

A new gobiconodontid mammal from the Early Cretaceous of Spain and its palaeogeographic implications

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A new gobiconodontid from Vallipón (Teruel, Spain) represents the first record of this family in Europe. The site has a diverse fossil assemblage mainly composed of isolated bones and teeth probably accumulated by tidal action and water streams in an ancient beach of upper Barremian, in the transitional marine-continental sediments of the Artoles Formation. The new gobiconodontid consist of an isolated upper molar, smaller in size than that element in other gobiconodontids, with a robust cusp A, characterised by lateral bulges on each mesial and distal flanges of that cusp, and a discontinuous cingulum raised at the lingual side. The occlusal outline is smooth compared with *Gobiconodon borissiaki*, *Gobiconodon hoburensis*, or *Gobiconodon ostromi*. The Gobiconodontidae record is exclusively Laurasiatic. The oldest gobiconodontid fossil remains are Hauterivian; though their probable origin has to be found at the Late Jurassic in Central Asia (as inferred from derived character of the first gobiconodontids as well as phylogenetic relationships). At the end of the Early Cretaceous they expanded throughout Laurasia as indicated by findings in Asia, North America, and Spain. Two dispersion events spread gobiconodontids: to the West (Europe) in the Barremian and to the East (North America) during the Aptian/Albian.

Key words: Cretaceous, Barremian, Mammalia, Gobiconodontidae, Europe, palaeogeography.

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Introduction

Fossils of Early Cretaceous mammals are quite rare and were only found in less than a dozen regions in the world. Gobiconodontids are especially interesting since they may be at the roots of the mammalian family tree (Rougier et al. 2001; Wang et al. 2001; Ji et al. 2002; Kielan-Jaworowska et al. in press). The gobiconodontid record is exclusively Laurasiatic, and its geographic distribution was quite widespread during the Mesozoic. They are known from eastern Asia, Siberia, and western Europe to Montana in the USA (Jenkins and Shaff 1988; Kielan-Jaworowska and Dashzeveg 1998; Maschenko and Lopatin 1998; Godefroit and Guo 1999; Rougier et al. 2001; this work). The aim of this paper is to study the first gobiconodontid from Europe and consider its palaeogeographic implications.

The site of Vallipón is located in the Teruel Province (NE Spain). The best access is from a local path that begins in Mas de las Matas village and goes westward towards Castellote (Fig. 1). Geologically the fossiliferous level is located at the northwestern part of the Maestrazgo Early Cretaceous Basin (Salas et al. 1995; Canudo et al. 1996). From bottom to top there are three Lower Cretaceous Formations at the Vallipón section: Mirambel, Artoles, and Utrillas. The Mirambel Formation is 50 m thick, with an unconformably contact to marine carbonate platform of Upper Jurassic (Fig. 1). It is mainly composed of massive red-orange lutites at the

bottom that turn grey towards the top, and laminated marls with abundant ostracods and charophytes. The top of the Mirambel Formation is dated within the biozone *Triquetra-Neimongoliensis*, subzone *Calcitrapus* (lower Barremian, Martin-Closas 1989).

The Artoles Formation is 8 m thick, with red and yellowish sandstone and conglomerates at the bottom (30 to 50 cm). This is the fossiliferous level, which is very peculiar and conspicuous in the field because it consists mainly of fossil vertebrate remains firmly cemented by iron carbonate. Overlying Vallipón there are grey marls and limestones, with abundant marine invertebrates, especially large foraminifers and molluscs. The macroforaminifer species *Paleorbitolina lenticularis lenticularis* gives a late Barremian–early Aptian age for the upper part of the Artoles Formation and, therefore the site of Vallipón might be late Barremian (Salas et al. 1995; Canudo et al. 1996). The Utrillas Formation overlies unconformably on top of the Artoles. These continental terrigenous sandy and clayish facies are dated as Albian (Querol et al. 1992).

The Vallipón site is a rich marine and continental fossil vertebrate assemblage with isolated bones and teeth. Canudo et al. (1996) proposed a coastal environment with a hard substrate where the materials were carried in by predators and accumulated by shallow streams and probably also tidal action. The vertebrate remains are mostly isolated pieces representing 43 different taxa (Ruiz-Omeñaca and Canudo 2001).

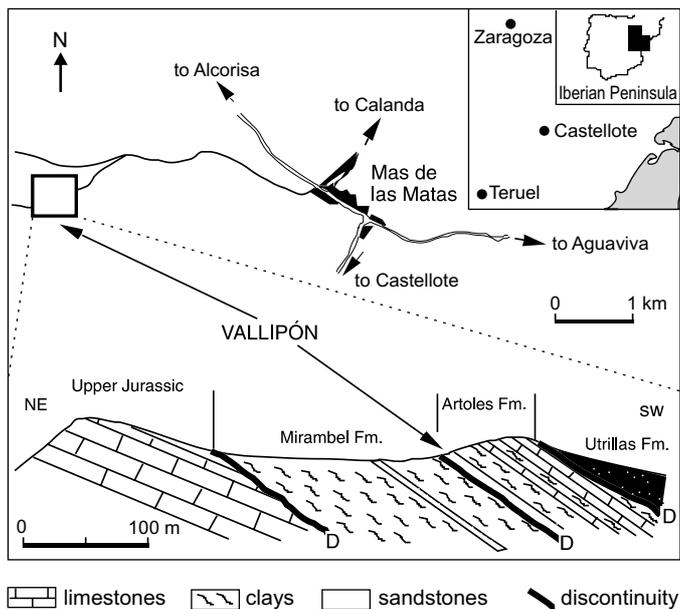


Fig. 1. Geographical and geological situation of the Vallipón site (upper Barremian, Teruel, Spain).

There are mammalian-isolated teeth of Multituberculata, Theria?, Docodonta, and Gobiconodontidae (Cuenca-Bescós et al. 1996, this paper).

Material, methods, and terminology

The specimen studied in this paper is an isolated left upper molariform, M3 or M4, housed at the Museum of Paleontology, Zaragoza University. Photographs were taken using a Scanning Electron Microscope, at the Electronic Photography Service (University of Zaragoza). Measurements were taken using a video camera adapted to the microscope that captured and transmitted the images to a computer, for direct distance measurements using the Matrox Inspector (an image analysis program). The teeth were identified and oriented by comparing with the dentition of *Gobiconodon borissiaki* Trofimov, 1978 and *Gobiconodon hoburensis* (Trofimov, 1978) in Kielan-Jaworowska and Dashzeveg (1998), and we follow the nomenclature for teeth of these authors and of Jenkins and Shaff (1988).

Institutional abbreviations.—MPZ, Museum of Paleontology, Zaragoza University, Zaragoza, Spain; PSS-MAE, Paleontological and Stratigraphical Section (PSS) of the Mongolian Academy of Sciences, Ulan Baatar, Mongolia, and collections of the joint Mongolian Academy of Sciences, American Museum of Natural History Expeditions (MAE); MCZ, Museum of Comparative Zoology, Harvard University, Cambridge.

Systematic palaeontology

Class Mammalia Linnaeus, 1758

Order Eutriconodonta Kermack, Musset, and Rigney, 1973

Family Gobiconodontidae Chow and Rich, 1984
(= Gobiconodontinae Chow and Rich, 1984)

The systematic position of Gobiconodontidae has been a subject of discussion in several papers. Traditionally authors included it in the order Triconodonta Osborn, 1888 (Trofimov 1978; Jenkins and Crompton 1979; Chow and Rich 1984; Jenkins and Shaff 1988; Maschenko and Lopatin 1998). A recent review of Kielan-Jaworowska et al. (in press) included Gobiconodontidae in the order Eutriconodonta. Some features of the Gobiconodontidae dentition are apomorphies for this group, i.e., the raised position of the cingulum and the outline of the crown of the upper molars (Fig. 2). In gobiconodontids, the three main cusps of the lower molariforms are aligned mesio-distally, as in other eutriconodontans (Kielan-Jaworowska et al. in press), whereas in the uppers, the main cusps form an obtuse angle.

Gobiconodontidae indet.

Figs. 2–4.

Description.—One left upper molariform, M3 or M4 (MPZ 2002/73) of small size. It has a robust cusp A, characterised by probably autapomorphic lateral bulges on each mesial and distal flanges of that cusp. It has a discontinuous cingulum raised at the lingual side. The tooth is 1.67 mm long and 1.13 mm wide (Table 1). It is almost complete, only the mesiolingual corner is broken, and a small portion of the anterolingual part of cusp B is missing. The tooth has two roots, the anterior one being broken. The posterior root is complete and compressed anteroposteriorly. In occlusal view the crown is “pillow-shaped”, more or less rectangular, and somewhat constricted in the middle. The mesial half is transversely narrower than the distal. The labial side is more indented than the lingual (Figs. 2–4). The tooth crown is fan-shaped in labial and lingual views. The central cusp A is the highest point of the crown (Fig. 2).

The three main cusps: the anterior B, medial A, and posterior C form a wide obtuse angle. Cusp A is more lingual with respect to cusps B and C. On the distal side the distal cingulum has a broad wear facet that may have had a cusplike D (Fig. 2A) with a lingual slope. Cusp A is the highest and the broadest with a small wear surface on its tip (Fig. 4A, B), and it has two mesial and distal bulges aligned anteroposteriorly with its tip, which gives it a massive appearance (Fig. 2A, B, D). Both protuberances are less visible but still noticeable in occlusal view, specially the distal one (Fig. 3). Cusp B is heavily damaged. Cusp C is about a third lower than the height of the main cusp A and has a distolingual wear facet. The cusps are separated by shallow incisions visible in both lingual and labial views. The

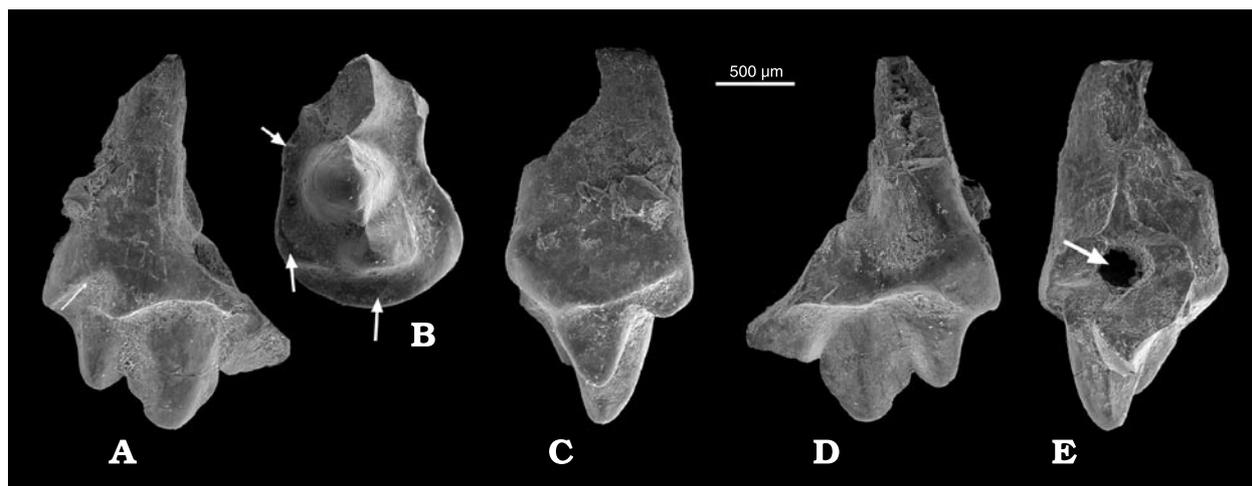


Fig. 2. Gobiconodontidae indet. SEM micrographs of the upper molariform M3 or M4 MPZ 2002/73 (Vallipón, Teruel, Spain, upper Barremian) in lingual (A), occlusal (B), posterior (C), labial (D), and anterior (E) views. White line in A shows the distal cingulum and the direction of tooth wear made possibly by cusp a of the corresponding lower molariform. In B, mesial is up, the arrows on the left show the lingual cingulum, the arrow at the bottom the distal cingulum. In E the arrow shows the pulp cavity.

notches have V-shape and they are less than 25% as deep as the cusps.

The cingulum widens on the lingual side, where it has two small cingular cusps. The proximal cingular cusp forms the mesiolingual corner of the base of cusp A, and the other is distal and at the bottom between cusps A and C, slightly higher and taller than the proximal (Figs. 2A, B, C, 4B).

A thin enamel layer, as observed in the broken part of cusp B (Fig. 4C, D), covers the crown. The effects of acid etching allowed us to study the internal structure of the enamel and dentine. The enamel is prismatic, with the prisms more or less perpendicular to the occlusal surface and the enamel-dentine junction arranged in a similar pattern described as the radial type (Koenigswald and Clemens 1992). The enamel is thin compared with the massive dentine. The radial structure of the dentine can be seen in Fig. 4C. The pulp cavity is visible in the anterior part (Fig. 2E), one can see the thickness of the dentine compared to the cavity, indicating that the molar belongs to an adult individual rather than to a juvenile.

Discussion

Comparisons of MPZ 2002/73 with “symmetrodontans”.

—The anterior upper molariforms of some “symmetrodontans” (Kielan-Jaworowska et al. in press) have a crescent outline and a reduced cingulum (Cassiliano and Clemens 1979). The cusps of the upper molars of tinodontids and kuehneotherids form an obtuse angle, as in MPZ 2002/73 and other gobiconodontids, but the outline of the crown in occlusal view is crescent-shaped instead of rectangular (Crompton and Jenkins 1967). In the derived spalacotheriid “symmetrodontans” (i.e., *Spalacotherium henkeli* Krebs, 1985 from the Hauterivian–Barremian transition in Spain),

the central cusp or paracone is higher and has a more lingual position in MPZ 2002/73 (Figs. 2, 3) than the anterior and posterior ones.

Comparisons of MPZ 2002/73 with eutriconodontans.—The order Eutriconodonta includes four families: “Amphilestidae”, Gobiconodontidae, Triconodontidae, and the *incertae sedis* family that comprises the genus *Jeholodens* (Kielan-Jaworowska et al. in press).

The MPZ 2002/73 differs from Triconodontidae because the main cusps in triconodontids are like conical pilasters, separated by grooves below the notches. The notches in the gobiconodontid from Vallipón are shallower. Typical traits of triconodontids are the distal inclination of the cusps that differ from the erect cusps of the MPZ 2002/73. Also, Triconodontidae molariforms differ from MPZ 2002/73, as well as from other Gobiconodontidae by their broad anterior aspect, the slope at the labial side and the nearly vertical lingual wall (Fig. 2C, E). On the other hand, the Amphilestidae kidney-shaped upper molariforms in occlusal view (Simpson 1925a, b; Prasad and Manhas 2002), differ from the more

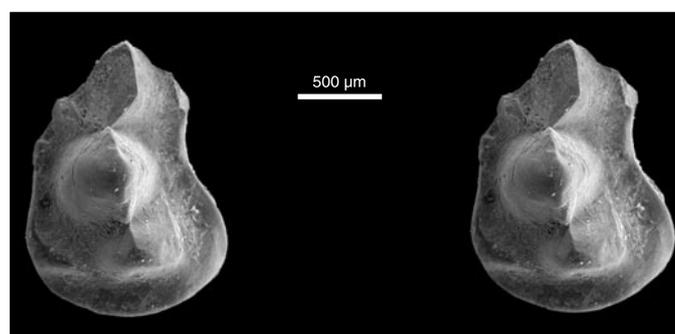


Fig. 3. Gobiconodontidae indet. Stereo SEM micrographs of the occlusal view of the upper molariform M3 or M4, MPZ 2002/73 (Vallipón, Teruel, Spain, upper Barremian). The mesial side is up.

Table 1. Teeth measurements of gobiconodontids based on the literature and this study (L, anteroposterior length; Wm, mesial width; Wd, distal width; H, height; (es), estimated, the letters Mx and D at the beginning of the label indicate maxilla or dentary, otherwise it is an isolated tooth; Va, Vallipón, Artoles Formation, Maestrazgo Basin, Teruel, Spain. upper Barremian; Osh, Oshih, Mongolia. Rougier et al. 2001; Kh, Khoboor Beds, Khoboor, Gobi desert, Mongolia. Kielan-Jaworowska and Dashzeveg 1998. MCZ: Cloverly formation, Montana, USA. Jenkins and Schaff 1988.

| Species | Element | Locality | L | Wm | Wd | H |
|-------------------------------|---------|--------------------|--------|------|------|------|
| Gobiconodontidae indet. | M3, 4 | Va MPZ 2002/73 | 1,67 | 1,13 | | |
| <i>Gobiconodon hopsoni</i> | M4 | Mx Osh PSS-MAE 140 | 5,2 | | | |
| | M5 | Mx Osh PSS-MAE 140 | 6 (es) | 4,1 | | |
| <i>Gobiconodon</i> sp. | p3 | D Osh PSS-MAE 137 | 1.25 | | | 2.54 |
| | p4 | D Osh PSS-MAE 137 | 1 (es) | | | 0.6 |
| | m1 | D Osh PSS-MAE 137 | 1.83 | | | |
| | m4 | D Osh PSS-MAE 138 | 2.57 | | | |
| | m5 | D Osh PSS-MAE 138 | 2.28 | | | |
| <i>Gobiconodon borissiaki</i> | M2 | Mx Kh PSS10-15b | 2.6 | 1.63 | | |
| | M3 | Mx Kh PSS10-15b | 2 | 1.7 | | |
| | M4 | Mx Kh PSS10-15b | 2.3 | 2 | | |
| | M5 | Mx Kh PSS10-15b | 1.8 | 1.8 | 1.4 | |
| | m1 | D Kh PSS10-15a | 2.6 | | 1.35 | |
| | m2 | D Kh PSS10-15a | 2.8 | 1.5 | | |
| | m1 | Kh PSS10-15 | 2.4 | 1.2 | | |
| <i>Gobiconodon hoburensis</i> | M1 | Mx Kh PSS10-37a | 1.6 | 0.7 | | |
| | M3 | Mx Kh PSS10-37b | 1.2 | 1.0 | | |
| | M4 | Mx Kh PSS10-37b | 1.3 | 1.2 | | |
| | M5 | Mx Kh PSS10-37b | 1.25 | 0.9 | | |
| | m1 | D Kh PSS10-37c | 1.66 | 0.8 | | |
| | m2 | D Kh PSS10-37c | 1.86 | 0.9 | | |
| | m3 | D Kh PSS10-37c | 1.7 | 0.95 | | |
| | m4 | D Kh PSS10-37c | 1.77 | 0.8 | | |
| | m5 | D Kh PSS10-37c | 1.33 | 0.6 | | |
| <i>Gobiconodon ostromi</i> | i | D MCZ 19860 | 3.30 | 2.80 | | 7.20 |
| | c | D MCZ 19860 | 2.15 | 1.90 | | 3.30 |
| | p1 | D MCZ 19860 | 2.05 | | | |
| | p2 | D MCZ 19860 | 2.45 | | | |
| | P3 | D MCZ 19860 | 2.60 | | | |
| | m1 | D MCZ 19860 | 4.25 | | | |
| | m2 | D MCZ 19860 | 4.75e | | | |

rectangular shape of MPZ 2002/73. The cingulum of gobiconodontids is usually higher than in *Jeholodens*.

Comparisons with Gobiconodontidae species.—As currently recognised (Kielan-Jaworowska et al. in press), Gobiconodontidae comprises the described taxa: *Gobiconodon hoburensis* (Trofimov, 1978) (= *Guchinodon khovburensis*), *Gobiconodon borissiaki* Trofimov, 1978, *Gobiconodon ostromi* Jenkins and Schaff, 1988, *Gobiconodon hopsoni* Rougier, Novacek, McKenna, and Wible, 2001, *Hangjinia chovi* Godefroit and Guo, 1999, and *Repenomamus robustus* Li et al., 2001. The inclusion of MPZ 2002/73 in the Gobi-

conodontidae is based on its “figure 8”-shaped outline, which is considered here as a synapomorphy of gobiconodontids. The wear facet development of this specimen fits well with the reconstructed occlusion pattern for *Gobiconodon*, according to Kielan-Jaworowska and Dashzeveg (1998). The MPZ 2002/73 shares with other gobiconodontid specimens a rectangular to 8-shaped outline, a well-developed and wide lingual cingulum, the occlusion pattern and the prismatic enamel (Fig. 4D and Table 1).

Size.—MPZ 2002/73 is one of the smallest Gobiconodontidae, five to six times smaller than *Gobiconodon ostromi* and

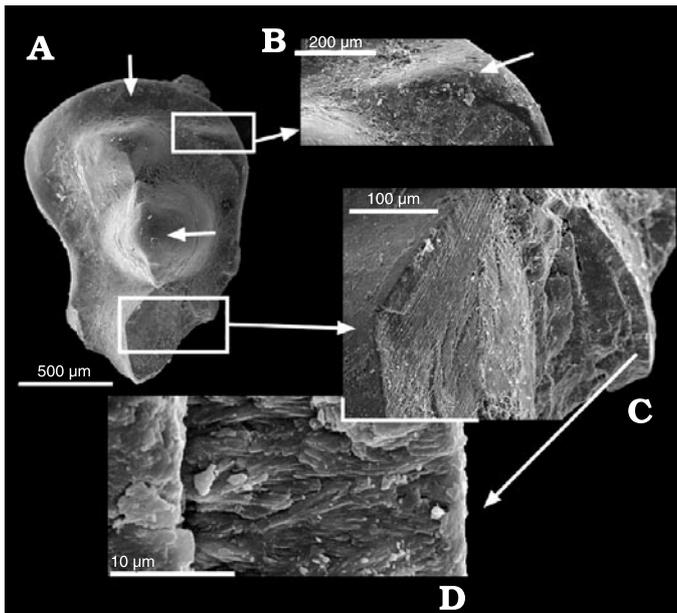


Fig. 4. Gobiconodontidae indet. SEM micrographs of the distal cingulum and the enamel at the occlusal view of the broken cusp B of the upper molariform M3, 4 MPZ 2002/73 (Vallipón, Teruel, Spain, upper Barremian) in occlusal view, mesial side is down (A), detail of distal cingular cuspule (B), dentine layers at the anterior broken part of the tooth and enamel cover detailed in D (C), a detail of the enamel ultrastructure showing the radial type of the enamel prisms (D).

G. hopsoni, intermediate in size between *G. hoburensis* and *G. borissiaki* (Table 1).

Cusps arrangement.—The three main cusps of the upper molars of *Gobiconodon* are arranged in a wide obtuse angle as in MPZ 2002/73. The difference in size among cusps A, B, and C is less dramatic than in the posterior molariforms of other gobiconodontids.

Cingulum.—In general, the cingulum of *Gobiconodon* upper molariforms is almost complete. In *G. borissiaki* it is prominent at the corners and reduced at the middle of the tooth. Below cusp A, the labial cingulum has minute cuspules (Fig. 2A, B). On the other hand, the morphology of *G. hoburensis* is similar except for the narrower distal cingulum without cuspules (Kielan-Jaworowska and Dashzeveg 1998). The lingual cingulum of *G. ostromi* is more expanded than the labial and both sides have small cuspules (specimen MCZ 19860; Jenkins and Schaff 1988). The molariform from Vallipón has only two lingual cuspules at the proximal and distal side of cusp A. These cingular cusps are at different positions than E and F cusps of *G. borissiaki* molariforms (Kielan-Jaworowska and Dashzeveg 1998). The *G. ostromi* lingual cingulum also has cuspules but they are more numerous and relatively smaller (Jenkins and Schaff 1988).

Outline.—The outline of the molariform MPZ 2002/73 is less rectangular than the shape of *Gobiconodon hoburensis*, *G. borissiaki*, and *G. ostromi* and similar to that in *G.*

hopsoni. The main difference is that the anterior part is slightly narrower than the posterior except the M3 of *G. hoburensis* where the mesial half is slightly narrower than the distal part.

Occlusion.—MPZ 2002/73 has a large wear facet on the distal cingulum that appears to be similar to that in *G. ostromi*, *G. borissiaki*, and *G. hoburensis*. According to Jenkins and Schaff (1988) and Kielan-Jaworowska and Dashzeveg (1998), the cusp of the lower molariforms may occlude with cusps C and D as indicated by the transverse groove on this part of the tooth. The same transverse groove is present in MPZ 2002/73 (Fig. 2A), which provides evidence of the same occlusion pattern. The wear pattern of *G. borissiaki*, *G. ostromi*, and the tooth from Vallipón provide evidence for a medial translation. The distal wear facet extends across most of the width of the crown and could not have been produced without a labial to lingual displacement of cusp of lower molars as suggested by Jenkins and Schaff (1988) and Kielan-Jaworowska and Dashzeveg (1998).

Enamel and dentine structure.—Enamel prisms are common in other groups of Mesozoic and modern mammals and it is observed in MPZ 2002/73 (Fig. 4D) and other gobiconodontid species, as *G. ostromi* (Wood 1996).

| Formation or locality | | OSHIH | YIXIAN | VALLIPÓN | EJINHORO | CLOVERLY | KHOBOOR | SHESTAKOVO |
|-----------------------|-----------------------------|-------|--------|----------|----------|----------|---------|------------|
| Taxa | <i>Gobiconodon hopsoni</i> | | | | | | | |
| | <i>Gobiconodon</i> sp. | | | | | | | |
| Age | <i>Gobiconodon</i> sp. | | | | | | | |
| | <i>Repenomamus robustus</i> | | | | | | | |
| LOWER CRETACEOUS | Albian | | | | | ■ | ■ | ■ |
| | Aptian | | | | | ■ | ■ | ■ |
| | Barremian | | ■ | | | ■ | | |
| | Hauterivian | ■ | ■ | | | | | |
| | Valanginian | | | ■ | ■ | | | |
| | Berriasian | | | | | ■ | | |
| UPPER JURASSIC | | | | | | | | |

Fig. 5. Stratigraphical distribution of the gobiconodontid record. The age and order of the localities and formations were established basing on Ostrom (1970), Lucas and Estep (1998), Averianov and Skutchas (2000), and Zhou et al. (2003).

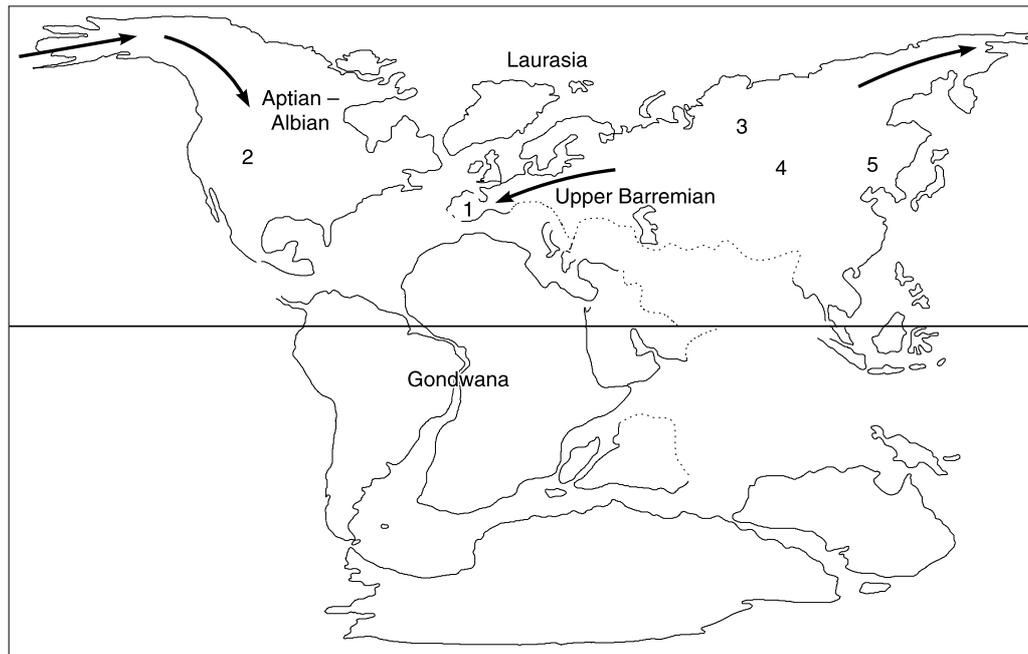


Fig. 6. Palaeogeography of the Hauterivian (*sensu* Smith et al., in Martill and Naish, 2001). Abbreviations: 1, Vallipón (upper Barremian, Spain); 2, Cloverly (Aptian–Albian, USA); 3, Shestakovo (Albian, Siberia); 4, Oshih (Hauterivian, Gobi, China), Ejinhor (Barremian, Gobi, China), Khoboor (Albian, Gobi, Mongolia), Mazongshan (Albian, Gansu, China); 5, Lujiatum Beds, Yixian Formation (Hauterivian, Liaoning, China).

Distribution and palaeogeography

The oldest and largest gobiconodontid is *Gobiconodon hopsoni*. If the species *Repenomamus robustus* is indeed a gobiconodontid, it shares with *G. hopsoni* large size. Together with *Repenomamus*, Wang et al. (2001) figured *Gobiconodon* sp. from the Yixian Formation, without providing stratigraphic details. According to Zhou et al. (2003), the Yixian ranges from the upper Hauterivian to the lower Aptian. A maxilla fragment (PSS-MAE 140) and a dentary (PSS-MAE 139) represent *G. hopsoni* from the Cannoball Member at the Oshih Depression in the Gobi desert, Mongolia (Rougier et al. 2001). Two mandible fragments of a smaller *Gobiconodon* species (PSS-MAE 137) are present at Oshih. The age of Oshih is correlated to the Tsagantsavian (Jerzykiewicz and Russell 1991; Rougier et al. 2001), that comprises a basaltic layer of 130 Ma (Samiolov et al. 1988); therefore *G. hopsoni* is probably Hauterivian (*sensu* Gradstein et al. 1999). *G. ostromi* from Cloverly Formation, Montana (United States) is represented by a partial skeleton of almost 40 cm long mammal without the tail. The age of the Cloverly fauna is Aptian–Albian (Ostrom 1970). Maschenko and Lopatin (1998) described new gobiconodontids from the Early Cretaceous site of Shestakovo (Western Siberia, Russia) in the Ilek Formation dated as Aptian–Albian. Shestakovo yields the first Mesozoic mammal of Siberia, classified as *G. borissiaki*. Its vertebrate assemblage is comparable to that of Khoboor, suggesting a similar age. Thus, the youngest gobiconodontid records are the species *G. borissiaki* and *G. hoburensis* from the Albian Shestakovo and Khoboor Beds

(Mongolia), following Averianov and Skutchas (2000). One more Albian locality with gobiconodontids is at the Mazongshan area, Gansu, China (Tang et al., 2001). The gobiconodontid *Hangjinia chowi* found at the Hangjin Qi site (Ejinhor Formation, Inner Mongolia, China) is dated after dinosaurs. They characterise the “*Psittacosaurus* fauna”, widely distributed throughout the Early Cretaceous basins of Central Asia, which implies that the Hangjin gobiconodontid is Valanginian–Albian (Godefroit and Guo 1998). *Gobiconodon* has been also found at the Mussentuchit Member of the Cedar Mountain Formation in Utah (Albian, Carpenter et al. 2002), at the Khamryn-Us, Dzunbain Formation (Albian, Mongolia, Averianov and Skutschas, 2000), and a Gobiconodontidae indet. at Xinmimbao (Tang et al. 2001).

In a recent summary of Early Cretaceous mammals from central Asia, Averianov and Skutchas (2000) re-evaluated the stratigraphic position of some localities yielding *Gobiconodon*. From bottom to top the localities Ejinhor, Khoboor and Shestakovo range from the Barremian to the Albian (Fig. 5). Note that the chronostratigraphy of the Lower Cretaceous is still a matter of discussion. Therefore, Oshih can also be Valanginian or Barremian in age (*sensu* Gradstein et al. 1999).

Palaeogeographic implications

The gobiconodontid record summarised above ranges from the Hauterivian to the Albian in the Laurasian supercontinent (Figs. 5, 6). It seems probable that gobiconodontids were

more diverse during the Albian. This may suggest either that the family reached its peak diversity at this time or that the Albian vertebrate localities are better known. At the moment there is no Late Cretaceous record of the gobiconodontid family, indicating they probably went extinct at the end of the Early Cretaceous.

The wide geographical distribution and the first record in the Hauterivian of Oshih and probably in the Yixian Formation suggests that Gobiconodontidae originated and diverged in the Laurasian supercontinent, probably from what is now Central and East Asia. The gobiconodontids may have had a ghost lineage extending earlier than their current available fossil record given the large size of the earlier species and their phylogenetic relationships. European origin seems less probable because the Jurassic and Early Cretaceous vertebrate record is relatively rich in mammal fossil localities in Europe and no gobiconodontids have been reported there (Clemens and Lees 1971; Krebs 1985; Kielan-Jaworowska and Ensom 1994; Canudo and Cuenca-Bescós 1996).

The biogeographic and biostratigraphic distribution of the Gobiconodontidae seems to reflect at least two dispersion events originating from Central Asia. The gobiconodontids eventually used the different connections in Laurasia during the early Cretaceous, which followed other vertebrate groups such as dinosaurs. Gobiconodontids probably migrated to Europe during the Late Barremian, within an event that coincided with the iguanodontid migration from Europe to Mongolia during the Barremian with shared species in Europe and Mongolia (Jerzykiewicz and Russell 1991; Norman 1998). By the Aptian–Albian, Central Asia came into contact with North America to form a new Asiamerican province (Le Loeuff 1997), with dinosaur migrations (Russell 1993). The presence of *Gobiconodon ostromi* of the Cloverly Formation in the western North America suggests that some mammals followed the same route as dinosaurs.

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