

A new species of *Acer* samaras from the Miocene Yeonil Group in the Pohang Basin, Korea

Jong Heon Kim* *Department of Earth Science Education, College of Education, Kongju National University, 182, Shinkwan-dong, Kongju 314-701, Korea*

ABSTRACT: *Acer pohangense* sp. nov. belonging to Aceraceae is described based on the six detached samaras collected from the Duho Formation of the Miocene Yeonil Group. This species is characterized by its comparatively large-sized samara with a wing and seed, and its wide divergent angle. The occurrence of such a large-sized samara is the first on record not only in the Korean Tertiary floras, but also in the East Asian Tertiary floras.

Key words: *Acer pohangense*, Aceraceae, samara, Duho Formation, Miocene

1. INTRODUCTION

Recently six detached samaras (Aceraceae) were collected together with many other fossil plants from the Duho Formation of the Miocene Yeonil Group distributed along the northern beach of Pohang-City. Although an organic connection between the present samaras and *Acer* leaves has not yet been found, it is highly probable that the samaras mentioned above belong to *Acer* (Aceraceae).

The Yeonil Group of marine origin has been known to yield abundant plant fossils and marine fossils such as mollusca, scaphopoda, gastropoda, corals, fish fossils, crab, etc (Kanehara, 1936). Among them, plant fossils were described by previous authors (Kryshstofovich, 1921; Oishi, 1935; Huzioka, 1943a, b, 1951, 1954a, b, 1955, 1972; Endo, 1950a, b, 1951, 1953; Tanai, 1952, 1983; Lee, 1975; Chun et al., 1982; Kim, 2005, 2008; Kim and Seo, 2007). The most recent paleobotanical works for the wood fossils of the Pohang Basin were made by Jeong et al. (2003, 2004).

Acer is one of the most common fossils in the Tertiary of East Asia and western North America, especially predominant in the Neogene (Tanai, 1977; Wolfe and Tanai, 1987), and also one of the most familiar trees to us in the temperate floras (Suzuki, 1963). As mentioned by Talor and Talor (1993), *Acer* is represented by generally monoecious trees and shrubs with opposing leaves and regular flowers, and the fruit of *Acer* is a two-winged schizocarp.

A large number of fossils such as fruits, seeds, and leaves have been found in the Tertiary floras of the world (e.g., Oishi & Huzioka, 1943; Suzuki, 1963; Inst. Bot. and Inst.

Geol. and palaeont., Acad. Sin., 1978; Tanai, 1983; Wolfe & Tanai, 1987). Pollen from the *Acer* has also been reported from the Oligocene (Piel, 1971). The fossil species of *Acer* have been found for 91 species from North America (Wolfe & Tanai, 1987), more than 40 species from Europe, and 35 species from Japan (Suzuki, 1963; Tanai, 1983). In addition to the species mentioned above, 13 species were described from China (Inst. Bot. and Inst. Geol. and palaeont., Acad. Sin., 1978).

The *Acer* fossil species are represented by both foliage and samara, and some are only foliage or samara, and most of the fossil samaras are generally small in size. To date, there have been no samaras or comparable species found similar to the present samaras. This paper deals with the description of *Acer pohangense* sp. nov. first found in the Korean Tertiary flora. The presence of *Acer pohangense* provides new evidence for biogeographic and climatic relationships.

2. GEOLOGICAL SETTING AND FOSSIL LOCALITY

The Tertiary strata of the Pohang Basin are distributed in the southeastern coast of South Korea, and are divided into the Yangbuk and Yeonil Groups in ascending order (Kim, 1987). The former consists predominantly of basalt, volcanic tuff, conglomerate, sandstone, shale and lignite, while the latter mostly of clastic sediments of marine origin. The Yangbuk Group is nearly equivalent to the Changgi (Janggi) Series of Tateiwa (1924).

Since Tateiwa's (1924) geological investigation on the Pohang Basin, many geological and palaeontological studies have been carried out by many authors (Um et al., 1964; Kim, 1965; Yoon, 1975, 1976, 1982, 1992; Lee, 1986; Yun, 1986, 1994; Lee et al., 1988; Chung and Choi, 1993 etc). Further paleontological references for flora, fauna and microfossils were shown by Tateiwa (1976), Lee (1987), Lim et al. (1994), Kim (1997), Yoon and Yun (2001). and Lee et al. (2004).

As shown in the correlation of stratigraphic sequence of the Yeonil Group in the Pohang Basin (Yoon, 1998), the stratigraphic divisions of the Yeonil Group suggested by some authors differ from each other. In the present study, the

*Corresponding author: jongheon@kongju.ac.kr

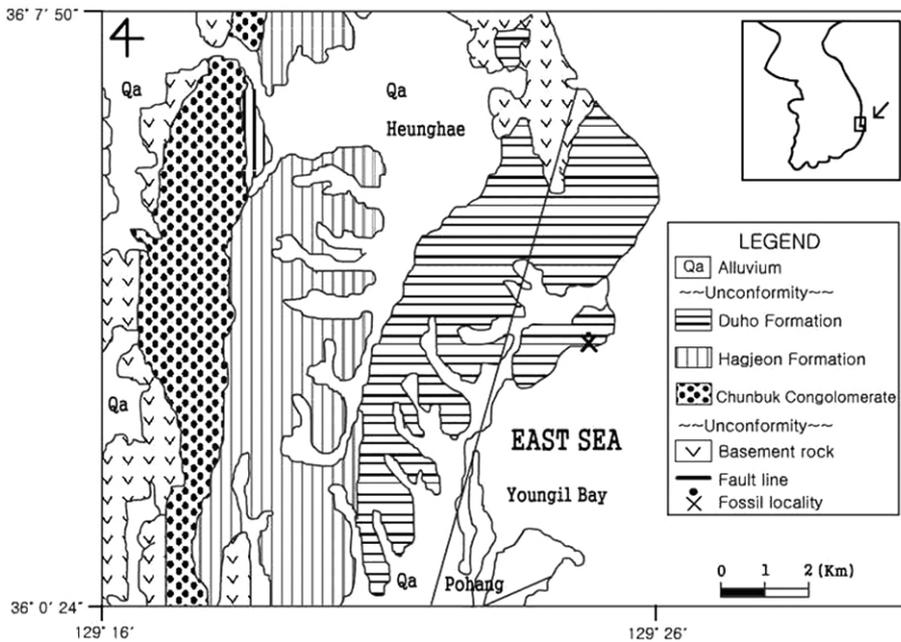


Fig. 1. Geologic map of the Pohang Basin (partly redrawn after Yi and Yun, 1995) and fossil locality.

stratigraphic terms are used which were suggested by Yun (1986). According to Yun (1986), the Yeonil Group is divided into the Chunbuk conglomerate, Hagjeon, and Duho Formation in ascending order. The fossil locality is shown in Figure 1.

The geological age of the Yeonil Group based on the fossil plants and faunas and microfossils has generally been considered to be Middle Miocene (e.g., Tateiwa, 1924; Kanehara, 1936; Huzioka, 1972; Yoon, 1975; Yun, 1981; Chun et al., 1983).

3. MATERIAL AND METHOD

Six samaras were obtained from an outcrop of the Duho Formation distributed along the northern beach of Pohang-City, Kyeongbuk Province (129°24'50"E, 36°04'03"N). These samaras are preserved as impressions in mudstone at a locality where fossil plants and marine faunas are abundant. The samaras were examined and mainly compared with samaras of *Acer* known from Korea, East Asia and North America. As shown in Figure 2, fossil fruits of *Acer* have been in most cases found as single detached winged seeds and rarely as two divergent winged seeds attached to a pedicel. In these cases essentially the same technique that biologists employ for investigating the exomorphic features of all extant species was used on the fossil samaras.

The terminology of morphologic characteristics of *Acer* fruit were illustrated in detail by Tanai (1983) and Wolfe and Tanai (1987). The terminology as suggested by Tanai (1983) is followed here. Major characteristics of *Acer* fruit are shown in Figure 2. As mentioned by Tanai (1983), the following characteristics of samara are useful for classification; size of samara, shape and thickness of seed, venation feature

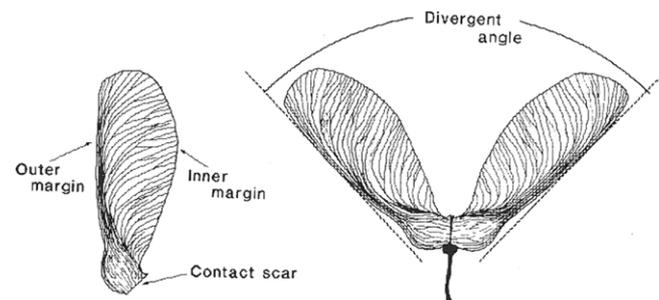


Fig. 2. Explanation of terms used in the description of *Acer* samaras (Tanai, 1983).

on the seed surface, length of contact scar of seed, divergent angles of its two wings, orientation of elongated seeds to the wing, and presence of hairs covering the seeds. Tanai (1983) also mentioned that the hairs and venation are generally of less value in fossils, but most characteristics are usually well defined in fossil samaras.

The specimens examined here will be kept at the Department of Earth Science, Kongju National University.

4. SYSTEMATIC DESCRIPTION

Order Sapindales

Family Aceraceae

Genus *Acer* Linne, 1753

Type species *Acer amboyense* Newberry 1895

Acer pohangense Kim sp. nov.

Figure 3. A~F

Material: Holotype; KNUM-980018, Paratype; KNUM-2001007, 980024, 2001006.

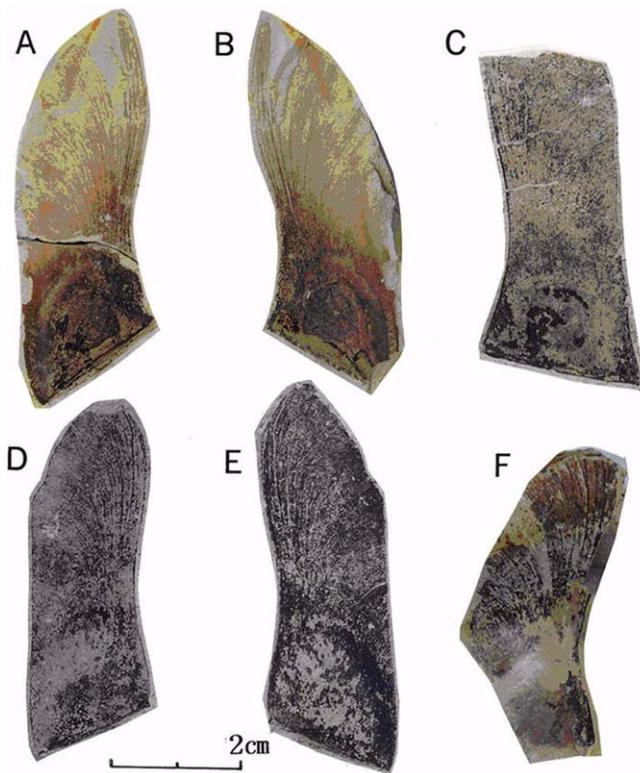


Fig. 3. Detached samaras of *Acer pohangense* sp. nov.

Locus typicus: Duhodong, Pohang-City.

Stratum typicum: Duho Formation of the Yeonil Group.

Derivatio nominis: This species is named after the geographical name, Pohang near the locality.

Occurrence: rare.

Specific diagnosis: Samara large, 6.3 cm long and 2 cm wide at the widest part near the base. Wing 3.8 cm long and 1.8 cm wide at the base. Length/width ratio 2.0 ~ 2.2. Margins nearly parallel-sided on the distal two thirds of the wing, obtuse at the apex; inner margin nearly straight at the distal two thirds and gradually narrowing to the tip. Outer margin slightly convex (covered) near junction with seed and then nearly straight to the tip. Veins numerous, about 20 in number at the base, curving inwards and irregularly, branching dichotomously, ending at the distal margin. Seed part large and thick, semicircular in shape, about 1.5 cm in diameter, seed about 0.9 cm in diameter contact line of the seed 2.1 cm long. Angle between outer margin and contact line of seed about 115°.

5. COMPARISON

As shown in Figure 3, the present samaras are characterized by their long and broad wing on a large seed, and by their wide divergent angles. Judging from the general outline such as venation-type, junction with seed and wing, and the presence of contact scar, it is highly probable that the present

samaras belong to the genus *Acer*. Accordingly, the present samaras were arbitrarily placed into the genus *Acer* until more information about this type of leaf and fruit is found.

Among more than 130 species of *Acer* hitherto known to originate from the Tertiary floras of East Asia (Tanai, 1983) and North America (Wolfe and Tanai, 1987), such long and broad samaras with a wide divergent angle as in the present specimens, have not yet been recorded. Although the whole form of the leaf and fruit for their separate occurrence from the vegetative leaf is as of yet unknown, a new specific name is proposed for the present samaras, *Acer pohangense* sp. nov.

Among the 35 species of *Acer* known from East Asia, 25 species were associated with their samaras. The following three species, *Acer ezoanum*, *A. palaeo-platanoides*, and *A. kokangenense* are comparable in samara size to the present species. *Acer ezoanum* established by Oishi and Huzioka (1943) from the Tertiary strata of Japan and later in detail by Tanai (1983) is most similar in size to the present species. According to Tanai (1983), the size of samaras is 4.8 to 11 cm long and 1.4 to 2.2 cm wide. But *Acer ezoanum* differs from the present species by its short contact scar (0.5 to 1 cm) as it relates to the length of the samara and ellipsoidal seed (1.1 to 2.5 cm long and 0.5 to 1.1 cm wide). *Acer palaeo-platanoides* and *A. kokangenense* both defined by Endo (1950) from the Tertiary of Hamjindong Formation and Janggi Group of Korea respectively are also similar in samara-size to the present species. According to Endo (1950), the size of *Acer palaeo-platanoides* and *A. kokangenense* is 5 cm long and 1.5 cm wide, 5.3 cm and 1.3 cm wide respectively. The former is distinguished from the present species by its oblong to oblanceolate samara with a small seed (0.9 × 0.7 cm) and narrow divergent angle (120°). The latter also differs from the present species by its triangular and small samaras (1 cm long) and by its short contact line (1 cm). According to Tanai (1983), Endo's *A. kokangenense* is conspecific to *A. fatsiaefolium* originally described by Huzioka (1943) from the Tertiary flora of Korea.

In China, 13 species of *Acer* have been described from the Palaeogene floras (Inst. Bot. and Inst. Geol. and Palaeont., Acad. Sin., 1978), but all of them clearly differ from the present species by their small-sized samaras.

The known fossil fruits and leaves of *Acer* from North America represent 91 species (Wolfe and Tanai, 1987). Among these 91 species, the samaras of *Acer busamarum*, *A. busamarum busamarum*, *A. busamarum fingerrockense* are the largest group for any species of *Acer*. For example, the overall length of samara of *Acer busamarum fingerrockense* is 5.4 to 9.7 cm (typically 7.5 cm). *Acer macrophyllum* also have a large samara (6.3 cm in length). However, all the samaras mentioned above clearly differ from the present species in the shape of samaras.

The samara of *Acer grahamensis* Knowlton et Cockerell described by Wolfe and Tanai (1980) is similar in seed size

and samara length to the present species, but the former is much narrower in width relative to the length of samara (1 cm width).

In detached samaras, the divergent angle of the two wings is determined by doubling the angle, which is measured between the contact scar and the outer margin of the wing. In most species of *Acer*, the divergent angles of the two wings are generally less than 100° (Tanai, 1983). However, the following five species have more than 100° between the divergent angles of the two wings; *Acer palaeo-platanoides*, *A. proto-miyabei*, *A. palaeo-rufinerve*, *A. proto-japonicum*, and *A. uemurae*. The former two species have the largest divergent angles and are 110° to 180° and 180° to 220° respectively (Tanai, 1983). *Acer proto-miyabei* is to the most similar in divergent angles to the present species, but the former is characterized by its small-sized samaras (1.8 to 3.5 cm long and 0.7 to 1.1 cm wide) and short contact scar (0.7 to 1.2 cm). The specific names of *Acer proto-miyabei*,

A. palaeo-rufinerve, and *A. proto-japonicum* suggested by Van Gelderen et al. (2005) are followed here.

In general the length of contact scar in the fossils of *Acer* samaras usually do not exceed 1.5 cm. In this point *Acer pohangense* sp. nov., with a long contact scar, is unique and quite different from any existing and previously described fossil species. According to Lee (2006), extant 15 species of *Acer* are now distributed in the Korean Peninsula. Among them, *Acer okamotoanum* Nakai distributed in Ulleungdo is comparable with the *Acer pohangense* sp. nov. in general outline, but it is distinguished from the present species by its small sized samaras (2 to 3 cm length, 1.5 to 1.8 cm width) with small divergent angles.

6. REMARKS

The first taxonomic work of *Acer* fossils in Korea was undertaken by Huzioka (1943) from the Tertiary strata of the

Table 1. List of *Acer* species recorded from the Korean Tertiary floras (Ablaev et al., 1993; Huzioka, 1972; Lim et al., 1994)

Taxa	Kyeongsangbuk-do		Gangweon-do		Hamgyeongbuk-do		
	Pohang		Tongcheon		Gilju-Myeongcheon		Kogeonwon
	Janggi flora	Yeonil flora	Tongcheon flora	Yongdong flora	Hamjindong flora	Kungshim flora	Kogeonweon flora
<i>A. ezoanum</i>	0		0		0		
<i>A. nordenskioldi</i>	0	0	0	0	0		
<i>A. subpictum</i>	0	0	0	0	0		
<i>A. pictum</i>		0	0		0		0
<i>A. rotundatum</i>	0			0			
<i>A. diabolicum</i>	0						
<i>A. palaeo-platanoides</i>			0		0	0	
<i>A. proto-trifidum</i>		0	0			0	0
<i>A. japonicum</i>			0				
<i>A. miohenryi</i>				0			
<i>A. cf. palaeodia bolicum</i>			0				
<i>A. kotchkoriensis</i>					0		
<i>A. endoanum</i>					0		
<i>A. meisense</i>					0		
<i>A. palaeo-diabolicum</i>					0		
<i>A. palaeo-rufinerve</i>					0		
<i>A. proto-japonicum</i>					0		
<i>A. pseudogimnala</i>					0		
<i>A. trilobatum</i> var. <i>productum</i>					0		
<i>A. trilobatum</i> <i>tricuspidatum</i>					0		
<i>A. miyabei</i>					0		
<i>A. trilobatum</i>							0
<i>A. tricuspidatum</i>							0
<i>A. sp. cf. A. negundo</i>							
<i>A. cuneatum</i>							0
<i>A. kokangense</i>							0
<i>A. koreanicum</i>	0						0
<i>A. fatsiaefolium</i>	0						0
<i>A. proto-miyabei</i>							0

Gilju-Myeongcheon district. Subsequently some short papers on the Korean Tertiary floras including *Acer* were published by Endo (1950, 1951) and Tanai (1952). The most comprehensive and descriptive work on the Korean Tertiary floras was made by Huzioka (1972). Huzioka described 44 species and 35 species from the Janggi and Yeonil Groups. Huzioka's paper included 18 species of *Acer* (excluding sp.).

Chun et al. (1982) reported 41 genera and 64 species (including 4 species of *Acer*) from the Pohang Basin without their descriptions. Tanai (1983) made a general review on the 35 species of *Acer* described by many authors from the Tertiary strata of East Asia. Tanai's paper contains a useful list of all species previously described in the Tertiary strata of Korea. His revision seems to be appropriate and is accepted in this study.

Ablaev et al. (1993) described 32 genera and 48 species of plant fossils from the Tertiary strata of the Gogeonwon district in the Hamgyeongbug-do. He added 4 species of *Acer*. Lim et al. (1994) described many species of fauna and flora (including 8 species of *Acer*) from the Tertiary deposits of North Korea. Table 1 shows the *Acer* species recorded by the previously mentioned authors from the Korean Tertiary floras.

As shown in Table 1, 29 species of *Acer* have been identified from the Tertiary of Korea. Among them, 20 species are represented by both foliage and samara, and 9 species only from their foliage or samara. The Janggi and Yeonil floras in the Pohang Basin include only 5 species and 3 species of *Acer* respectively. They are smaller in number relative to the same age of Hamjindong flora with 14 species of *Acer*. It is thought that the difference of floral composition between Janggi, Yeonil and Hamjindong floras is a result of the difference of mean annual temperature due to differences of latitude.

According to Huzioka (1972), about 140 species of fossil plants are known from the Miocene floras of Korea. Among them, *Acer* occupies about 21% of the Yeonil flora and is the largest taxa in the species level. It is thought that the paleoclimate of middle Miocene in the Korean Peninsula might be the optimal climate for *Acer* habitation.

The extant mapple family, Aceraceae includes more than 140 extant species that are mostly distributed in temperate regions and some tropical mountains (Ogata, 1967; Park, 1986; Talor and Talor, 1993). Therefore there is no doubt that the Yeonil flora bearing *Acer pohangense* sp. nov. might have flourished in a temperate climate.

7. CONCLUSIONS

A new species of *Acer pohangense* was proposed on the basis of the detached large-sized samaras of *Acer*. The occurrence of such a large-sized samara is the first recorded not only in the Korean Tertiary flora, but also in the East Asian Tertiary floras.

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