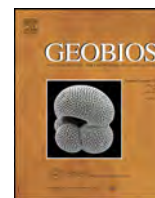




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Original article

## New data about Early Cretaceous Ginkgoales from southwestern Europe (middle-late Albian of Spain)<sup>☆</sup>

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### ABSTRACT

We present in this work a leaf-type corresponding to the Ginkgoales genus *Sphenobaiera* recorded in deposits from the middle-upper Albian (Lower Cretaceous) of northeastern Spain. The fossil leaf shows a widely dissected lamina that forks regularly six times ending at the apex in sixty-four tiny wedge-shaped segments, which are characters similar to those in *Sphenobaiera pecten* from the Middle Jurassic of England. The exceptional preservation of this fossil leaf, which preserves all segments in connection with its base, in addition to taphonomical and sedimentological data, indicates a nearby location for the parent plant, which grew near the shores of a tidally-influenced fluvial environment. A palaeoenvironmental reconstruction of the sub-environments where the different types of Ginkgoales known from the Albian of northeastern Spain developed is also presented. The presence of a variety of different types of Ginkgoales in middle-upper Albian deposits from Spain represents a new contribution to the knowledge of the palaeoenvironmental conditions for this region of southwestern Eurasia during the late Early Cretaceous.

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## 1. Introduction

There are many morphological variations in fossil Ginkgoales leaves, ranging from simple lanceolate to dissected shapes. Among Mesozoic Ginkgoales, both genera *Baiera* Braun emend. Florin and *Sphenobaiera* Florin emend. Harris et Millington present similarities as they share dissected (deeply dissected occasionally) and wedge-shaped leaves with dichotomous venation, but *Baiera* should be used only if a distinct petiole (part below the lamina that is consistent in width) is present, while *Sphenobaiera* should be used exclusively for this kind of leaves that lack a distinct petiole (Harris et al., 1974).

Evidences concerning the presence of ginkgoalean leaves in the “mid” Cretaceous (Albian to Turonian) from western Eurasia – within the Eurosinian province – were classically restricted to records of taxa with simple, oblanceolate-shaped lamina corresponding to the genera *Eretmophyllum* Thomas and *Nehvizdya* Hlušítk – despite the last genus is considered as a synonym of the first one by many authors – from the Albian deposits of Spain (Gomez et al., 2000; Sender, 2012) and from the Cenomanian of

France (Pons et al., 1976, 1980; Nguyen Tu et al., 1999) and Czech Republic (Hlušítk, 1977, 1986; Knobloch and Mai, 1999; Kvacek, 1999).

Other genera within Ginkgoales that show leaves with a dissected lamina – as *Ginkgoites* Seward emend. Watson, Lydon et Harrison, and *Sphenobaiera* – constitute a common record in the Upper Triassic to basal Lower Cretaceous continental deposits from the Eurosinian region (Zhou, 2009), except for the Albian Stage where they are absent. Nevertheless, relatively recent findings from the Iberian Peninsula changed this assertion because complete leaves of the two cited ginkgoalean genera were found in middle-upper Albian fluvial deposits in northeastern Spain (Sender et al., 2005, 2008).

In this work, a new kind of ginkgoalean leaf corresponding to the genus *Sphenobaiera* is described from Albian deposits in northeastern Spain, western Eurasia. This new finding gives support to previous data indicating that warm and humid environmental conditions were present in the Iberian Plate during the late Early Cretaceous.

## 2. Geographical and geological settings

The ginkgoalean leaf studied in this paper was collected in the so-called San Just-2 fossil site, close to the Utrillas village in the

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Cuencas Mineras Comarcal (Teruel Province, Aragón region, northeastern Spain; coordinates: 40°46'42.58"N, 0°50'03.22"W), which is located 118 km south of Zaragoza city and 64 km north of Teruel city (Fig. 1). The stratigraphic level containing the studied fossil leaf belongs to the upper part of the Middle Member – or “Regachuelo” Member – of the Escucha Fm. (Aguilar et al., 1971; Fig. 2), a mainly continental detrital unit consisting of alternate sandstones and clays with intercalations of coal seams and sporadic marine limestones deposited in a delta-estuary system with tidal influence (Pardo and Villena, 1979; Pardo et al., 1991; Querol, 1990; Querol et al., 1992; Salas et al., 2001). The Escucha Fm. in this area overlays the marine deposits of the Villarroya de los Pinares Fm., which is Aptian in age in the Utrillas area (Villanueva-Amadoz et al., 2010); it is limited to the top by the sandy fluvial deposits of the Utrillas Fm., which is middle-late Albian in age. The stratigraphical level of the San Just-2 fossil site containing the studied Ginkgoales leaf has yielded an angiospermous palynological assemblage composed of several species corresponding to monosulcates genera (*Clavatipollenites* Couper, *Dichastopollenites* May, *Hammenia* Ward, *Jusinghipollis* Jansonius et Hills, *Liliacidites* Couper, *Pennipollis* Friis, Pedersen et Crane, *Retimonocolpites* Pierce emend. Juhász et Góczán, and *Transitoripollis* Góczán et Juhász) and also tricolpates (*Phimopollenites* Dettmann, *Rousea* Srivastava, *Striatopollis* Krutzsch, and *Tricolpites* Cookson ex Couper emend. Jarzen et Dettmann), which indicate a middle to late Albian age for the fossil site (Villanueva-Amadoz et al., 2010). The lithology of the stratigraphic interval where the fossil was found in San Just-2 locality exhibits white to light brown cross-bedded sandstones with intercalations of grey-colored claystones and siltstones (Querol et al., 1992; Pardo et al., 1991).

### 3. Material and methods

The studied fossil consists of an impression of a single leaf preserved in grey-colored siltstones. The fossil was prepared using a pneumatic hammer, small needles and soft brushes. Photographs

of the fossil leaf were taken using a Nikon D-90 camera with an AF-S Micro Nikkor 60 mm macro-lens. The specimen is stored at the Museo Paleontológico Aragonés – Fundación Conjunto Paleontológico de Teruel (Teruel city, Spain) under the designation MAP-7726.

### 4. Systematic palaeobotany

Order Ginkgoales Warburg, 1913.

Family Ginkgoaceae Engler, 1897.

Genus *Sphenobaiera* (Florin) emend. Harris et Millington, 1974.

*Sphenobaiera* cf. *pecten* (Harris) emend. Harris et Millington, 1974.

Fig. 3

**Description:** Nearly complete leaf, wedge-shaped in outline, 7.4 cm long and 5.3 cm wide, presenting an acute to attenuate base without a distinct petiole (Fig. 3(A)). The length of basal region is 4.5 mm, with lamina deeply divided into two primary segments (Fig. 3(D)) which divides in long linear-shaped segments forking six times (Fig. 3(A)) to end in two tiny and thin linear-shaped segments at the top of the leaf (Fig. 3(C)). The complete leaf would present sixty-four apical tiny wedge-shaped segments at its apex. Angle of dichotomies is about 15° to 20° in basal medial dichotomies and less than 5° on average in the terminal ones. Maximum width of segments in medial zone of the leaf is 2 mm; minimum width of segments, corresponding to the apical zone, is 0.8 mm. The maximum width of segments between dichotomies is located in the medial zone (1.8 mm wide), becoming narrower towards both the base and the apex of the leaf (Fig. 3(A)). Veins are straight and marked, running parallel to the margins. Apparently, a single basal vein dichotomizes from the base to the apex of the lamina with four to five veins per segment in the median area of the leaf (Fig. 3(B)). Vein density in the widest part of segments is 3 veins per mm. The number of veins decreases in the thin linear-shaped segments at the top of the leaf up to two veins, which enter each apical segment ending in the distal margin.

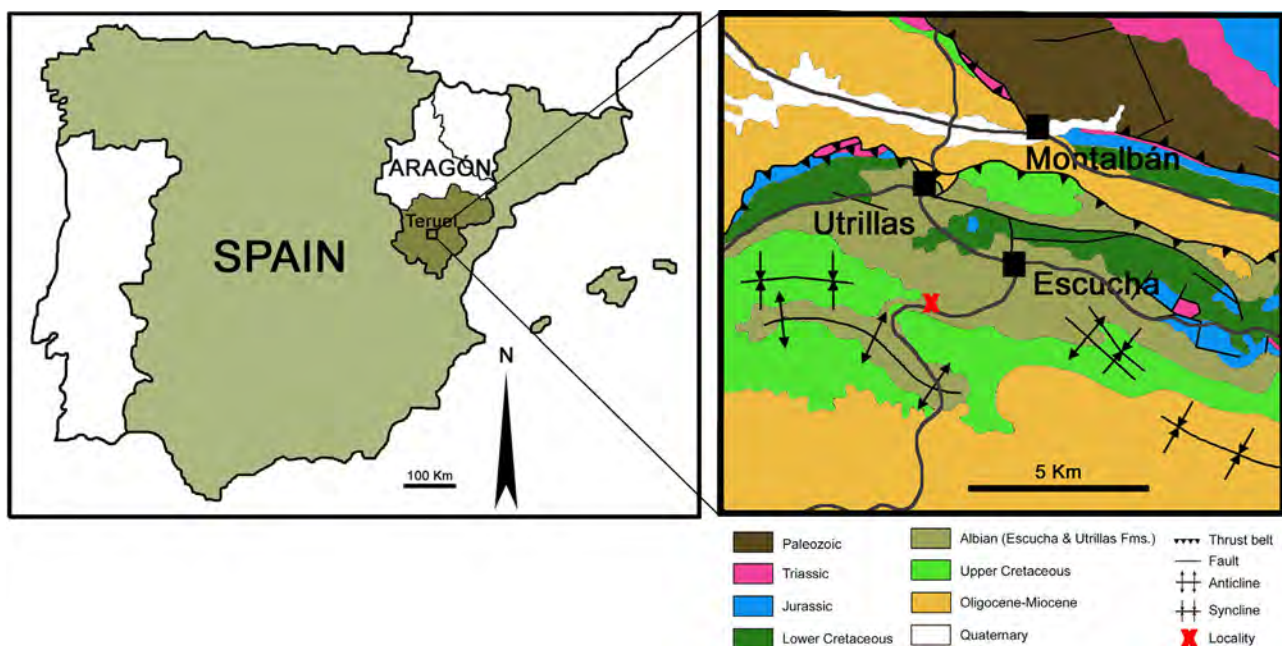
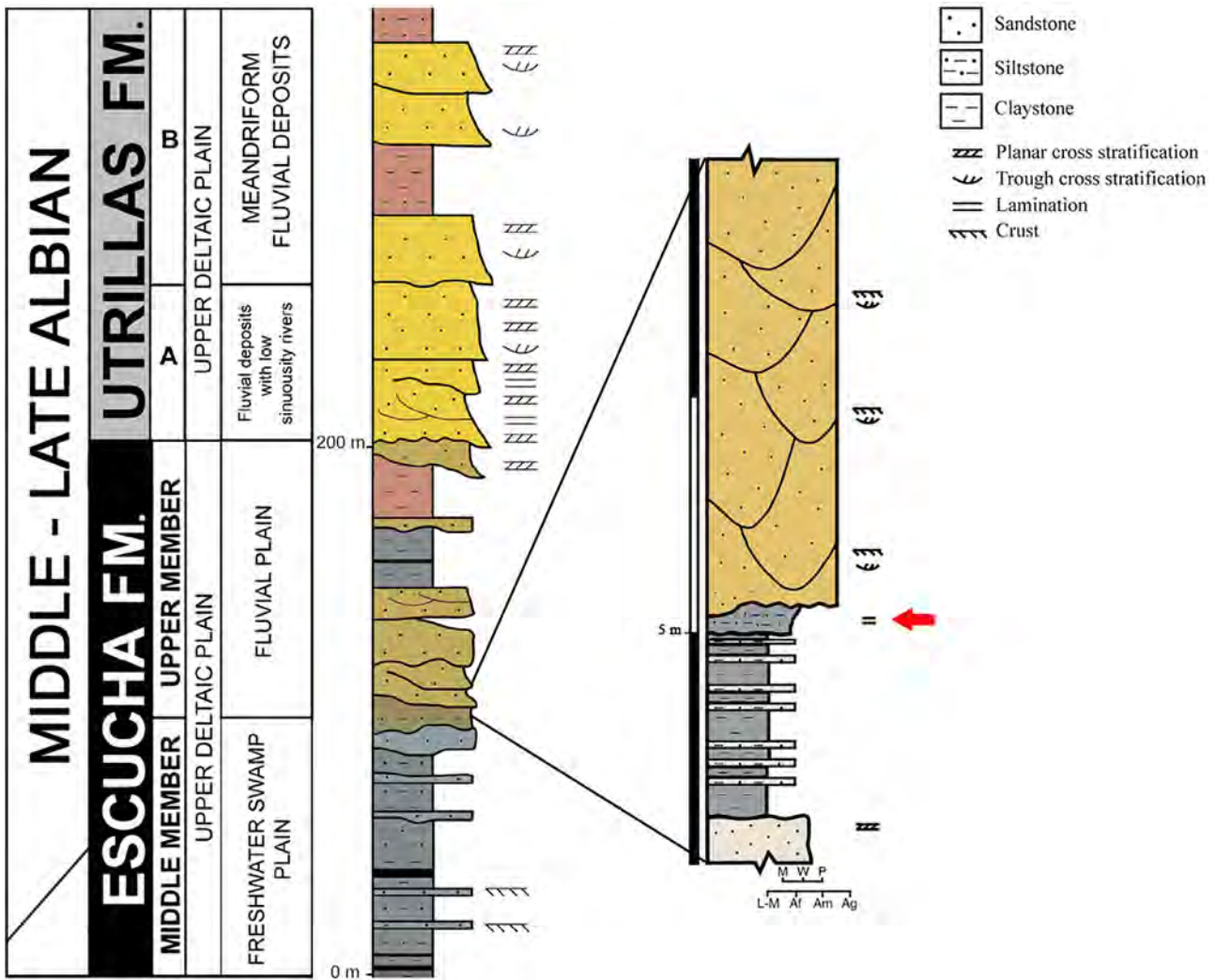


Fig. 1. Geographic location of the plant fossil site and geological map of the area near Escucha village where the fossil leaf was found. The fossil site is indicated by a red cross.



**Fig. 2.** Synthetic stratigraphic section of part of the Escucha and Utrillas formations, which are exposed in the area of the fossil locality in northeastern Spain, indicating depositional environments and sub-environments (modified from Villanueva-Amadoz, 2009). The position of the stratigraphical level bearing the studied leaf is indicated by a red arrow.

## 5. Discussion

### 5.1. Taxonomical remarks

The genus *Sphenobaiera* occurs in Mesozoic deposits worldwide (Zhou, 2009; Bauer et al., 2013). Cretaceous records of this taxon in Laurasia have been found:

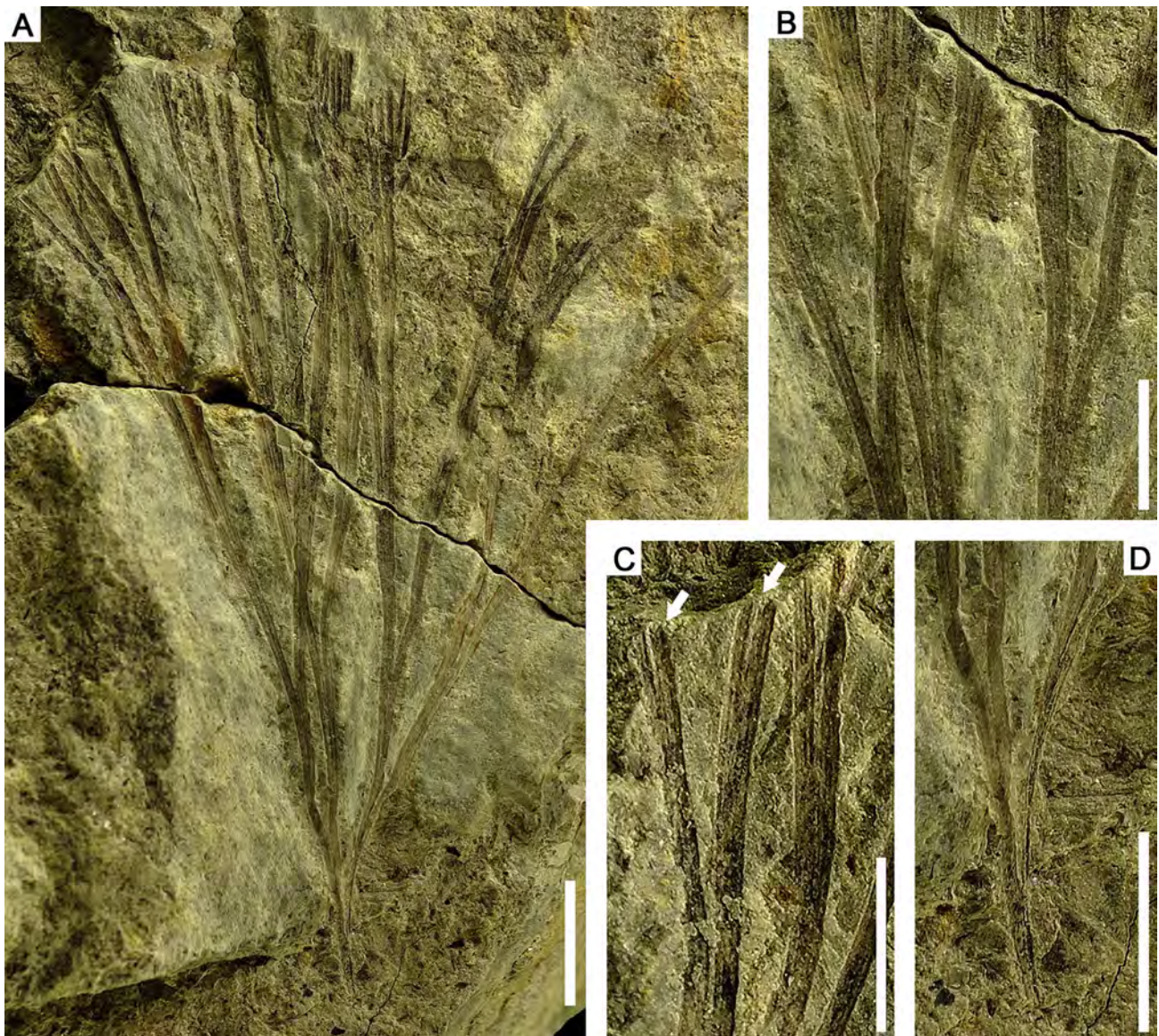
- in Lower Cretaceous deposits from south Prymorye (Krassilov, 1967), Bureja (Krassilov, 1972) and Aldan basins (Samylina, 1956, 1963, 1967);
- in Albian deposits of northern Siberia (Spicer and Herman, 2001; Herman and Spicer, 2010), all of them in Russia;
- in the Lower Cretaceous of northern China (Guo, 1990) and Mongolia (Sun et al., 2003);
- in Albian to Cenomanian rocks from Alaska (Spicer and Herman, 2001);
- in Lower Cretaceous deposits from the Bowser Basin in Canada (MacLeod and Hills, 1991) and the Black Hills from western USA (Cahoon, 1960);
- in Barremian to Aptian deposits from Greenland (Seward, 1926; Lydon et al., 2003) and Svalbard (Pott et al., 2016).

The Cretaceous species of this genus exhibit a common morphological pattern that consists of deeply dissected leaves lacking a distinct petiole with a triangular and wedge-shaped lamina, which present from two to five primary segments that fork at least once, showing dichotomous venation (Florin, 1936; Harris et al., 1974).

The leaf described here from the Albian of Spain fits well with the diagnosis of this genus, but some singular characteristics as the number of dichotomies of the thin segments and the number of apical segments morphologically distinguish it from all Cretaceous species known to date. It differs mainly from genus *Baiera* in the absence of a true petiole and especially in the number of veins per lobe: typically between 2 to 4 in *Baiera* and 4 to 6 in *Sphenobaiera*. (Florin, 1936).

Unfortunately, the studied leaf does not preserve cuticular remains, which could indicate a possible relation with a known species. The external morphology of the studied leaf resembles those observed in several *Sphenobaiera* species from Upper Triassic to Lower Cretaceous deposits around the world (Table 1). Nevertheless, characters as the dissected morphology of the lamina, the number of successive divisions of the segments, the





**Fig. 3.** **A.** Nearly complete leaf of *Sphenobaiera cf. pecten*, MAP-7726. **B.** Detail of divided segments and venation pattern. **C.** Detail of the last division of segments showing the thin linear-shaped segments at the top of the leaf (white arrows). **D.** Detail of the basal part of the leaf and the primary division of segments. Scale bars: 1 cm (A), 5 mm (B–D).

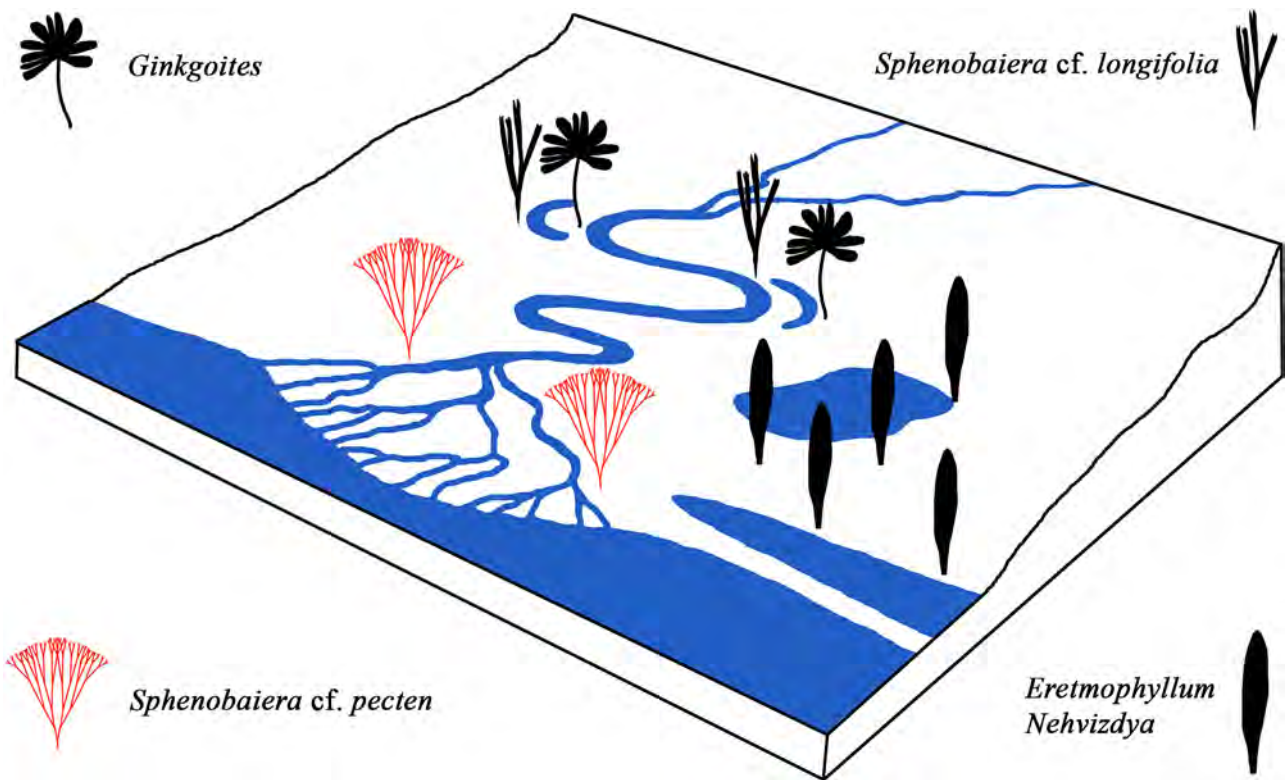
number of dichotomous veins present on them, and the angle between of dichotomies fit with those observed in *Sphenobaiera pecten* Harris from the Middle Jurassic deposits of Yorkshire, England (Harris et al., 1974). On the other hand, terminal segments in our leaf are both shorter and wider than those from the leaves of the English Jurassic deposits. In addition, two veins enter these

terminal segments in the Spanish specimen, which differs from the single medial vein ending at the tip of the ultimate segments in the leaves from the Yorkshire locality. The main difference between the studied leaf and leaves of *Sphenobaiera pecten* consists on the vein density, which is three times larger in the present specimen (i.e., 3 vs. 1 vein per mm). This fact is due to the narrow segments

**Table 1**  
Comparison between the studied leaf and other similar-shaped leaves assigned to *Sphenobaiera* species.

Species	Lamina	Division times	Shape of medial segments	Maximum width of segments	Shape of last segments	Number of veins	Vein density (per mm)
<i>Sphenobaiera schenkii</i> (Feistmantel) Florin	Wedge-shaped	4	Linear-shaped	3 mm	Narrow linear	2–5	2
<i>Sphenobaiera pecten</i> (Harris) emend. Harris et Millington	Wedge-shaped	6	Linear-shaped	3 mm	Thin linear	1–4	1
<i>Sphenobaiera longifolia</i> Pomel (Florin) emend. Harris et Millington	Wedge-shaped	4	Linear-shaped	6 mm	Narrow linear	4–11	2
<i>Sphenobaiera ophyoglossum</i> Harris et Millington	Narrowly wedge-shaped	3 at least	Linear-shaped	8 mm	Narrow linear	5–19	2
<i>Sphenobaiera ikorfatensis</i> (Seward) Florin	Narrowly wedge-shaped	2	Strap-shaped	8–10 mm	Rounded	10–15	1
<i>Sphenobaiera spetsbergensis</i> (Nathorst) Florin	Narrowly wedge-shaped	2	Linear-shaped	1 mm	Rounded	Numerous	–
<i>Sphenobaiera cf. pecten</i> (this paper)	Wedge-shaped	6	Linear-shaped	1.8 mm	Thin linear	2–5	3





**Fig. 4.** Palaeoenvironmental reconstruction of the deltaic-estuarine environment developed during deposit of the Escucha Fm. The silhouettes corresponding to the different genera and species of Ginkgoales recorded in this geological formation are associated with the closest sub-environments where they grew (see Section 5.2).

on the studied leaf, which are almost half the size of those in *Sphenobaiera pecten*.

#### 5.2. Palaeoenvironmental and palaeophytogeographical implications

Some other Ginkgoalean leaves have been found previously in the middle to upper Albian deposits of northeastern Spain: leaves of *Eretmophyllum andegavense* Pons, Boureau et Broutin from the Escucha, Utrillas and Portalrubio localities (Sender, 2012) and *Nehvizdya penalveri* Gomez from Rubielos de Mora locality, both taxa being recorded in deposits of the Middle Member of the Escucha Fm., and *Ginkgoites* cf. *pluripartita* and *Sphenobaiera* cf. *longifolia* from Alcaine locality deposits corresponding to the Upper Member of the same geological formation (Sender et al., 2008). The data provided by the preservation of fossil remains and the sedimentological features of the deposits containing them make it possible to relate the plants bearing these leaves to the nearby areas of different depositional sub-environments within the deltaic-estuarine environment that was present in this area during Albian times (Fig. 4).

A great amount of complete Ginkgoalean leaves corresponding to *Eretmophyllum andegavense* and *Nehvizdya penalveri* species were found as concentrations in laminated claystones deposited in

both brackish and freshwater swamp sub-environments. This great amount of leaves and their good preservation – with both apex and base intact – would indicate a minimum transportation from the areas where these plants grew. On the other hand, leaves of *Ginkgoites* cf. *pluripartita* and *Sphenobaiera* cf. *longifolia* preserve petioles in connection with laminae and segments of leaves with their apex without any biostratinomical evidences of alteration due to transportation. Both facts constitute clear evidences indicating that the parent plants of these leaves grew in the close vicinity of oxbow lakes and inundated areas of fluvial plains where they were buried (Querol et al., 1992; Sender et al., 2008; Sender, 2012; Fig. 4; Table 2). The exquisite preservation of the leaf *Sphenobaiera* cf. *pecten* from San Just-2 locality described here – preserving all segments in connection without evidences of erosive transportation by water – would also indicate that its parent plant grew in the close vicinity of a tidally-influenced fluvial environment where the leaf was buried.

Based on the observed stratigraphic sequences and sedimentary structures – as “herring-bone” lamination and typical rhythmites with cross-lamination containing mud drapes and re-activation surfaces –, the sedimentary interpretation relates these deposits with highly tidally-influenced fluvial environments close to the sea, departing from deposits containing the other mentioned Ginkgoalean leaves that show depositional conditions

**Table 2**  
 Occurrence of Ginkgoalean remains in localities from the Albian deposits of northeastern Spain and their related sedimentary depositional environments.

Species	Geological unit	Localities in Spain	Depositional environments	References
<i>Nehvizdya penalveri</i>	Middle Member of Escucha Fm.	Rubielos de Mora	Brackish and freshwater swamps	Gomez et al. (2000)
<i>Eretmophyllum andegavense</i>	Middle Member of Escucha Fm.	Escucha, Utrillas, Portalrubio	Brackish and freshwater swamps	Sender (2012)
<i>Ginkgoites</i> cf. <i>pluripartita</i>	Upper Member of Escucha Fm.	Alcaine	Oxbow lake and fluvial plain	Sender et al. (2008)
<i>Sphenobaiera</i> cf. <i>longifolia</i>	Upper Member of Escucha Fm.	Alcaine	Oxbow lake and fluvial plain	Sender et al. (2008)
<i>Sphenobaiera</i> cf. <i>pecten</i>	Middle Member of Escucha Fm.	Utrillas	Tidally-influenced fluvial plain	This paper

with a minor tidal influence (Querol et al., 1992; Villanueva-Amadoz et al., 2010; Sender, 2012).

Until the beginning of the 21th century, the evidence showed that both genera *Ginkgoites* and *Sphenobaiera* had disappeared from western Eurasia during the Early Cretaceous, being restricted to the Siberian-Canadian province since the late Aptian or early Albian (Vakhrameyev, 1991; Pott et al., 2016). Nevertheless, evidences confirming the presence of these ginkgoalean genera have been detected in middle-upper Albian deposits of the Iberian Plate, within the southwestern part of the EuroSinian province (Sender et al., 2008; this study). The data concerning the presence of the two ginkgoalean genera in this area, in addition to the presence of “out of place” taxa corresponding to some Pteridophytes (Sender et al., 2005), Gymnosperms (Sender et al., 2008) and angiosperms (Sender et al., 2016) genera, could evidence the presence of a transitional zone between the warm-subtropical belt and temperate belt in the Northern Hemisphere, which would be located in the area corresponding to the islands that constituted the Iberian Peninsula during the Albian. Nevertheless, it could also indicate that these islands may have been a southern relict refuge for these plants during middle-late Albian times, whereas they had climatic and environmental conditions similar to those of boreal regions such as the Sibero-Canadian province (Vakhrameyev, 1991) during the late Early Cretaceous.

## 6. Conclusions

A new record of fossil leaf assigned to the genus *Sphenobaiera* from the middle-upper Albian deposits of northeastern Spain share some characters with *Sphenobaiera pecten* from the Middle Jurassic of England. Taphonomical and sedimentological data concerning preservational features of the leaf indicates that its parent plant grew close to a tidally-influenced fluvial environment. In addition to the distribution of other ginkgoaleans found within different middle-upper Albian sedimentary environments from northeastern Spain, this new record of this unexpected taxa would indicate special palaeoenvironmental conditions for this region of southwestern Eurasia during this time interval.

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