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Thallites yabei (Kryshtofovich) Harris from the Lower Cretaceous Nakdong Formation of Sindong Group, Korea

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Abstract: In this study, fossil liverwort (Hepaticae) of *Thallites yabei* (Kryshtofovich) Harris is described based on the newly obtained material from the Lower Cretaceous Nakdong Formation of Sindong Group, Korea. The thalli of *T. yabei* is ribbon-like, bifurcating at least three or four times, and has a distinct midrib. Although the thalloid plants are herbaceous with little hard part, the thalli of *T. yabei* is relatively well preserved to show the sequentially bifurcating pattern in the specimens occurred in the same fossil locality. Such characteristics indicate that they were probably buried in situ. The abundant occurrence of thalli plants also indicate that land was covered densely by them as one of the terrestrial land plant members, and flourished under the tall arbor trees in the humid environment during the Early Cretaceous in the Gyeongsang Basin.

Keywords: liverwort, Hepaticae, *Thallites yabei,* Nakdong Formation, thalli

Introduction

In the Gyeongsang Basin, the Lower Cretaceous Sindong Group is distributed in the western margin of Nakdong Trough with a NNE trending (Chang, 1987). The group is divided into the Nakdong, Hasandong, and Jinju Formations in the ascending order. It is known to yield abundant plant fossils, while containing other vertebrate and invertebrate fossils. Many fossil plants have been identified from the Nakdong Formation, but a few were described from the Hasandong and Jinju Formations. Since the plant fossils of the Nakdong Formation were first studied by Yabe (1905), numerous paleobotanical studies have subsequently been carried out by other researchers (Ogura, 1927; Tateiwa, 1929; Hatae, 1937; Oishi, 1939, 1940; Kobatake, 1958; Chun et al., 1994; Kenrick et al., 2000; Kimura, 2000; Seo and Kim, 2009; Kim, 2009; Kim et al., 2012). As already mentioned by Kenrick et al. (2000), despite the widespread occurrence of non-marine sediments and a long history of paleontological investigation, the Cretaceous flora is still poorly studied. Besides plant fossils, the Nakdong Formation yields many kinds of fossils such as mollusks (Kobayashi and Suzuki, 1936; Chang, 1975; Chang et al., 2003) and charophytes (Choi, 1989).

Recently, we collected a large number of plant fossils from one fossil site of the Nakdong Formation distributed in the Bongsanri area of Gumi-city. Among them, we recognized a large number of liverwort-like thalli plants belonging to bryophyta. The fossils of thalli plants are extremely scantly observed in the Korean Mesozoic strata, especially from the Nakdong Formation (Yabe, 1905). Fossil bryophytes are important in shaping the paleoecosystem in earth history and are significant in understanding the origin and evolutionary history of land plants and terrestrial ecosystems (Wang and Wu, 2007; Griffiths et al., 2011). They are widespread around the world during the Phanerozoic Eon, particularly from the Carboniferous to Cretaceous (Jovet-Ast, 1967; Wallmann, 2008; Li et al., 2014). Two major classes of living bryophyta, Hepaticae (liverworts) and Musci (mosses) are widely distributed and extensively recorded (Wang and Wu, 2007). According to Wu (1998), about 18,000 species belonging to 500 genera of Musci and 5,000-8,000 species of

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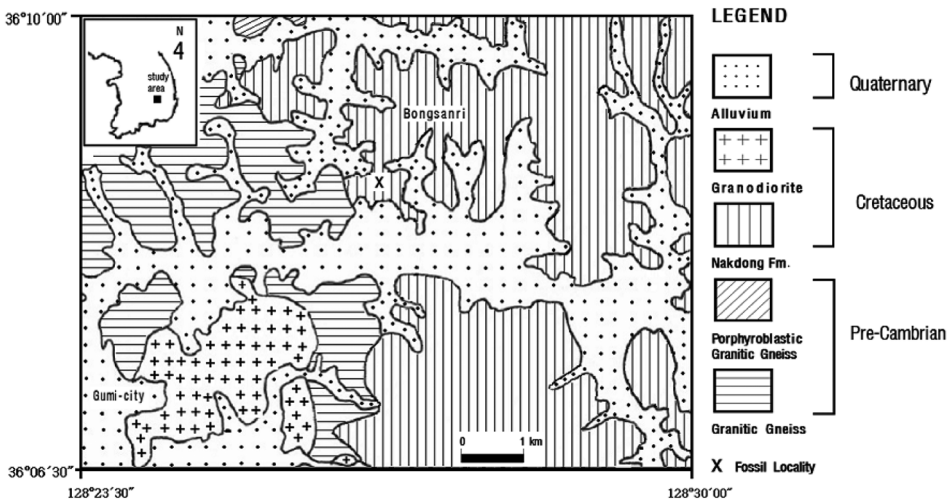

Fig. 1. Geological map of the study area (Kim and Im., 1974) and fossil locality.

250 genera of Hepaticae have been recognized globally. However, the fossil record with definite bryophytic affinity is extremely rare. The global record of fossil Musci is no more than 100 species during pre-Quaternary history (Jassens et al., 1979). Consequently, the fossil record of fossil Hepaticae is very limited in its record (Wang and Wu, 2007).

In this study, we describe *Thallites yabei* (Kryshtofovich) based on the material newly obtained from the Lower Cretaceous Nakdong Formation, Sindong Group, Korea.

Geological Setting and Fossil Locality

The Lower Cretaceous Gyeongsang Supergroup of non marine origin is widely distributed in southeastern Korean Peninsula, and divided into the Sindong, Hayang, and Yucheon Groups in ascending order (Chang, 1975, 1987). The Sindong Group is restricted in distribution to western part of the Gyeongsang Basin and further divided into the Nakdong, Hasandong, and Jinju Formations in ascending order. According to Kim and Im (1974), the Nakdong Formation in the Gumi area is the lowest part of the Sindong Group, which distributes extensively in Gyeongsang Province. The formation lies on the precambrian granitic gneiss, and the thickness of the formation is about 840 to 2,100 m in thickness. It generally consists of conglomerate, sandstone, siltstone, shale, and coaly shale.

The fossil locality is shown in Fig. 1. The sedimentary rocks in the fossil locality consists mainly of dark grey to black shale and fine-grained sandstone in ascending order. The fossils of thalli plants occurred in the black shale together with many other plant fossils.

The geological age of the Nakdong Formation has generally been estimated as the Barremian to Aptian (Choi, 1989; Chang et al., 2003; Lee et al., 2010, 2012; Kang and Paik, 2013).

Material

All of the fossil plants described here were collected from the one fossil locality of the Nakdong Formation. Although the fossils of thalli plants are abundant in the fossil locality of Nakdong Formation, they are all impressions, metamorphosed in the course of the Bulguksa orogeny with the intrusion of the Bulguksa granite. Consequently, no cuticles of thalli plants have been preserved. All specimens used here in this study are deposited in the Department of Earth Science, College of Education, Kongju National University.

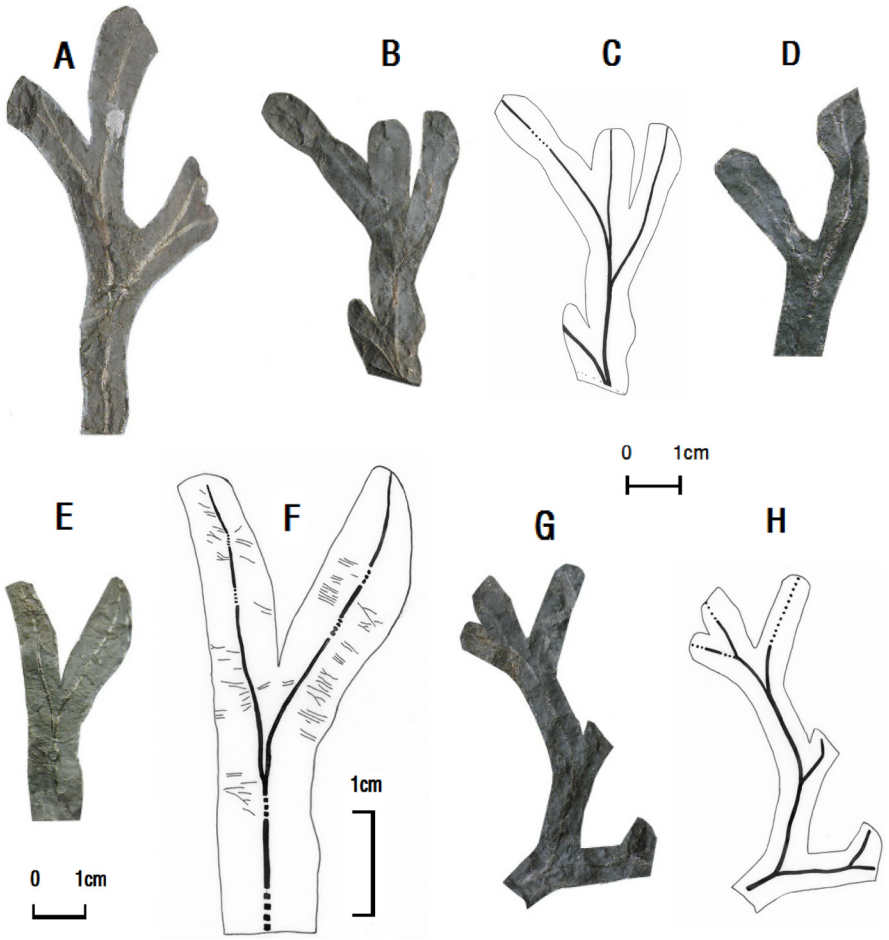

Fig. 2. *Thallites yabei* (Kryshtofovich) Harris. A, B, C: Thalli with three times bifurcating midrib (A: KNU-20081121106, B: KNU-2009102102, C: Drawn from B) D, E, F: Thalli with twice bifurcating midrib (D: KNU-20081121040, E: KNU-20090102053, F: Drawn and enlarged from E, showing faint lateral veins.) G, H: Thalli with four times bifurcating midrib (G: KNU-20081121041, H: Drawn from G)

Systematic Description

Phylum Bryophyta
Class Hepaticae
Order Marchantiales
Family Marchantiaceae
Genus *Thallites* Walton, 1925

Thallites yabei (Kryshtofovich) Harris
Figs. 2A-F

1905 *Sagenopteris bilobata* var. *major* Yabe, pl. 3, fig. 16a, (non 16b,c)
1930 *Marchantites yabei* Kryshtofovich, pl. 15, Fig. 3
1940 *Marchantites yabei* Kryshtofovich, Oishi, pl. a, Fig. 1
1942 *Thallites yabei* (Kryshtofovich) n. comb., Harris, p. 396
1967 *Thallites yabei* (Kryshtofovich) Harris, Jovet-Ast, p. 32

Material: KNU-20081121106 and other fifteen rock specimens.

Locality and Formation: This species occurred from one fossil site of the Nakdong Formation

distributed near the Bongsanri Sandong-myeon Gumi-city Gyeongsangbuk-do, Korea (36°08'54"N, 128°26'30"E).

Distribution and occurrence: This species has been only known from the Nakdong Formation. A large number of specimens were obtained.

Description: Many specimens were obtained, but they are all fragments. Thalli is linear and narrow in shape, narrowing gradually to the tip, and bifurcates irregularly at least three times to four times or more than four times. The longest one is 7 cm long and 0.7-0.8 cm wide in the lower or middle part. The branches of thalli are 1.5-3 cm long and 0.7 cm wide, with branching angles 30°-40°. Thalli margins are entire and nearly parallel-sided. The midrib is prominent, 0.1 cm wide. Lateral veins are mostly poorly preserved, but some of which still show the faint venation under microscope; fine lateral like veins arise from the midrib at a wide angle, forking at least twice or thrice, but elongate meshes are not preserved. No special surface marking on the thalli are seen. Reproductive organs are not detected.

***Remarks*:** More than one hundred years ago, the fossil plant of thalli form was first described by Yabe (1905) from the Nakdong Formation of Korea as *Sagenopteris bilobata* var. *major* sp. nov. However, he did not know what it was that plants liverwort at that time. Moreover, Yabe's new species is lack of proper description and any other information as already mentioned by Kryshtofovich (1930). And then Kryshtofovich (1930) established new species of *Marchantites yabei* based on his new material and Yabe's material (Fig. 16a only). Later Harris (1942) assigned Kryshtofovich's *Marchantites yabei* to the form genus *Thallites,* used by Walton (1925) for plants exhibiting thalli form, but of unknown affinity. The generic name of *Thallites* suggested by Harris (1942) is followed here. The morphological characters of the present thalli plants agree well with those of *Thallites yabei* (Kryshtofovich) Harris described by Kryshtofovich (1930) from the Lower Cretaceous Nikanian Series of the Far East. *Thallites yabei* (Kryshtofovich) Harris has been known from the Jurassic Tetori and Ryoseki Series of Japan (Oishi, 1940).

Discussion

Yabe (1905) mentioned that the lateral veins of *Sagenopteris bilobata* var. *major* (Fig. 16a) are very fine, anastomosing, and leaving from the median vein at an acute angle. Kryshtofovich (1930) pointed out that lateral veins of *Sagenopteris bilobata* var. *major* mentioned by Yabe (1905) appears to be a mere rugose. However, Oishi (1940) illustrated that fine vein-like striations are diverging upwards from the midrib. In the present specimens, the lateral veins are clearly identified, but the details of them are uncertain. The lateral veins such as *Thallites blairmorensis* (Berry) Lundblad (1954) are fine, forked at all level and forming elongated meshes. It is considered that the present specimens have lateral veins similar to those of *T. blairmorensis* (Berry) Lundblad.

During the Phanerozoic Eon, the fossil plants of liverworts or liverwort-like thalli have been assigned to various morphogenera such as *Thallites*, *Hepaticites*, *Jungermanntites*, *Metzgerlites*, or *Marchantites.* As already mentioned by Taylor et al. (2009), *Thallites* was widely used for thalloid fossils that may represent liverworts or algae. *Hepaticites* was used for thalli that can confidently be assigned to the liverworts, but cannot be classified further. *Marchantites* was also used for thalli that can be classified to the ordinal level within the hepatophytes (Cantrill, 1997). However, the affinities of most pre-Jurassic forms are still uncertain (Oostendorp, 1987), because the most fossil records are incomplete.

The record of *Thallites* has been known from the Carboniferous to Cretaceous (Jovet-Ast, 1967; Wang and Wu, 2007). Approximately thirteen species of *Thallites*, have been reported. Among them, three species of *Thallites* are known from the Carboniferous, and the remains are Mesozoic in age. This suggests that the genus *Thallites* had been widespread and

flourished during the Mesozoic age. Similar view was mentioned by Cantrill (1997). According to Cantrill (1997), the liverworts such as *Hepaticites* and *Thallites* were both diverse and abundant in the Albian floras, and appeared to occupy a number of different ecological niches in high latitude region.

The fossil plants previously known from the Nakdong Formation (Tateiwa, 1929; Oishi, 1939, Oishi, 1940; Kobatake, 1958) consist mostly of arbor trees except for liverworts such as *Thallites*. The fossil and extant liverworts are herbaceous without any hard part. The thalli of *Thallites* in the Nakdong Formation is also presumably susceptible to mechanical damage and biological degradation compared to the vascular plants during the diagenesis (Cantrill, 1997; Wang and Wu, 2007). Nevertheless, the thalli of *Thallites* from the Nakdong Formation is relatively well preserved as impression, also it shows sequentially twice to four times bifurcating in the specimens occurred in the same fossil locality. There is no apparent mechanical damage or indication of transport. Such characters mentioned above indicate that they were probably buried in situ. The thalli of *Thallites* is also locally abundant in the Nakdong Formation and sometimes thickly massed in several layers of the bed. This suggests that they flourished, covering densely terrestrial land during the Cretaceous Period of Korea. The extant species of Marchantiales live almost in shady and humid environments (Gao and Wu, 2010). Li et al. (2014) mentioned that the presence of fossil species of Marchantiales provides another evidence for the humid environment. We agreed with Li et al.'s opinion. Therefore, the presence of *Thallites yabei* (Kryshtofovich) Harris from the Nakdong Formation means that it might live under the tall arbor trees in the humid environment during the Early Cretaceous in the Gyeongsang Basin.

Conclusion

A large number of thalli plants occurred in situ from the Nakdong Formation. As the result of our detailed examination of these thalli plants varied in form and size, we concluded that they belong to a single and the same species of *Thallites yabei* (Kryshtofovich) Harris. The abundant occurrence of thalli plants indicates that land was covered densely by them as one of the member of terrestrial land plant.

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References

Chang, K.H., 1975, Cretaceous stratigraphy of southeast Korea. Journal of the Geological Society of Korea, 11, 1-23.

Chang, K.H., 1987, Cretaceous strata. In Lee, D.S. (ed.), Geology of Korea. Geological Society of Korea, Kyohak-sa, Seoul, Korea, 175-194.

Chang, K.H., Suzuki, K., Park, S.D., and Uno, K., 2003, Recent advances in the Cretaceous stratigraphy of Korea. Journal of Asian Earth Sciences, 21, 937-948.

Cantrill, D.J., 1997, Hepatophytes from the Early Cretaceous of Alexander Island, Antarctica: Systematics and paleoecology. International Journal of Plant Sciences, 158, 476-488.

Choi, S.J., 1989, Fossil charophytes from the Nagdong Formation in Seonsangun, Gyeongsangbukdo, Korea. Journal of the Paleontological Society of Korea, 5, 28-38.

Chun, H.Y., Choi, S.J., Kim, Y.B., and Kim, B.C., 1994, Stratigraphy and paleontology of the Kyeongjeongdong Formation. KIGAM Research Report, KR-93-1G-1, 69 p. (in Korean with English abstract)

Gao, Q. and Wu, Y.H., 2010, Genera Hepaticopsida et Anthocerotopsida Sinicorum. Science Press, Beijing, China, 613 p. (in Chinese)

Griffiths, H., Royles, J., Horwath, A., Hodell, D.A., Convey, P., Hodgson, D., Wangate, L., and Ogeé, J., 2011, Bryophytes as climate indicators: Moss and liverwort photo synthetic limitations and carbon isotope signals in organic material and peat deposites. American Geophysical Union, Fall meeting 2011, abstract #B13K-02.

Harris, T.M., 1942, On two species of *Hepatics* of the Yorkshire Jurassic flora. Annals and Magazine of

Natural History, 11, 393-401.

Hatae, N., 1937, Geological atlas of Chosen (Korea), no. 18, Yonghae and Yongdeok sheets (1:50,000) and the explanatory text. Geological Survey of Korea, 19 p.

Jassens, J.A.P., Horton, D.G., and Basinger, J., 1979, *Aulacomnium heterostichoides* sp. nov., an Eocene moss from south central British Columbia. Canadian Journal of Botany, 57, 2150-2161.

Jovet-Ast, S., 1967, Bryophyta. In Boureau, E. (ed.), Traité de Paléobotanique. Vol. II. Masson and CIE, Paris, France, 19-186.

Kang, H.C. and Paik, I.S., 2013, Review on the geological ages of the formation in the Gyeongsang Basin, Korea. Journal of the Geological Society of Korea, 49, 17-29. (in Korean with English abstract)

Kenrick, P., You, H.S., Koh, Y.K., Kim, J.Y., Cho, S.H., and Kim, H.G., 2000, Cretaceous plant fossils from the Kohung area, Chonnam, Korea. Journal of the Paleontological Society of Korea, 16, 45-56.

Kim, J.H., 2009, New occurrence of *Cupressinicladus* sp. from the Lower Cretaceous Jinju Formation, Sindong Group, Korea. Journal of the Korean Earth Science Society, 30, 605-610.

Kim, J.H. and Im, J.H., 1974, Geological map of the Gumi area (1:50,000) and the explanatory text. Geological and Mineral Institute of Korea, 20 p.

Kim, J.H., Seo, J.H., and Nam, G.S., 2012, *Pseudofrenelopsis* cf. *parceramosa* and its reproductive organs from the Lower Cretaceous Youngdong Group of Korea. Geosciences Journal, 16, 399-407.

Kimura, T., 2000, Notes on the two Early Cretaceous floras in South Korea. Geosciences Journal, 4, 11-14.

Kobatake, N., 1958, Some plants of the Rakuto flora. Science Report of South and North Colleges of Osaka University, Japan, 7, 103-113.

Kobayashi, T. and Suzuki, K., 1936, Non-marine shells of the Naktong-Wakino Series. Japanese Journal of Geology and Geography, 13, 243-257.

Kryshtofovich, A., 1930, A liverwort from the Middle Daido Formation of Korea and the Nikan Series of the Manchurian Border. Annuaire Society Palaeontologique, Russie, Leningrad, 8, 144-147.

Lee, T.H., Park, K.H., Chun, J.H., and Yi, K., 2010, SHRIMP U-Pb zircon ages of the Jinju Formation and Silla Conglomerate, Gyeongsang Basin. Journal of the Geological Society in Korea, 19, 89-101. (in Korean with English abstract)

Lee, T.H., Park, K.H., and Yi, K., 2012, SHRIMP U-Pb zircon ages of the Nakdong and Ulyeonsan Formation in the Gyeongsang Basin. 2012 Fall Joint Annual Conference of the Geological Societies in Korea (abstract), Jeongseon. October 24-27, 134 p. (in Korean)

Li, R., Sun, B., Wang, H., He, Y., Yang, G., Yan, D., and Lin, Z., 2014, *Marchantites huolinhensis* sp. nov. (Marchantiales) - A new fossil liverwort with gemma cups from the Lower Cretaceous of Inner Mongolia, China. Cretaceous Research, 50, 16-26.

Lundblad, B., 1954, Contributions to the geological history of the Hepaticae. Fossil Marchantiales from the Rhaetic-Liassic coal mines of Skromberga (Prov. of Scania), Sweden. Svenka Botanisk Tidsrift, 48, 381-417.

Ogura, Y., 1927, On the structure and affinities of some fossil ferns from Japan. Journal of Faculty Science, Imperial University of Tokyo, Japan, Section 3, 1, 351-380, pls. 2-8.

Oishi, S., 1939, Notes on some fossil fern from the Naktong Series of Korea. Journal of the Faculty of Science, Hokkaido Imperial University, Series IV, 4, 307-312.

Oishi, S., 1940, The Mesozoic floras of Japan. Journal of the Faculty Science, Hokkaido Imperial University, Series 4, 5, 123-480, pls. 1-48.

Oostendorp, C., 1987, The Bryophytes of the Paleozoic and the Mesozoic. Bryophytorum bibliotheca, Berlin, Germany, 112 p.

Seo, J.H. and Kim, J.H., 2009, Conifer fossils from the Lower Cretaceous Youngdong Group and their paleoclimatic implication. Journal of the Korean Earth Science Society, 30, 444-453. (in Korean with English abstract)

Tateiwa, I., 1929, Geological atlas of Chosen (Korea), no. 10, Gyeongju, Yongcheon, Daegu, and Waegwan sheets (1:50,000). Geological Survey of Korea, 25 p.

Taylor, T.N., Taylor, E.L., and Krings, M., 2009, Paleobotany. The biology and evolution of fossil plants. Second edition, Elsevier, New York, USA, 1230 p.

Wallmann, K., 2008, Mesozoic climate: Liverworts and all. Nature Geoscience, 1, 14-15.

Walton, J.M.A., 1925, Carboniferous Bryophyta. I. Hepaticae. Annals of Botany, 39, 563-572, pl. 13.

Wang, Y.D. and Wu, X.W., 2007, Records and diversity of the fossil bryophytes in China. Chenia, 9, 61-71.

Wu, F.C., 1998, Bryological biology. Introduction and diverse branches. Science Press, Beijing, China, 357 p. (in Chinese with English titile)

Yabe, H., 1905, Mesozoic plants from Korea. Journal of the College of Science, Imperial University, Tokyo, Japan, 20, 1-59, pls. 1-4.

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