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A new contribution to the middle Miocene woody flora of Gökçeada (Turkey)

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Abstract

The fossil site in Gökçeada has a rich diversity of fossil woods. New fossil woods found in different times may improve our knowledge of this fossil site. The purpose of this study is to demonstrate the identification results of new fossil woods. After taking thin sections from three different directions of fossil woods as transverse, tangential and radial, identifications were performed. As result, *Ginkgoxylon lesboense* Süss was determined for the first time in Gökçeada, together with re-identifications of *Ostryoxylon gökceadaense* Akkemik, *Cryptocaryoxylon grandoleaceous* Akkemik, and *Laurinoxylon litseoides* Süss with the new fossil wood fragments. Due to the absence of the Aegean Sea in the middle Miocene, today's islands were a permanent piece of land, and therefore, new findings also revealed that the woody flora, during the middle Miocene in Gökçeada and Lesbos islands, were similar. This study also showed that the genus of *Ginkgo* L., which is represented with only one species today in China, had a common species in the middle Miocene forests of the Aegean basin.

Keywords: *Ginkgoxylon lesboense*, *Ostryoxylon*, *Laurinoxylon*, *Cryptocaryoxylon*, fossil wood, petrified wood.

1. Introduction

Gökçeada (Imbros) is an island located in the westernmost Turkey, and has a valuable fossil site. The palaeobotanical studies on the fossil woods from this island (Güngör et al., 2019; Akkemik, 2021; Iamandei et al., 2018; Mantzouka et al., 2022) revealed many different fossil genera and species such as *Alnoxylon* Felix, *Fagoxylon* Stopes & Fujli, *Platanoxylon* E.Hofmann, *Pinuxylon* Knowlton, *Taxodioxylon gypsaceum* (Göppert) Krausel, *Laurinoxylon litseoides* Süss, *Cryptocaryoxylon grandoleaceum* Akkemik, *Eucarpinoxylon kayacikii* Akkemik, *Ostroxylon gokceadaense* Akkemik, *Quercoxylon* Hofmann Sect. *Ilex, Cupressinoxylon pliocenica* Akkemik, *Palmoxylon coryphoides* Ambwani & Mehrotra, Recently, Mantzouka et al. (2022) identified a new cypress wood as *Cupressinoxylon matromnense* Grambast together with insect injuries.

The Aegean islands have great fossil sites, the most famous one is Lesbos Fossil Forest. These fossil sites have petrified woods from the early-middle Miocene. The genera of *Taxodioxylon* Hartig, *Pinoxylon*, *Quercus* L. and *Alnus* Mill. were identified both from Gökçeada (Güngör et al., 2019) and from the well-known petrified forests site, called Lesvos Petrified Forest by Süss and Velitzelos (1994 a, b) and Velitzelos and Zouros (1997).

It is possible to reach new findings with new fossil specimens that have come to light. These new fossil findings will contribute to understanding the forest compositions in different conditions of the Aegean basin. In this context, the purpose of the present study is to make a contribution to our knowledge of the middle Miocene forests of Gökçeada with new fossil wood identification.

2. Material and Methods

Detailed information and geology of the fossil site in Gökçeada were given by Güngör et al. (2019), Akkemik (2021), and Mantzouka et al. (2022). Four new fossil wood pieces were collected from the fossil site located in the east of Eşelek Village of Gökçeada Island, adjacent to the coastline of the island and in the north of Lesbos island (Figure 1). The moved fossil wood pieces were covered by the lava of a volcanic eruption of Kesmekaya Volcanics in the middle Miocene and unearthed by soil erosion. Due to good preservation, we could identify the fossil wood at the species level.

Figure 1. The location of the fossil site (Gökçeada island) and Lesbos island, where there is an excellent fossil forest.

Three thin sections (about 30 µm thick), which are transverse section (TS), radial longitudinal section (RLS), and tangential longitudinal section (TLS) from all specimens were taken. All identifications of the fossil woods were performed on these sections at the Laboratory of Tree-ring Researches and Wood Anatomy in the Forest Botany Department of the Faculty of Forestry, Istanbul University Cerrahpaşa. During identification studies, reference collection housed in Forest Botany Department of Faculty of Forestry, Istanbul University Cerrahpaşa (ISTO Fossil Wood Collection) and online database called InsideWood (http://insidewood.lib.nsc.edu) were used and for terminology, the descriptions given in the IAWA Committee (1989) for hardwood identification and IAWA Committee (2004) for softwood identification were followed. Moreover, the published original descriptions of the related fossil species were used in identifications.

3. Result and Discussion

The new findings and the former studies (Güngör et al., 2019; Akkemik, 2021; Mantzouka et al., 2022) in the fossil site of Gökçeada showed a very rich woody plant diversity from the middle Miocene (Table 1).

Table 1. The identified fossil wood genera/species from Gökçeada.

ISTO-FW-No (Code)	**Family**	**Fossil species**	**Reference**
ISTO-FW-00250	Ginkgoaceae	*Ginkgoxylon lesboense* Süss	This study
	Cupressaceae	*Cupressinoxylon pliocenica* Akkemik	Güngör et al. (2019); Akkemik (2020)
	Cupressaceae	*Cupressinoxylon matromnense* Grambast	Mantzouka et al. (2022)
	Cupressaceae	*Taxodioxylon gypsaceum* (Göppert) Kräusel	Güngör et al. (2019); Akkemik (2020)
	Pinaceae	*Pinuxylon* Knowlton	Güngör et al. (2019)
	Araceae	*Palmoxylon coryphoides* Ambwani & Mehrotra	Güngör et al. (2019); Iamandei et al. (2018)
	Betulaceae	*Alnoxylon* Felix	Güngör et al (2019)
	Betulaceae	*Eucarpinoxylon kayacikii* Akkemik	Güngör et al. (2019); Akkemik (2021)
ISTO-FW-00249	Betulaceae	*Ostroyoxylon gökceadaense* Akkemik	Güngör et al. (2019); Akkemik (2021); this study.
	Fagaceae	*Fagoxylon radiatum* Süss	Güngör et al. (2019); Akkemik (2021)
	Fagaceae	*Quercoxylon* Hofmann Sect.*Ilex*	Güngör et al. (2019)
ISTO-FW-00251	Lauraceae	*Cryptocaryoxylon grandoleaceous* Akkemik	Akkemik (2021); this study
ISTO-FW-00245	Lauraceae	*Laurinoxylon litseoides* Süss	Güngör et al. (2019); Akkemik (2021); this study
	Platanaceae	*Platanoxylon catenatum* Süss & Müller-Stoll.	Güngör et al. (2019); Akkemik (2021)

In this study, one new species was identified as *Ginkgoxylon lesboense* Süss for the first time from Gökçeada. Beside this, *Ostryoxylon gokceadaense* Akkemik, *Cryptocaryoxylon grandoleaceous* Akkemik, and *Laurinoxylon litseoides* Süss were re-identified, with new samples. In these fossil species, new features were obtained in their descriptions as follows:

Familya Ginkgoaceae Engler 1897
Genus *Ginkgoxylon* Chudajb. 1962
***Ginkgoxylon lesboense* Süss 2003**
Figure 2

Sample code and repository. ISTO-FW-00250 (Repository: Laboratory of Wood Anatomy and Dendrochronology, Faculty of Forestry, Istanbul University-Cerrahpasa).

Identification: In transversal section, growth ring boundary slightly visible or indistinct, and transition from earlywood to latewood indistinct (Figure 2:1). Tracheid shapes are usually irregular, square, or rectangular and sometimes polygonal. Resin canals are absent and their tips generally leaning (Figure 2:2). The wood parenchyma cells are generally unclear in the transversal section. The rays are homogeneous and 1-2 cupressoid type pits are present in cross-field areas (Figure 2:3). Rays uniseriate, and ray cells of variable diameter (Figure 2:4).

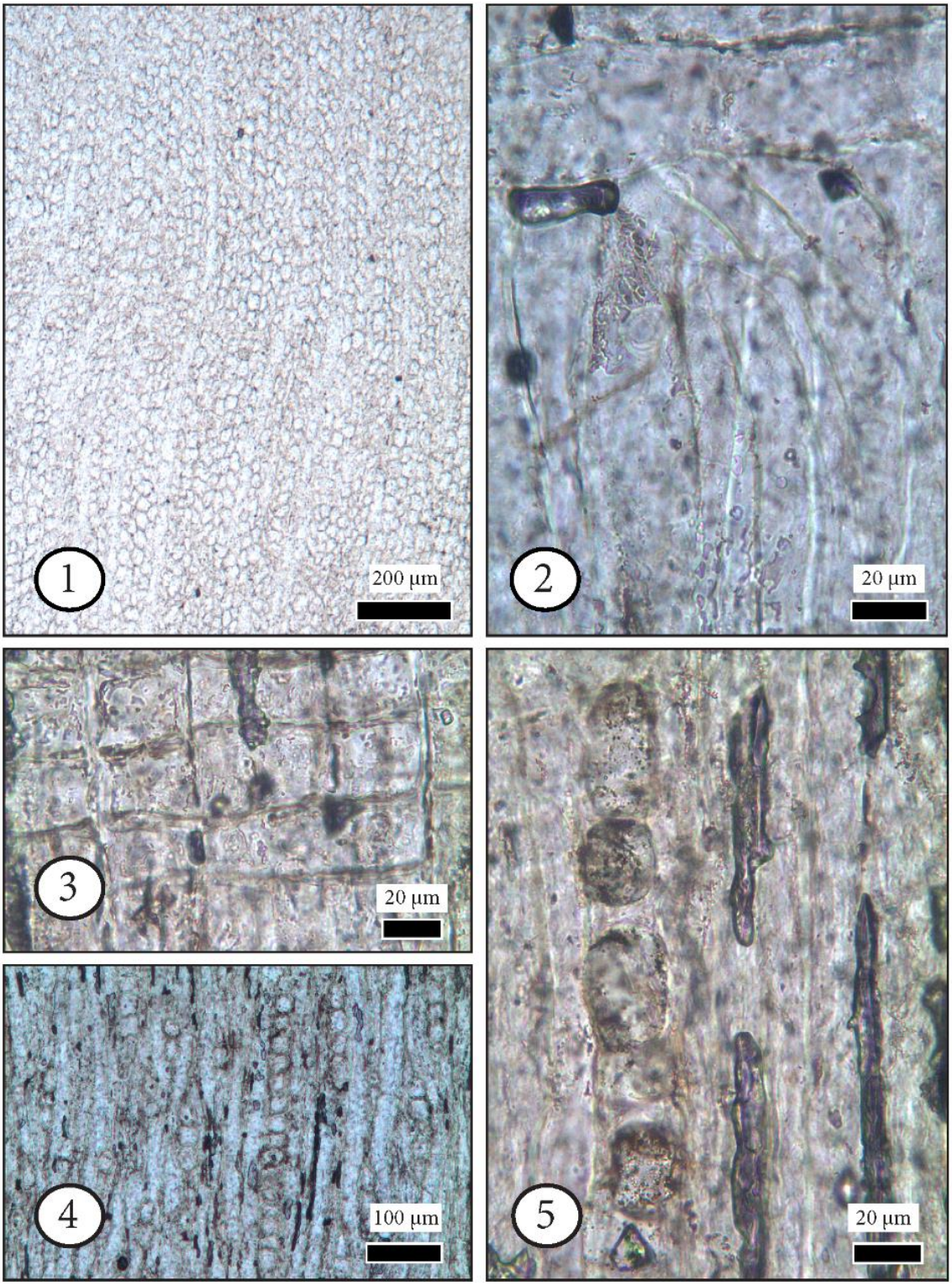

Figure 2. Wood anatomical sections of *Ginkgoxylon lesboense*. 1) Transversal section with indistinct growth ring boundary; 2) Leaning tips of tracheids; 3) Cupressoid type of cross-field pits in radial section; 4) Uniseriate rays in tangential section; 5) Enlarged axial parenchyma cells.

As a typical feature in *Gingko* type woods, axial parenchyma shows a knotty structure in tangential and radial sections; their middle part is enlarged, and their horizontal walls are

generally flat (Figure 2:5) and, however, because of poor preservation, horizontal walls mostly unclear.

In radial section, the tracheidal pits on the walls of the tracheids are uniseriate or partly biseriate. Idioblast-like cells are also found in the wood. The fact that the annual ring boundary is slightly visible or indistinct, the tracheids have irregular diameters, the absence of the resin canal, the presence of homogeneous, enlarged axial parenchyma cells and the presence of large cupressoid type gross-field pits indicate that the studied sample belongs to the species *Ginkgoxylon lesboense*.

This type of fossil wood was determined by Süss (2003) for the first time on Lesbos island and called the name of this island. Later, Çevik Üner et al. (2020) identified this type of wood from the late Oligocene- the early Miocene of Malkara (Thrace). With these studies, we can discuss that its presence in the Aegean basin was wide from the late Oligocene to the middle Miocene. Furthermore, Şanlı (1982) determined the pollen of *Ginkgo* from the Pliocene of Thrace. Royer et al. (2003) stated that this species occasionally replaces angiosperms in humid conditions, for example, it outclasses other species due to its slow growth rate, late reproductive maturity, extended reproductive cycle, large and complex seeds, and large and slow-developing embryos.

Family Betulaceae Gray, 1822
Genus *Ostryoxylon* Akkemik, 2018 emend. Akkemik, 2021
***Ostyoxylon gokceadaense* Akkemik**
Figure 3

Sample code. ISTO-FW-00249 (Repository: Laboratory of Wood Anatomy and Dendrochronology, Faculty of Forestry, Istanbul University-Cerrahpasa).

Identification: All the features found in this wood are close to the features of *Ostryoxylon gokceadaense*, previously described from the same area. The features of this fossil species were updated as follows: Growth ring boundaries distinct, with 1–2 rows of marginal fiber cells. Wood diffuse-porous, and vessels arranged in radial multiples of 2–4 or more (up to 13 vessels). Mean tangential diameter of vessel lumina less than 50 μm. Vessel frequency 50–100 per mm^2 (Figure 3:1).

Helical thickening on vessels is very common. Axial parenchyma present and diffuse. Rays width 1–4-seriate (Figure 3:2), aggregate rays not observed. Rays per mm per mm^2 ≥12. Maximum ray height up to 71 cells. Perforation plates are simple (Figure 3:3). Intervessel pits are generally alternate (Figure 3:4) and rarely opposite, circular in shape (Figure 3:4). Rays heterocellular; body ray cells procumbent with mostly 1–4 rows of upright and/or square marginal cells.

This type of wood was identified for the first time by Güngör et al. (2019) and later the species description by Akkemik (2021) from the same fossil area. With this new sample, the wood anatomical features were updated. As discussed by Akkemik (2021), this fossil wood is similar to both *Carpinus* Mill. and *Ostrya* Scop. Based on this finding, we can suggest that these two similar genera from the family of Betulaceae may have been evaluated from the same ancestor. For this, genetic studies may be performed to find more precise evidence.

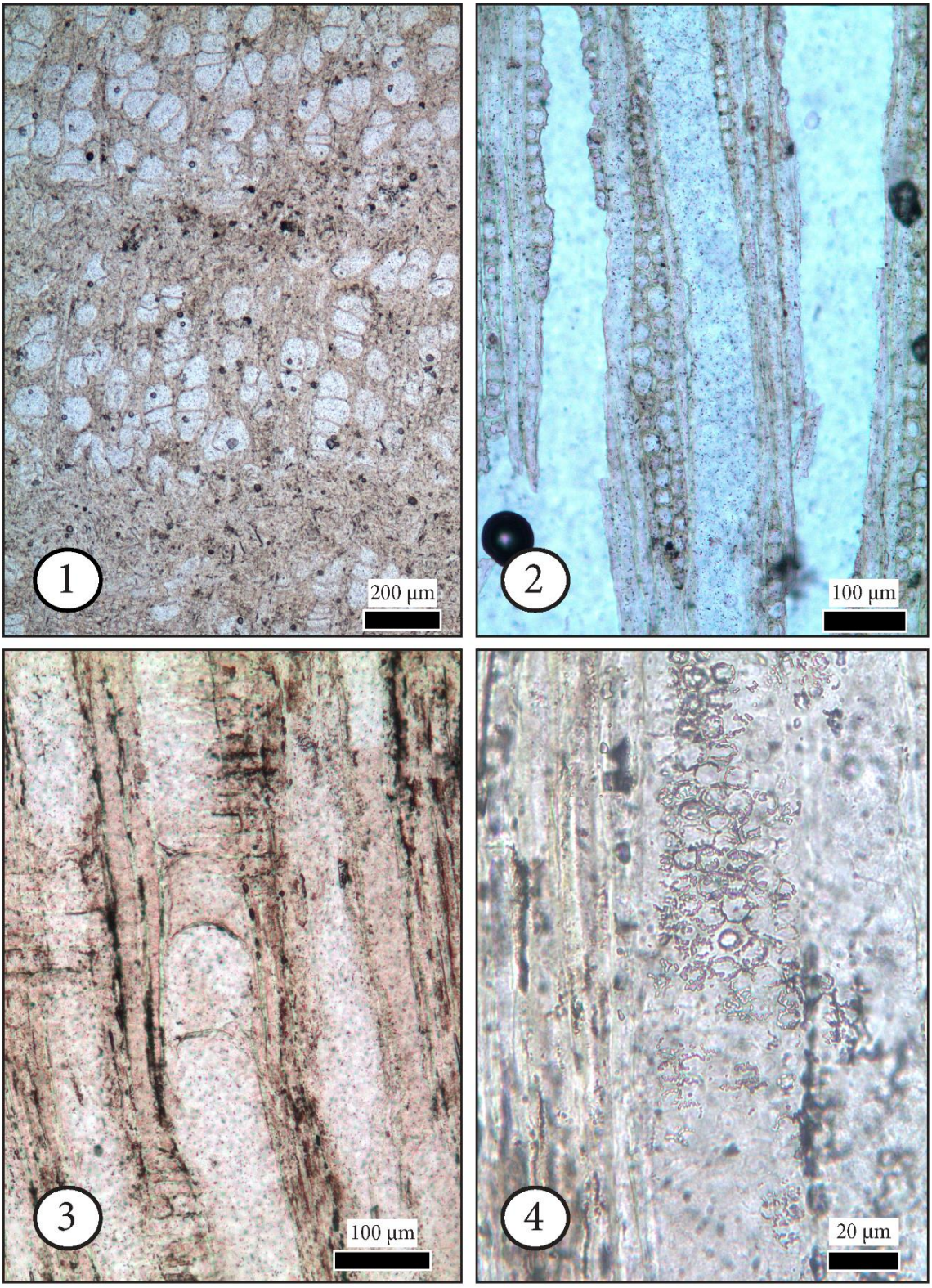

Figure 3. Wood anatomical sections of *Ostryoxylon gokceadaense*. 1) Distinct growth ring boundary in transversal section with diffuse porous vessels; 2) Tangential section with 1-3 seriate of rays; 3) Simple perforation plate in radial section; 4) Alternate arrangement of pits on vessels.

Family Lauraceae 1789
***Cryptocaryoxylon grandoleaceum* Akkemik 2021**
Figure 4

Sample code. ISTO-FW-00251 (Repository: Laboratory of Wood Anatomy and Dendrochronology, Faculty of Forestry, Istanbul University-Cerrahpasa).

Identification: All the features found in this wood are close to the features of *Cryptocaryoxylon grandoleaceum*, previously described from the same area. The features of this fossil species were updated with this new wood as follows: Growth ring boundary distinct, with a couple of radially flattened fibers and axial parenchyma. Wood diffuse porous, and slightly semi ring porous, vessels are mostly solitary, sometimes in radial multiples up to 2 vessels. Tangential diameters of vessels are 50-100 and 100-200 μm, radial diameters are generally 100-200 μm, and vessel number per square mm is 5-20 or sometimes 20-40 vessels. Tylosis is present in vessels (Figure 4:1-2). Axial parenchyma scanty paratracheal and marginal (Figure 4:2). Rays 1-3 seriate, large oil and mucilage cells at the tips of rays are common. Axial parenchyma strands up to 8 cells. Oil and mucilage cells are associated with rays (present through the ray body cells and between upright marginal cells) and among fibers (Figure 4:3). Rays are heterocellular, body ray cells procumbent with 1-2 seriates of upright cells, and oil and mucilage cells large, present through ray body cells and between upright cells. Perforation plates are simple (Figure 4:4).

Based on its grand oil and mucilage cells, Akkemik (2021) has described this species as *Cryptocaryoxylon grandoleaceum* Akkemik, on a material coming from the same fossiliferous site. This lauraceae wood may also indicate the abundance of trees as a represent of Lauraceae-dominated biomass in the middle Miocene of the Aegean basin.

***Laurinoxylon litseoides* Süss 1958**
(*Laurinoxylon* type 1, Mantzouka et al., 2016)
Figure 5

Sample code. ISTO-FW-00245 (Repository: Laboratory of Wood Anatomy and Dendrochronology, Faculty of Forestry, Istanbul University-Cerrahpasa).

Identification: All the features found in this wood are close to the features of the former *Laurinoxylon litseoides*, described from the same area. The features of this fossil species were updated with this wood as follows: Growth ring boundary distinct with 1-2 rows of radially flattened fibers. Vessels diffuse, solitary, or in radial rows up to 4 vessels. Vessels circular, tangential diameters of vessels <50 μm and 50-100 μm, and radial diameters about the same, 20-40 vessels per square mm. Tylosis is present in some vessels (Figure 5:1). Dark materials are common in enlarged oil and mucilage cells are visible in the transverse section. Axial parenchyma scanty paratracheal and rarely diffuse (Figure 5:1). Rays 1-3 seriate. Irregularly and partly biseriate. In some rays enlarged oil and mucilage cells are present (Figure 5:2). Body ray cells procumbent with one or two upright cells, and multiseriate (2-3 seriate) rays end with a long upright cells at the tips. Perforation plates are simple (Figure 5:3). Fibers are usually unpitted. Intervessel pits in a medium size (7-10 microns), dense, sometimes in honeycomb shapes, and alternate. Axial parenchyma strands up to 4 cells. Septate fibers were observed (Figure 5:4). All

these features found in this wood are about the same as the former *Laurinoxylon litseoides* described from the same area.

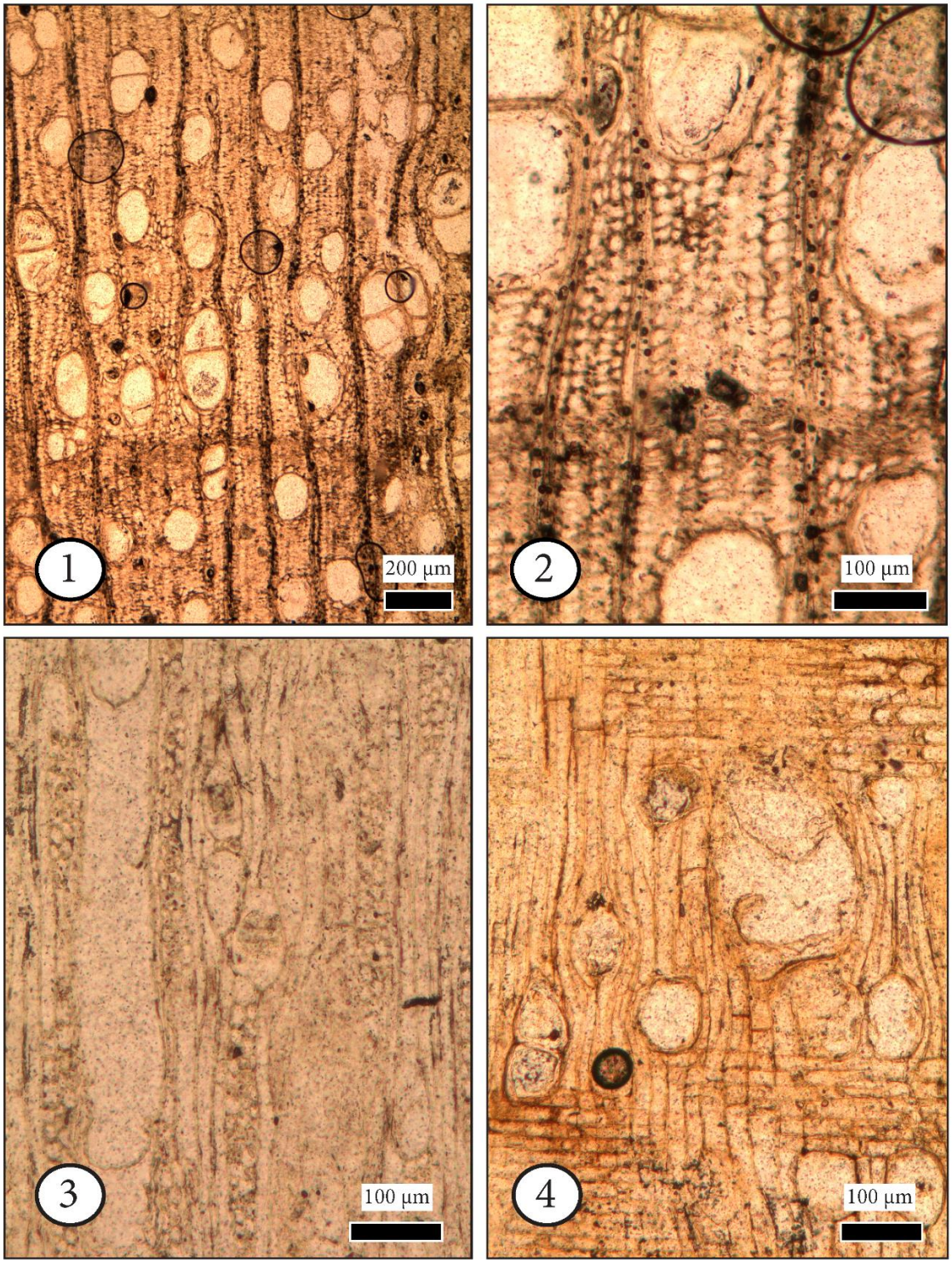

Figure 4. Wood anatomical features of *Cryptocaryoxylon grandoleaceum*. 1)Transversal section with distinct growth ring boundary distinct; 2) Marginal axial parenchyma in the growth ring boundary; 3) 1-3 seriate of rays and grand oil and mucilage cells in rays; 4) Simple perforation plate and grand oil and mucilage cells associated with rays, and among fibers.

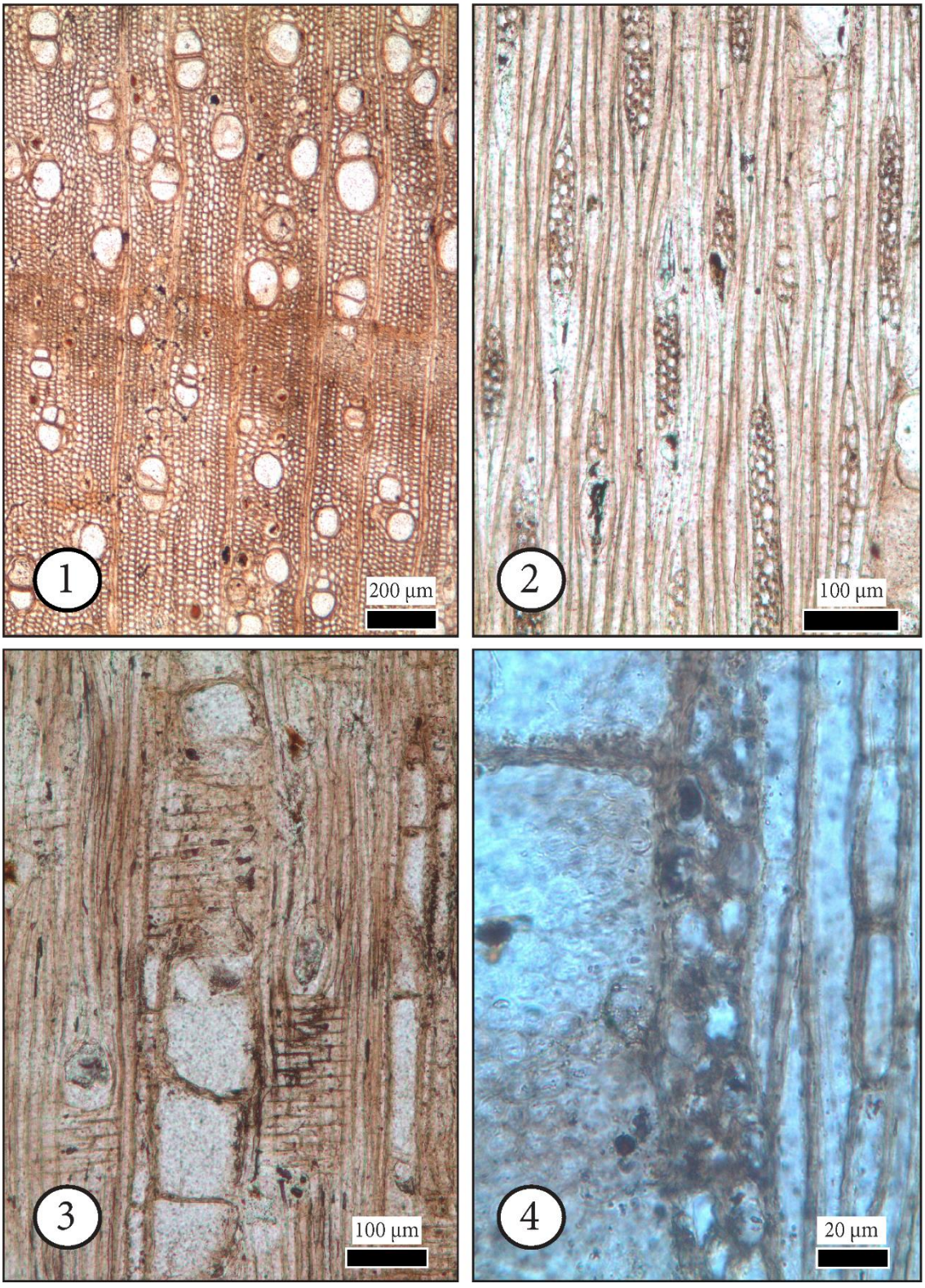

Figure 5. Wood anatomical features *Laurinoxylon litseoides*. 1) Transversal section with distinct growth ring boundary and diffuse porous; 2) 1-3 seriate of rays and oil and mucilage cells associated with rays; 3) Simple perforation plate in radial section; 4) Alternate arrangement of pits on vessel, axial parenchyma strand and septate fiber in tangential section.

After in the first description of *Laurinoxylon litseoides* by Süss (1958) from the middle to late Oligocene of Germany, this fossil species was identified in the Aegean Basin, firstly in Lesbos island (Mantzouka et al., 2016) and later in İstanbul (Akkemik et al., 2019), and in Gökçeada (Akkemik, 2021). All these identifications showed that this fossil species found from the middle Oligocene to the middle Miocene at these locations. Most of the features of this fossil species are rather similar to modern species, *Laurus nobilis* L. as indicated by Akkemik (2021; Table 4). The anatomical features of this new specimen is also very similar to the modern species, *Laurus nobilis*. Based on these similarities, we can affiliate with the *Laurus nobilis*, which is the widest laurel species today in the Mediterranean Basin, may be *Laurinoxylon litseoides*. New findings from the later geological times will help to understand the presence and evolution of *Laurinoxylon litseoides* in the Aegean Basin.

4. Conclusion

Increasing number of the fossil woods in Gökçeada showed the richness of the woody flora in the middle Miocene of Turkey. With this study, distribution of *Ginkgoxylon lesboense* was extended after Lesbos, İstanbul and Thrace, and added Gökçeada to this distribution area. Due to being a great land area and the Aegean Sea was missing during the middle Miocene, this species had a continuous distribution area through Turkey to Greece.

Laurinoxylon litseoides, which is one of the common fossil species in this region, is very similar to modern *Larusu nobilis*. The wood anatomical features may indicate that this fossil species is the potential ancestor of *L. nobilis*.

The presence of lauraceous-type fossil woods in this study indicates the presence of a Lauraceae-dominated forest in the middle Miocene period in the region. The presence of lauraceous-type woods in other regions also revealed that Lauraceae biomes should be taken into consideration more in the Early-Middle Miocene periods. This biomass may indicate the presence of subtropical warm and humid climate type in Aegean basin.

Acknowledgement

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