First Cenomanian dinosaur from Central Europe (Czech Republic)

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We describe the first dinosaur skeletal remains found in the Czech Republic, consisting of one complete femur and indeterminable bone fragments. They were recovered from the upper Cenomanian near-shore marine sediments deposited on the slopes of an ancient archipelago, several kilometres north of the larger Rhenish-Bohemian Island that was situated in what is now the middle of Europe. Sediments yielding dinosaur remains are of late Cenomanian age, *Inoceramus pictus–I. pictus bohemicus* inoceramid zone of the local lithostratigraphic unit, the Peruc-Korycany Formation. These are the first uncontested dinosaurian fossils reported from this formation and also the first Cenomanian dinosaur record in Central Europe. They document a small ornithopod belonging to an iguanodontid species comparable with similar Late Cretaceous European forms. The herbivorous dinosaur lived among a vegetation transitional between salt marsh flora, with abundant halophytic conifer *Frenelopsis alata*; and an alluvial plain assemblage dominated by lauroid angiosperms.

Key words: Dinosauria, Iguanodontidae, palaeoenvironment, vegetation, Cenomanian, Bohemian Cretaceous Basin, Czech Republic, Europe.

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Introduction

Reptile remains are very rare in the Bohemian Cretaceous Basin (BCB). All were critically revised by Ekrt et al. (2001). Hitherto, only remains of four turtles, a partial pterosaur skeleton, some reptilian bones doubtfully referred to *Iguanodon*, a problematic lizard-like skeleton and several plesiosaurid and/or mosasaurid remains (see below) have been reported from the BCB. Reuss (1855) described isolated marine reptile teeth from Bílá Hora (lower Turonian) as a then-new genus and species *Aptychodon cretaceus*, and Fritsch (1878) reported additional marine reptile teeth and bones from the same locality, identified as *Polyptychodon interruptus* Owen, 1841. Other records of this species were reported later from Zámostí near Mladá Boleslav. From abandoned quarries near Hudcov and Lahošť (NW Bohemia), late Turonian plesiosaur phalanges were attributed to *Plesiosaurus*? sp. cf. *P. bernardi* (Owen, 1850). Fritsch and Bayer (1905) later revised this identification and favoured a less precise nomenclature, referring the teeth to Mosasauridae rather than to Plesiosauria. Plesiosaur bones from Lysá nad Labem were described as *Cimoliasaurus* (*Plesiosaurus*) *lissaensis* (Fritsch and Bayer, 1905), and Fritsch (1906) recorded marine reptile remains (described as *Cimoliasaurus teplicensis* and *C. vicinus*, respectively) from Hudcov and Chrást near Mladá Boleslav. Additional finds from Hudcov were presented by Fritsch (1910). Bayer (1914) reviewed all reptile discoveries from the BCB and synonymised plesiosaurid genera (also including Fritsch's *Iserosaurus* and *Hunosaurus*) with *Cimoliasaurus* (Leidy, 1851). Late Turonian plesiosaur remains were reported from Třebovice near Česká Třebová. Also, an extraordinarily well preserved mosasaurid jaw was found in Dolní Újezd near Litomyšl. The large marine reptilian bone assemblage is dominated by plesiosaurs; it is stored in the National Museum in Prague and in the Regional Museum of Teplice (Ekrt et. al. 2001).

Fritsch's (Fritsch and Bayer 1905) "*Iguanodon exogiranus*" represents a poorly preserved undeterminable fragment of a hollow bone, which could also belong to a bird (a group not yet recorded from the BCB) or a pterosaur (recorded in the BCB). No dinosaur remains were identified during this last revision (Ekrt et. al. 2001).

Dinosaur remains have recently been recovered from the locality of Mezholezy (between the towns of Kutná Hora and Čáslav). They were discovered in 2003 by one of us (Michal Moučka) during a field visit to an abandoned quarry north of the village of Nová Lhota. The near-shore marine sediments exposed in this area are of late Cenomanian age (see below). They represent typical beach sandy deposits, intercalated with horizons containing oysters and rudists (partly allochtonous). Regionally, these deposits formed on the southern slopes of an ancient archipelago (Fig. 1; Malkovský et al. 1974; Čech and Valečka 1991).

Institutional abbreviation.—IGP, Institute of Geology and Palaeontology, Faculty of Science, Charles University, Prague.

Geological setting

Cretaceous sedimentation in the BCB started in the early Cenomanian and continued during the middle Cenomanian as a typical characteristic depositional regression sequence (Peruc Beds of the local stratigraphic column; Malkovský et al. 1974). Fluvial sedimentation with a very coarse matrix prevails; however, fine grained sandstones, siltstones and clayey siltstones are also present. Marine transgression started in the middle Cenomanian (see Fig. 2). The typical late Cenomanian marine facies are predominantly sandstones. In addition, organodetritic limestones surround islands and shallow marine slopes, with silts predominant in the deeper basin (Korycany Beds of the local stratigraphic column). The boundary between the Peruc and the Korycany Beds is irregular, with paralic development of several marine incursions into terrestrial areas. During this process, erosion, material transport, and redeposition of sediment were frequent. Therefore, we use the term Peruc-Korycany Formation to characterize the mixed lithologies deposited in this area (Houša 1987). Some marine deposits of the Korycany Beds and continental sediments of the Peruc Beds are considered to be isochronous (Houša 1987). Thus, the dinosaur remains can be described as originating from the near-shore marine sediments of the Peruc-Korycany Formation.

The principal land area in the Central European Basin during the Cenomanian was the large Rhenish-Bohemian Island that was situated in the middle of present-day Europe (Diedrich 2001). Several kilometres to the north, the Cenomanian topographic islands are preserved in the vicinity of Kolín, Kutná Hora, and Čáslav, where it is called the Kutná Hora Crystalinite in the local geologic terminology. The late Proterozoic to early Palaeozoic metamorphic rocks of these Cenomanian islands are composed mostly of para-gneisses and migmatites. The axial trend of Kutná Hora Island , as well as smaller nearby islands, is oriented in a NW-SE direction (Klein 1962; Malkovský et al. 1974), which is parallel to the axis of the main basin as well. The dinosaur bones were preserved in a channel between two of the larger islands (see Fig. 1) with a very irregular shoreline. This area is also located between the archipelago (to the north) and the centre of the Rhenish-Bohemian Island (to the south).

Sediments deposited on the shore of the archipelago are predominantly fine-grained sandstones with larger quartzitic and gneisses clasts that were washed from the Kutná Hora Cristalinite elevations. They are intercalated with organodetritic sandy limestones. Klein (1962) supposed these to be a threshold facies (Schwellenfacies) and Houša (1987) interpreted them as fossil beaches with allochtonous material. The contact between the sandstones and limestones is sharp with a typical hardground fabric. However, tempestites were also reported from here. Biodetrital sandy limestones are composed mainly of the large oyster *Rhynchostreon suborbiculatum* (Lamarck, 1801) and the rudist bivalve *Radiolites sanctae-barbarae* Počta, 1889. The bivalve fauna is locally rich and abundant. Sandy limestones overlie the fine grained beach sandstones that yield dinosaur bones. Quartzitic and gneissic clasts are distributed infrequently in the fine-grained sandstone. The marine fauna of this facies is poorly preserved. The preservation of the dinosaur bone is relatively good, suggesting a very rapid burial combined with stable diagenetic processes. Traces of gnawing (apparently by sharks) are preserved on the surface of the bone.

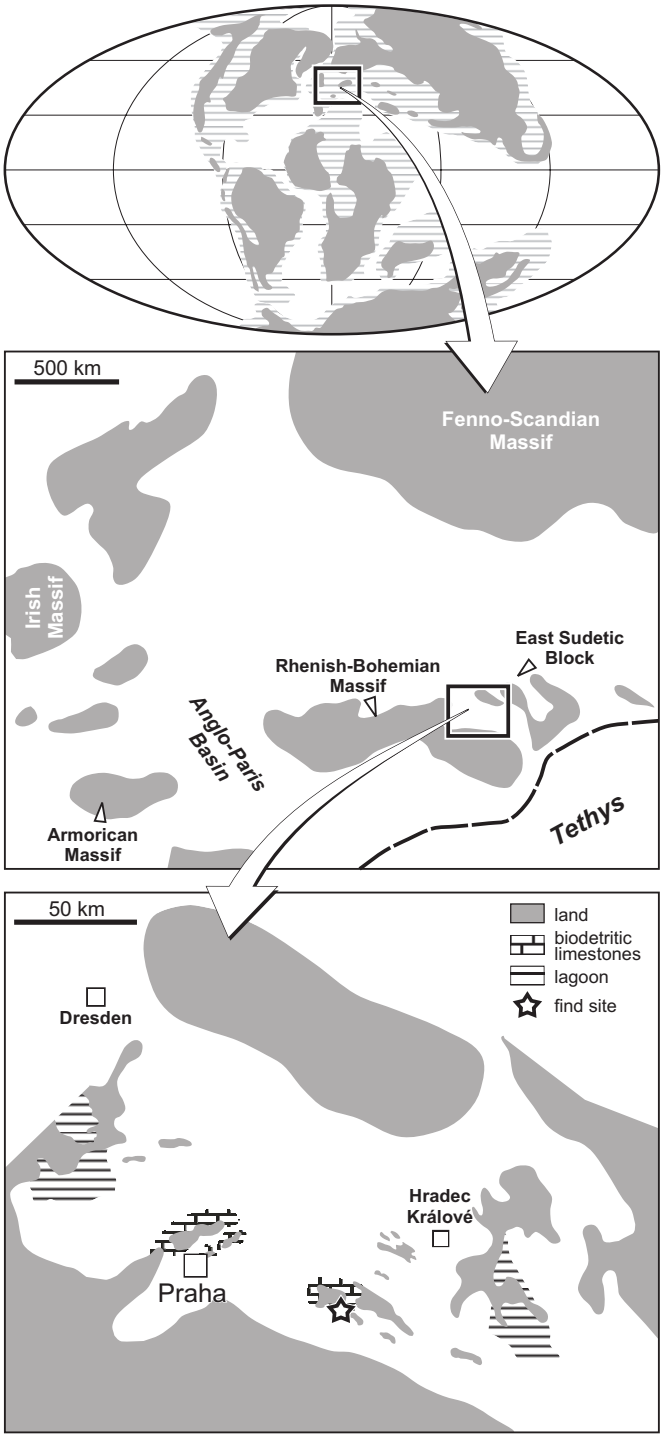

Fig. 1. Late Cenomanian Central European palaeogeography. Modified after Malkovský et al. (1974), Diedrich (2001), Čech and Valečka (1991).

Stratigraphy

Sediments yielding dinosaur remains are of late Cenomanian age. They represent part of the Peruc-Korycany Formation, middle part of late Cenomanian. Biostratigraphically, this horizon belongs to the *Inoceramus pictus–Inoceramus pictus bohemicus* inoceramid zone (Stanislav Čech, personal communications 2004), and/or, probably to the lower part of *Metoicoceras geslinianum* ammonite zone, below the *Praeactinocamax plenus* belemnite zone. This important belemnite has recently been recorded from overlying organodetritic limestones from Kutná Hora (Košťák, unpublished).

Description

Order Ornithischia Seeley, 1888
Suborder Ornithopoda Marsh, 1881
cf. Iguanodontidae Cope, 1869; gen. et sp. indet.

The left femur of the Iguanodontidae gen. et sp. indet. (IGP MZHLZ/2003/1) is well preserved, without any traces of long transport and redeposition (Fig. 3). However, on its surface, bite marks can be observed (Fig. 4). Given the marine/lagoonal palaeoenvironmental context, sharks of different size can be considered as potential scavengers. The bone was found *in situ*, in a fossiliferous layer. It was fractured and sligtly dislocated in several parts and subsequently reassembled by the discoverer. Originally the distal end of the bone was enclosed in a limonitic concretion, which enabled detailed preservation.

The measurements of the femur: The total length (proximally reconstructed) = 400 mm, distal width = 78 mm, distal diameter = 97 mm, depth of the intercondylar groove = 39 mm; middle width of the diaphysis = 48 mm, middle diameter of the diaphysis = 40 mm.

The shaft of the femur is straight in parasagittal plane and anteroposteriorly slightly compressed, showing in the middle section a subrectangular shape. The posterior surface of the shaft is nearly flat, the anterior one is rather rounded. In the anterior and posterior views, the shaft is gently curved in the transverse plane resulting in a concave medial margin.

The proximal end of the femur is crushed and poorly preserved. Only the separated head of the femur and the greater trochanter can be reattached to the shaft. In proximal view, the femoral head and its neck form an angle of 100–110° with the long axis of the shaft. The damaged fragment of the greater trochanter is poorly preserved.

The distal part is transversely oriented, expanded medially to the longitudinal axis. Both laterally compressed distal condyles are oriented nearly in the parasagittal plane, the lateral one extends longer posteriorly, the medial one is shorter. In distal view the lateral condyle is shifted posteriorly, the medial one laterally. The anterior view of the distal part shows in the middle a narrow sharp groove oriented at an angle 15° to the shaft. In the posterior view it continues distally into a relatively broader and deeper intercondylar groove oriented at an angle of 20° to the shaft. Approximately above the middle of the posteromedial portion of the shaft, the fourth trochanter forms a narrow crest.

The specimen shows immature bone microstucture in the spongy inner zone, without secondary Haversian osteons, and lamellar mature bone histology with Haversian system in the outer layer.

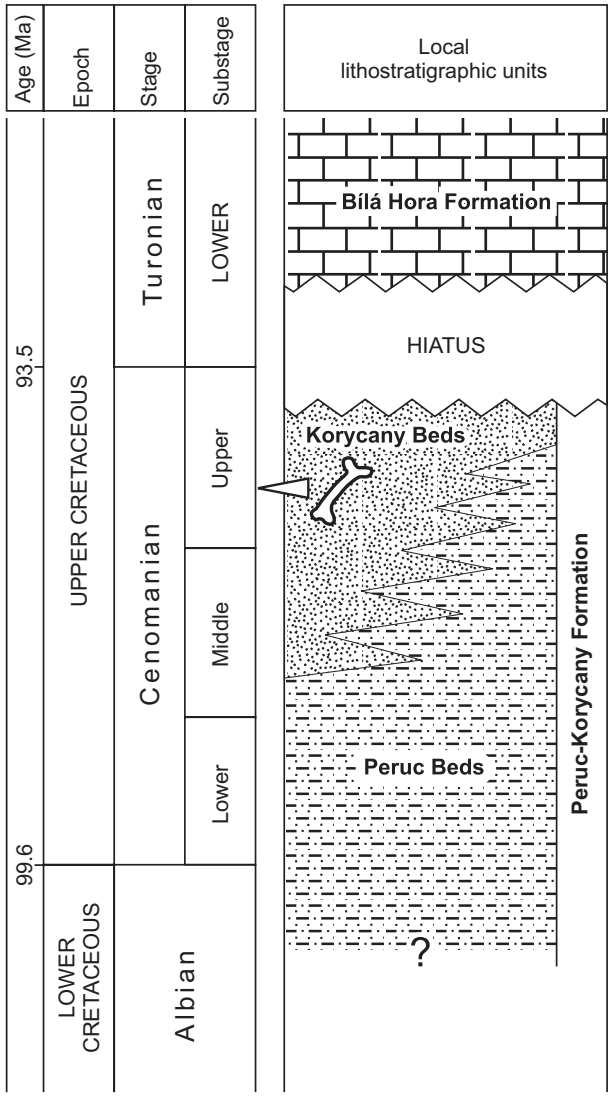

Fig. 2. The stratigraphic position of the dinosaur remains in the Bohemian Cretaceous Basin. Time scale after Gradstein and Ogg (2004).

Morphological comparison and taxonomic discussion

The iguanodontids, like other dinosaurs, are almost unknown from the late Cenomanian deposits in Europe. Thus, the comparison with other iguanodontid species is almost impossible

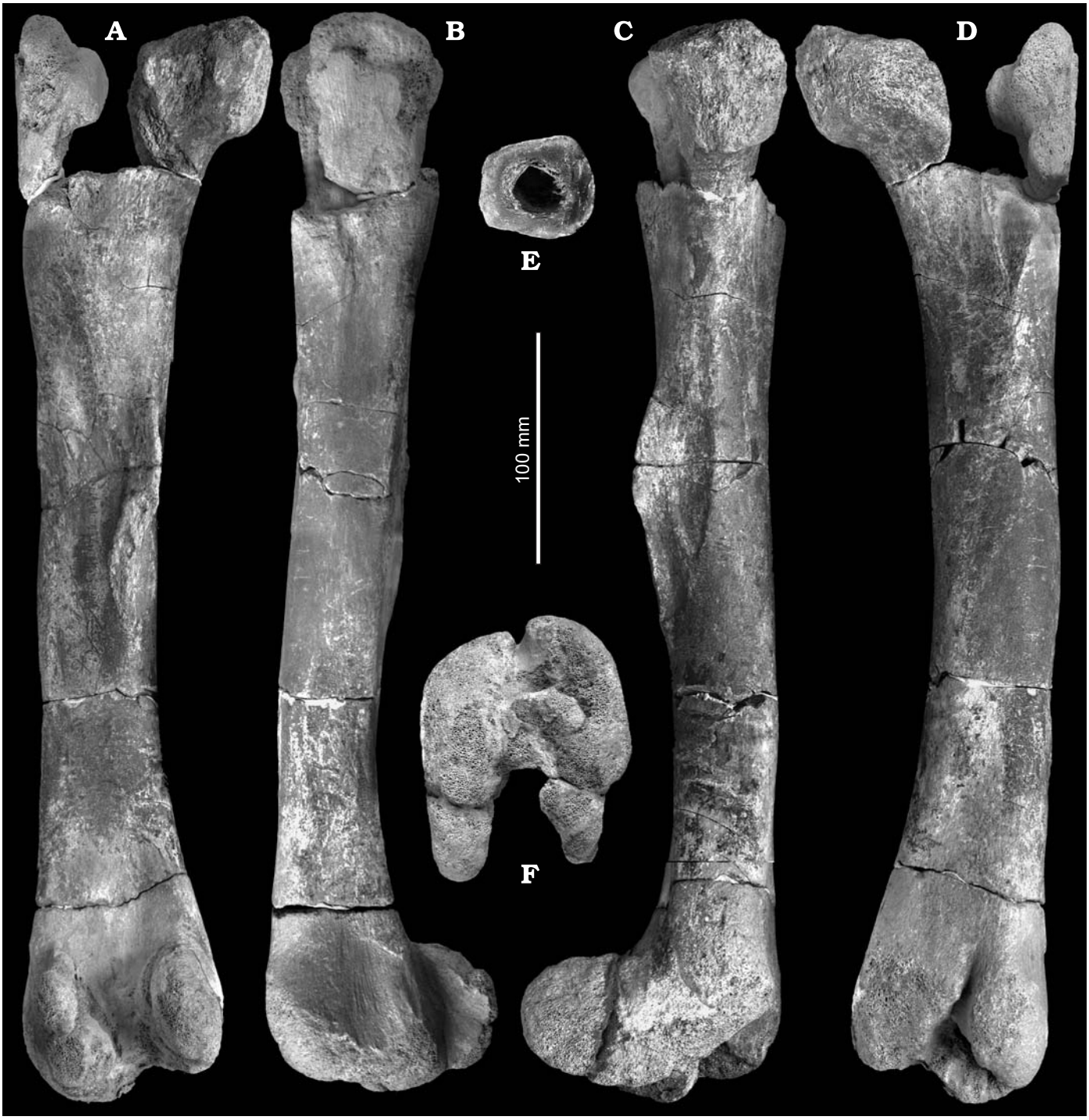

Fig. 3. Left femur of cf. Iguanodontidae gen. et sp. indet. (Ornithischia, Ornithopoda), IGP MZHLZ/2003/1, in posterior (**A**), lateral (**B**), medial (**C**), anterior (**D**), and distal (**F**) views, with transverse cross-section through the femoral shaft (**E**).

and quite excessive due to a very long stratigraphic gap. Size-wise, the closest species seem to be Aptian iguanodontids from Romania (probably also insular)—i.e., *Vectisaurus* and *Iguanodon* (Grigorescu 2003). Morphologically, the femur of the Czech iguanodontid also shows marked similarities to Early Cretaceous iguanodontids (Norman 2004) rather than to Late Cretaceous European (French) iguanodontids (Alain and Suberbiola 2003). However, the length of the reported femur is only about 40 percent that of an adult *I. bernissartensis* Boulenger, 1881 (see, e.g., Norman 2004).

The femur shows primitive character of basal Iguanodontia (Weishampel and Heinrich 1991; Norman 2004). Intercondylar (extensor) groove is deep and open in a cranial part, the distal condyles moderately expand only caudally, the distal half of the shaft is straight and the angle between the shaft and the neck of femur does not exceed 100°. The

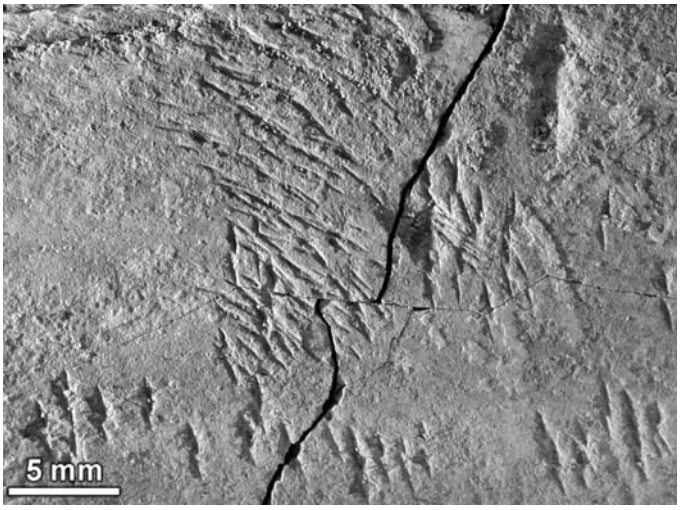

Fig. 4. Details of the surface of the left femur of cf. Iguanodontidae gen. et sp. indet. showing bite marks probably caused by sharks.

fourth trochanter is not complete, but it probably was of a pendent form (Norman 2004). Derived forms of iguanodontids, e.g., *Rhabdodon* from the upper Campanian of France (Allain and Suberbiola 2003) has the distal shaft of the femur curved caudally, crested fourth trochanter, and the angle between the femur shaft and neck exceeds 100°.

The stratigraphically closest iguanodontid has been described by Néraudeau et al. (2003) from the early Cenomanian deposits of the Fouras Peninsula (France). However, only the ulna and tibia are known.

Note on the mid-European Cenomanian vegetation

The vegetation is reconstructed based on our knowledge of the flora from the Peruc Beds found at two nearby localities, Horoušany and Brník (located for about 20 km WSW from the dinosaur site), of approximately the same age. Reconstructed Cenomanian vegetation of coastal areas near estuaries of the Bohemian archipelago includes a mosaic of habitats combining salt marsh, back swamp, and alluvial plain environments. By analogy to recent seashore terrestrial plant communities, the Cenomanian vegetation was arranged in zones, driven by concentrations of salt and ground water level (Uličný et al. 1997; Nguyen-Tu et al. 2002). The salt marshes are characterised by high concentrations of salt and a high water table. They hosted a low diversity plant community characterised by the shrubby conifer *Frenelopsis alata* (K. Feistmantel, 1881) Knobloch, 1971; a ginkgoalean plant with leaves, *Eretmophyllum obtusum* (Velenovský, 1885) Kvaček, 1999a; the endemic dwarf gymnosperm *Dammarites albens* Presl in Sternberg, 1838; and possibly a gnetalean plant *Pseudoasterophyllites cretaceus* O. Feistmantel ex Velenovský, 1887. The back-swamp plant community grew in areas with a permanent high water table having no or low influence of salt water (Nguyen-Tu et al. 2002). It is characterised by the cupressoid conifers *Cunninghamites lignitum* (Sternberg, 1825) Kvaček, 1999b, *Quasisequoia crispa* (Velenovský, 1885) Kvaček, 1999b, *Sequoia heterophylla* Velenovský, 1885, among others. The plant community on the alluvial plain grew under conditions of lower water table and no salt-water influence. It occurred in inland areas of estuaries and consisted mostly of angiosperms, e.g., *Platanus laevis* (Velenovský, 1882) Velenovský, 1889, *Myrtophyllum geinitzii* Heer 1869, and *Debeya coriacea* (Velenovský, 1884) Knobloch, 1964.

The most suitable forage for the herbivorous dinosaur in the near-shore areas could have been the shrubby conifer *Frenelopsis alata* (K. Feistmantel, 1881) Knobloch, 1971 (Kvaček 2000), which usually formed monodominant stands in salt marshes occurring in sea-influenced areas of estuaries (Fig. 1). The conifer had unusual segmented needle-less twigs. Each segment consisted of three fused leaves. Its twigs were soft and juicy, similar to the modern halophytic angiosperm *Salicornia*.

Conclusions

The isolated find of the medium-sized ornithischian femur in the Upper Cretaceous (upper Cenomanian) of Mezholezy, Czech Republic, is the first record of a smaller sized (?juvenile–subadult) dinosaur in Central Europe. The fossil alone does not allow more accurate determination. The morphology of the femur supports its attribution to a species of the iguanodontian clade. The fragmentary nature of the record does not allow more precise identification. We designate it here as small (possibly insular) cf. Iguanodontidae gen. et sp. indet. This could be supported by fact that the bone microstructure shows the lamellar histology of a mature bone with Haversian system. Thus, the bone probably belonged to an adult rather than a juvenile animal. A similar form (based on the femur morphology) could be represented elsewhere in the Cretaceous iguanodontian record of Western and Eastern Europe (e.g., from the Lower and Upper Cretaceous of Romania—Codrea et al. 2002; Grigorescu 2003, and from the Upper Cretaceous of northern Spain, López-Martinez 2001). Vegetation of the presumed dinosaur palaeoenvironment is reconstructed as a mixture of salt marsh dominated by the halophytic conifer *Frenelopsis alata* and vegetation of the alluvial plain dominated by lauroid angiosperms.

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