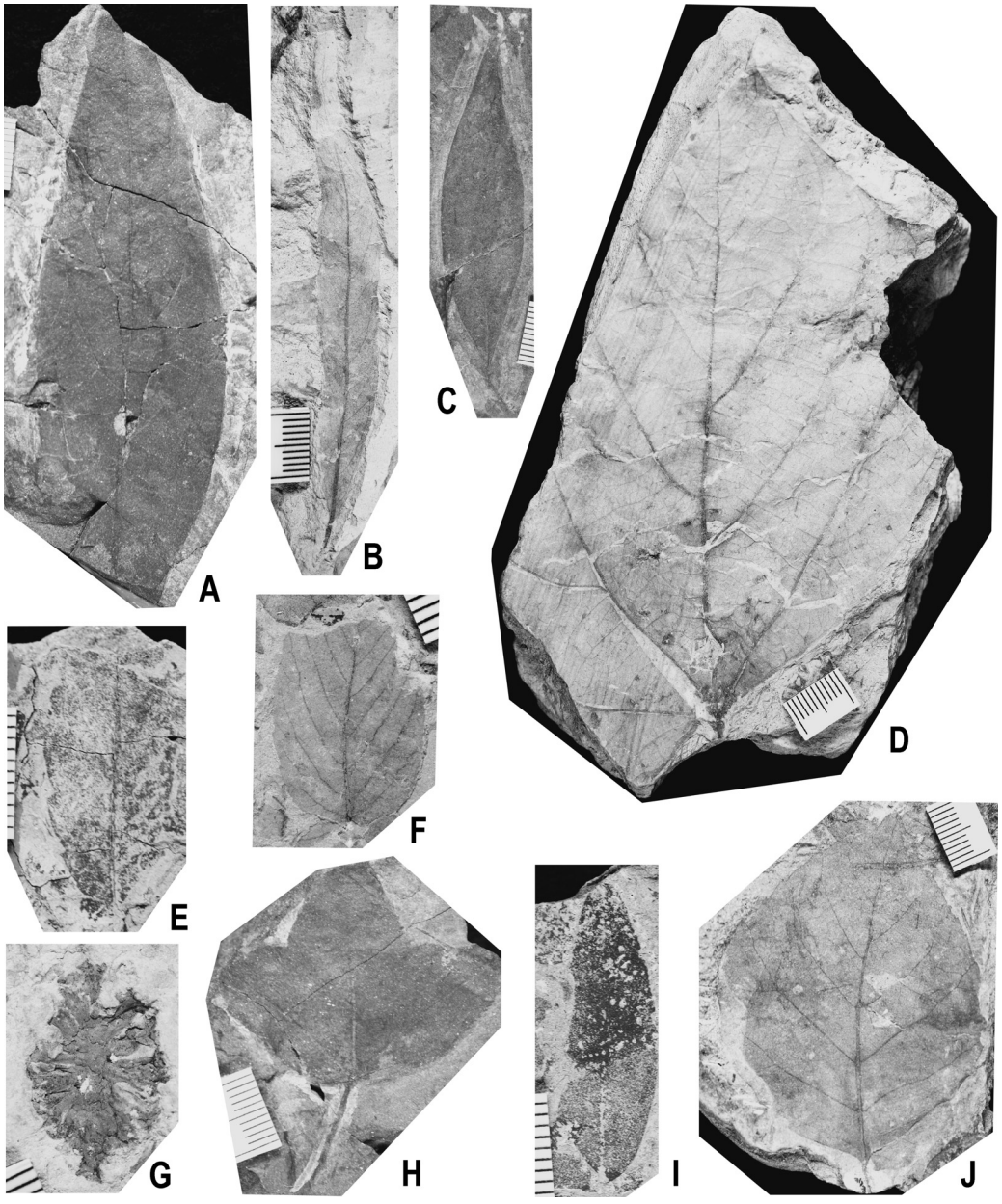

Fig. 3. Selected plant megafossils from the Yaeyama Formation (Early to Middle Miocene) from Iriomote-jima and Yonaguni-jima. A, *Neolitsea* sp., NSM-PP 15160a; B, *Salix* sp. 1, NSM-PP 11557; C, *Cinnamomum lanceolatum* (Unger) Heer, NSM-PP 15161; D, "*Alangium*" *aequalifolium* (Goeppert) Kryshtofovich et Borsuk, NSM-PP 11558; E, *Zelkova ungeri* (Ettingshausen) Kovats, NSM-PP 1515191; F, *Carpinus* sp., NSM-PP 15180; G, *Alnus* sp. (infructescence), NSM-PP 11559; H, *Liquidambar miosinica* Hu et Chaney, NSM-PP 15164; I, *Podogonium knorrii* Heer, NSM-PP 15186; J, *Alnus* sp. cf. *A. preneparensis* Hu et Chaney, NSM-PP 11560. A, C, H, loc. Arakawa-bana, Yonaguni-jima; B, D, G, loc. west of Uebaru, Iriomote-jima, collected by T. Onoe; E, F, I, loc. west of Mt. Goza-dake, Iriomote-jima, collected by Y. Saito and others; J, loc. south of Sonai, Iriomote-jima. Scales: 10 mm, except for figs F and G (in mm).

flora shows the resemblance with evergreen sclerophyllous broad-leaved forests, as is the case of the Shihti flora. Among all, evergreen members of the Fagaceae are abundant and diverse, together with many evergreen members of the Lauraceae (Fig. 2). In Fig. 2 are included two additional species of oak, *Cyclobalanopsis mandraliscae* (Gaudin) Tanai and *C.* sp. cf. *C. nathorstii* (Kryshtofovich) Huzioka, collected by us in 2005. Of the 24 woody dicots reported by Li (2000), 15 species have an entire-margin (63%), indicating a subtropical climate.

Miocene Floras from Yonaguni-jima and Iriomote-jima

In Yonaguni-jima and Iriomote-jima of the southwestern end of Japan, the coal-bearing Yaeyama Group is widely distributed (Hanzawa, 1935; Saito *et al.*, 1973; Sakai *et al.*, 1978; Nakagawa *et al.*, 1982; Yazaki, 1982). Takahashi and Matsumoto (1964) reported pollen and spore assemblages from Iriomote-jima. They pointed out that the assemblages are characterized by the dominance of *Alnus* pollen. Although the occurrence of plant megafossils from the Yaeyama Group, including silicified woods, have been known, no detailed study was published. The Yaeyama Group is assigned as the Early to Middle Miocene (Hanzawa, 1935; Nakagawa *et al.*, 1982; H(iroshi) Nakagawa, pers. comm.).

Plant megafossils were collected from Arakawa-bana in Yonaguni-jima, in which members of the Lauraceae are prominent (Fig. 3). Total species recognized are not enough (nine species; Table 2), but these lauracean members as well as *Liquidambar* are numerically abundant. Thus the flora from Yonaguni-jima shows the same feature in the Daijima-type floras (Tanai, 1961) in Hokkaido, Honshu, and Kyushu.

From four localities in Iriomote-jima, 17 species are recognized (Table 2). Three localities, south of Sonai, Hoshitate, and west of Uebaru, are from the upper part of the Yaeyama Group exposed in Iriomote-jima, and the remaining locality, west of Mt. Gozadake (Saito *et al.*, 1973), is from the middle part. These assembalages are characterized by the dominance of *Alnus* sp. cf.

Table 2. List of plants from the Early to Middle Miocene floras in Yonaguni-jima and Iriomote-jima.

Genera and species	Yonaguni-jima	Iriomote-jima
Cinnamomum lanceolatum (Unger) Heer	×	×
Lindera sp.	×	–
Litseaphyllum sp.	×	–
Neolitsea sp.	×	–
Liquidambar miosinica Hu et Chaney	×	–
Parrotia sp. cf. *P. pristina* (Ettingshausen) Stur	–	×
Zelkova ungeri (Ettingshasusen) Kovats	–	×
Castanopsis sp. cf. *C. miocuspidata* Matsuo	×	–
Cyclobalanopsis sp.	×	×
Alnus sp. cf. *A. preneparensis* Hu et Chaney	–	×
Alnus sp. (leaves)	×	×
Alnus sp. (infructescence)	–	×
Carpinus sp.	–	×
Salix sp. 1	–	×
Salix sp. 2	–	×
"*Alangium*" *aequalifolium* (Goeppert) Kryshtofovich et Borsuk	–	×
Gleditsia sp.	–	×
Podogonium sp.	–	×
Leguminosites sp.	–	×
Ilex sp.	×	–
Fraxinus sp.	–	×
Gramineae gen. et sp. indet.	–	×
Palmae gen. et sp. indet.	–	×

A. preneparensis Hu et Chaney, and are shown collectively in Table 2. *Alnus prenepalensis* is abundant or dominant species in the Oligocene of Kyushu and southwestern Honshu, Japan (Uemura, 1998). Most of the silicified woods often recovered from this island are taxodiaceous conifers, though not yet investigated. Although the plant megafossil collection is small in size, there is marked difference between the floras from Iriomote-jima and Yonaguni-jima. The flora from Iriomote-jima contains many deciduous and temperate members, such as *Zelkova*, *Alnus*, *Carpinus*, and *Salix* (Fig. 3). *Parrotia pristina* (Ettingshausen) Stur and *Podogonium knorrii* Heer, though deciduous, are characteristic elements in the Daijima-type floras. However, the paucity in evergreen members of the Fagaceae and Lauraceae should be mentioned for the flora in Iriomote-jima.

Concluding Remarks

The overall similarity in floral composition between the Shihti flora and the flora from Yonaguni-jima supports that the Yaeyama Group is correlative to the Middle Coal horizon, including the Shihti Formation. The difference from the flora from Iriomote-jima, which shows more temperate aspect, may ascribe to the climatic fluctuation from temperate to warmer conditions within the Early Miocene. Such possibility is suggested by molluscan fossil assembalages of the Yaeyama Group in Iriomote-jima (see Nakagawa *et al.*, 1982). The marked floral change from the Aniai-type floras to the Daijima-type (Tanai, 1961, 1992) is also consistent with this. More detailed studies on the plant megafossil floras in the Lower and Middle Coal horizons of Taiwan are thus necessary in the future.

The Lilongshan flora shows much modern aspect in the floral components, differing from the above three floras. Regarding this flora, more precise bio- and chronostratigraphic studies remain to the future as well.

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台湾の中新世植物群：その概要と日本西南端の中新世植物群との比較

植村和彦・李　慶堯

台湾の中新世植物群の概要を述べ，台湾北部の石底植物群（前期中新世後期）と南部の里龍山植物群（後期中新世）の植物群特性について述べた．とくに，与那国島および西表島の八重山層群の前期～中期中新世植物群との比較を行った．石底および里龍山植物群は与那国島の植物群と同様，暖温帯から亜熱帯地域のクス・カシ林の様相を示す．西表島の植物群は湿生でより温帯の要素で特徴づけられる．台湾および日本の与那国島，西表島のこれら植物群は，最近までほとんど研究されることのなかった，低緯度地域の中新世植物群についての証拠資料となる．