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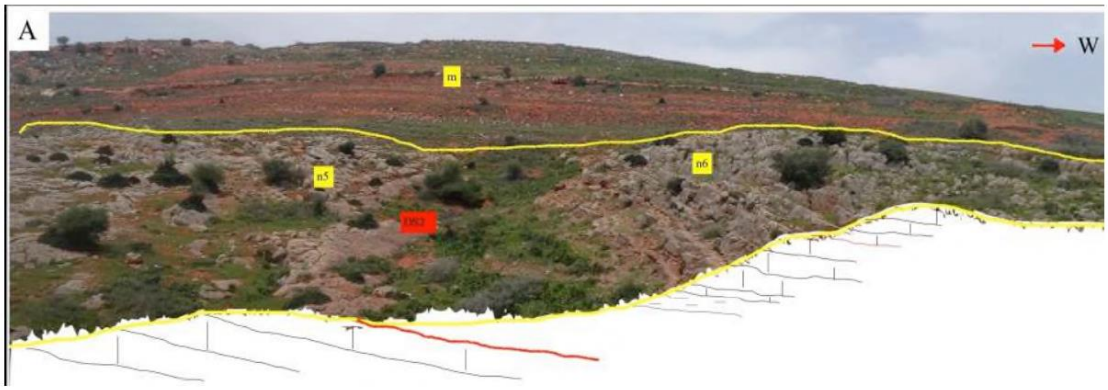

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ORNITHOPOD DINOSAUR BONE REMAINS FROM THE EARLY CRETACEOUS OF THE LUSITANIAN BASIN, PORTUGAL)

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Abstract

Early Cretaceous ornithopod fossil bones from Portugal are reported only from the Papo-Seco Formation (lower Barremian) at Cabo Espichel, south of Lisbon. Ornithopod and other vertebrate remains from the Papo-Seco Formation occur in limestones, marls, sandstones and conglomerates in a succession interpreted as deposited in lagoonal and estuarine environments. The study of the ornithopod remains from the Papo-Seco Formation suggests the presence of a large styracosternan-like iguanodontian, and they are provisionally assigned to Ornithopoda indet., Iguanodontia indet. and cf. Styracosterna indet.. In this study, we evaluate the ornithopod fossils from the Papo-Seco Formation at Cabo Espichel (Portugal), including a review of previously published data from Boca do Chapim and the description of new fossils from three sites: Boca do Chapim, Praia do Areia do Mastro and Praia do Guincho.

Key words: Barremian, dinosaurs, Iguanodontia, Styracosterna, Cabo Espichel.

Introduction

Vertebrate fossils from the Lower Cretaceous at Cabo Espichel are known since the 19th century. Fossil of dinosaurs and crocodiles were the first remains reported from the Papo-Seco Formation (Fig. 1). They were discovered at the Boca do Chapim site (Sauvage, 1897-1898). Subsequently, turtle, crocodile and dinosaur fossils have been described from this site. Among dinosaurs, theropod teeth, initially referred to *Megalosaurus superbus* (Sauvage 1897-1898; Lapparent and Zbyszewski 1957), were later considered as Carnosauria *incertae sedis,* by Galton (1994) or as Theropoda indet. by Ruiz-Omeñaca and Canudo (2003). Jaw fragments bearing teeth from Boca do Chapim were originally regarded as crocodilian and identified as *Suchosaurus girardi* (Sauvage 1897-1898), and later referred to the spinosaurid theropod *Baryonyx* (Buffetaut 2007). Mateus *et al.* (2011) described cranial and postcranial remains from Praia das Aguncheiras (= Praia do Guincho; see Figueiredo *et al.* 2015) and attributed them to *Baryonyx walkeri*. These materials were further studied and described as belonging to the new species *Iberospinus natarioi* (Mateus and Estraviz-López, 2022). At Praia do Areia do Mastro site, in the Boca do Chapim Formation (the formation above the Papo-Seco Formation), microvertebrate remains were reported by Rodrigues *et al.* (2008). Other vertebrate remains belonging to a diverse fauna of actinopterygians, chelonians, crocodyliforms, pterosaurs, dinosaurs were reported from this site (Figueiredo *et al.*, 2015; 2020).

Sauvage (1897-1898) identified herbivorous dinosaur teeth from Boca do Chapim as the ornithopod *Iguanodon mantelli* and as the sauropod *Pleurocoelus valdensis*. The sauropod teeth have subsequently been referred to *Astrodon valdensis* (Lapparent and Zbyszewski 1957; Galton, 1994) or to Sauropoda indet. (Antunes and Mateus 2003). Ornithopod remains from the Boca do Chapim site (teeth, vertebrae and a fragment of femur), were attributed to *Iguanodon mantelli* by Lapparent and Zbyszewski (1957), later assigned to *Iguanodon* cf. *atherfieldensis* by Crespo (2001) and to *Iguanodon* sp. by Antunes and Mateus (2003). These authors also mentioned one tooth and one deformed vertebral centrum kept in the personal collection of M.T. Antunes, which they attributed to *Iguanodon* sp. (Mateus and Antunes, 2003). This material was referred without description, so we cannot confirm this taxonomic attribution. In recent years, fieldwork carried out by a palaeontological team from the CPGP (Centro Português de Geo-História e Pré-História) identified new fossils from the Papo-Seco Formation. At the Boca do Chapim site, a partial ornithopod skeleton, including postcranial (vertebral and appendicular) remains has been found (Figueiredo, 2010). At the Praia do Areia do Mastro site, a maxillary fragment with teeth and isolated teeth of an *Iguanodon*-like iguanodontians have been reported (Figueiredo et al. 2015). At the Praia do Guincho site it was discovered a prezygapophysis of a vertebra and a natural cast of an ornithopod footprint (Figueiredo *et al.*, 2017, 2022b).

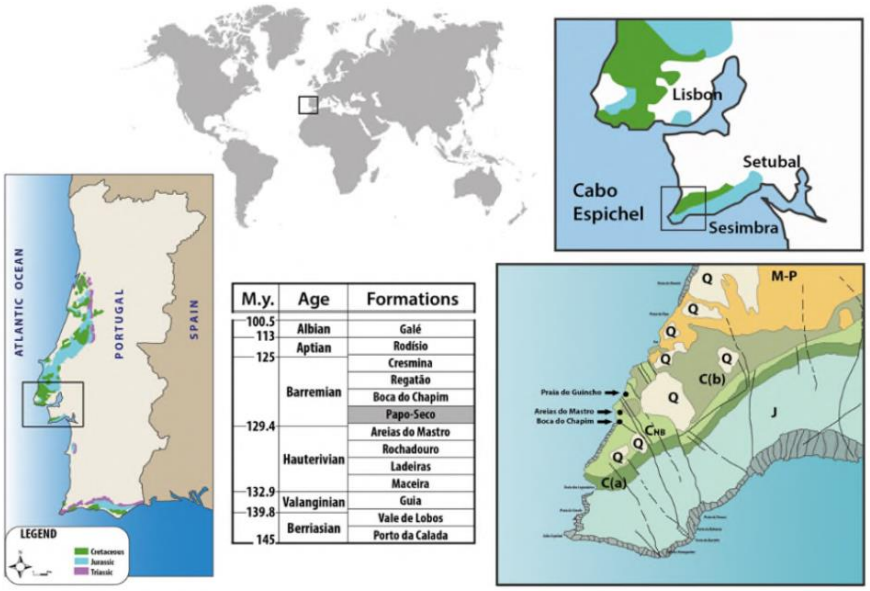

Fig. 1 – Location and geological setting of the studied sites (extracted from Figueiredo et al., 2020). (J – Jurassic; C(a) – lower Berriasian to lower Hauterivian; Chb – lower Hauterivian to lower Barremian; C(b) – upper Barremian to Aptian; M-P – Miocene to lower Pleistocene; Q – middle to upper Pleistocene and Holocene).

Materials and methods

The ornithopods from the Early Cretaceous of Cabo Espichel area were discovered in three paleontological sites: Boca do Chapim, Praia do Areia do Mastro and Praia do Guincho. Most of the remains have been collected from the lower beds of the formation at the base of the coastal cliffs of the Espichel Cape. The material consists of cranial and postcranial. Cranial remains are represented by isolated teeth and a maxillary fragment (Fig. 2).

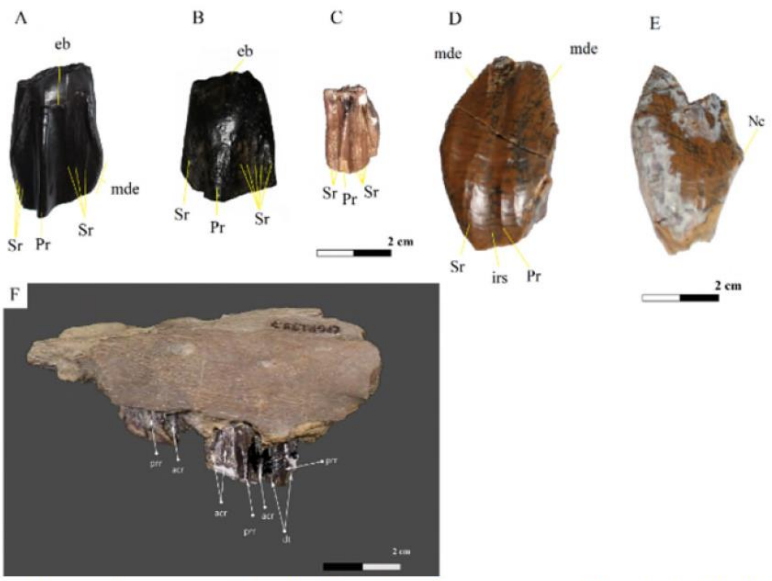

Fig 2. Cranial remains of Iguanodontia indet. from the Papo-Seco Formation: maxillary teeth: MG4744 (A), CPGP.1.18.44 (B) and CPGP.1.01.1 (C); dentary teeth MNHNUL.DIN.002 (E) and MNHNUL.DIN.003 (D). Maxilla fragment CPGP.1.99.7. (F). Abbreviations: d – lingulate denticles; eb – enamel border; irs – inter-ridge surface; mde – marginal denticles; Nc – neck; pr – primary ridge; sr – secondary ridges. Scale: 2 cm

The postcranial elements include vertebral remains, fragmentary limb bone (Fig. 3) and a partial skeleton. The ornithopod remains reported here includes previous specimens and other recently found (1999-2018). Previous

finds were described by Lapparent and Zbyszewski (1957), that are housed at the MG (Museu Geológico) and in the MNHNUL / MUHNAC (Museu Nacional de História Natural da Universidade de Lisboa). New specimens include teeth, a maxillary fragment (Figueiredo et al., 2015) and a partial skeleton with disarticulated vertebral and appendicular remains from Boca do Chapim site (Figueiredo, 2010), one tooth and one vertebra from Praia do Areia do Mastro site, and one vertebral fragment, a prezygapophysis, from Praia do Guincho site. These specimens are housed in the collection of the CPGP. The fossil material was photographed and measured followed by biometric, taxonomic and taphonomic studies, through a comparison and analysis of the main characteristics of the fossils.

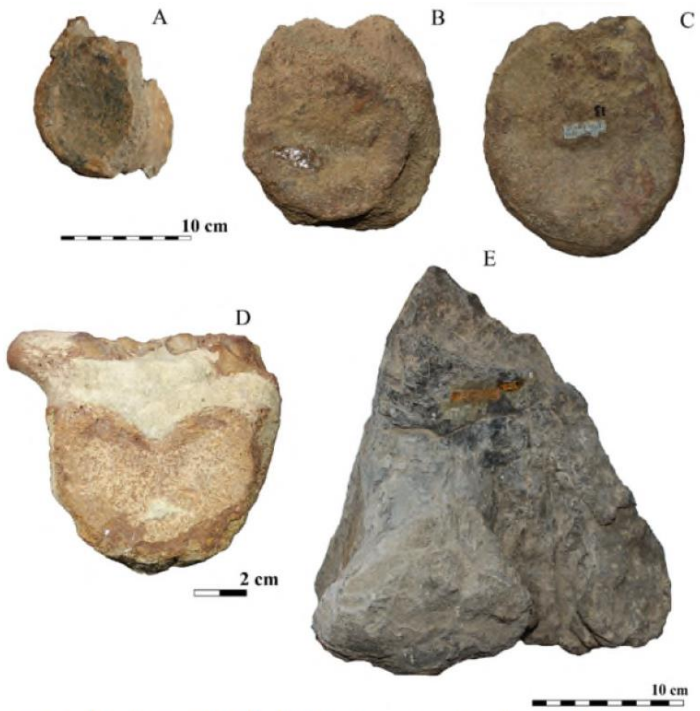

Fig 3. Postcranial remains of Axial and appendicular skeleton remains: A to D - caudal vertebrae of Iguanodontoidea indet, in cranial view.: A - MG4741; B - MG 13.2; C - MG 13.1 D - CPGP.1.14.18. E – distal fragment of a femur of Iguanodontoidea indet. (MG4740), in caudal view. Scales 10 cm (A, B, C and E); 2 cm (D).

Results and discussion

The ornithopods from the Papo-seco Formation at Cabo Espichel (Lusitanian Basin, Portugal) are from several different individuals. The fossils suggest the presence of a large styracosternan-like iguanodontian (Figueiredo et al., 2022b), but they do not allow confirmation of the occurrence of *Iguanodon* (Sauvage, 1897-1898; Lapparent and Zbyszewski, 1957; Crespo, 2001; Antunes and Mateus, 2003) or *Mantellisaurus* (Figueiredo et al., 2015). The recently discovered ornithopod remains from the Papo-Seco Formation are provisionally assigned to Ornithopoda indeterminate, Iguanodontia indeterminate and cf. Styracosterna indeterminate (Figueiredo et al., 2022b). The teeth morphology and the relative size of the remains suggest a probable Styracosterna. The discovery of new ornithopod material increases the record of this group of dinosaurs in the Iberian Early Cretaceous, and more specifically in the lower Barremian of Portugal. Iguanodontians are ornithopod dinosaurs of medium to large size, herbivores and primarily bipedal (Norman 2004). Iguanodontia consists of multiple genera and species, which were typical components of the Early Cretaceous dinosaur faunas, known throughout Europe, especially in Western Europe (e.g., Norman 2004, 2011; Pereda-Suberbiola *et al.* 2012; Verdú 2017; Santos-Cubedo et al., 2021), but also in North America and Asia. Large iguanodontians from the Barremian of Europe are highly diverse and include the styracosternans (i.e. Norman 2011; Ruiz-Omeñaca 2011; Gasulla *et al.* 2015; Fuentes-Vidarte *et al.* 2016; Verdú *et al.* 2017; Lockwood *et al.* 2021). Most of them are represented in the Iberian (Spanish) Barremian sites. Some taxa, such as *Iguanodon* species, are included within the clade Iguanodontoidea, others are considered to be basal styracosternans, basal hadrosauriforms, or even basal hadrosauroids (see phylogenetic hypotheses of Norman 2015; Verdú et al. 2017; Lockwood et al.

2021). Teeth found in the deposits of the Papo Seco Formation are the most informative elements of the ornithopod assemblage. These teeth exhibit common features of Iguanodontia (sensu Norman 2011, 2015). Furthermore, the morphology of the dentary teeth from Boca do Chapim site housed in MNHNUL (MNHNULDIN.002 and tentatively MNHNULDIN.003, Fig. 2 D, E) should be referred to as cf. Styracosterna indet Figueiredo et al., 2022b).

In the Boca do Chapim and Praia do Areia do Mastro sites, tracks belonging to the ichnogenus *Caririchnium* were described by Figueiredo et al. (2022a). This ichnogenus can be assigned to iguanodontian ornithopods; the producers of those tracks may be a basal member of Ankylopollexia or a basal Styracosterna. In the Praia do Guincho site a natural footprint cast of an ornithopod was discovered in a small block of coarse-grained limestone (Figueiredo et al., 2017). The cast was also attributed to a *Caririchnium* (Figueiredo *et al.*, 2022a). The footprints of Areia do Mastro and Papo-Seco formations assigned to the ichnogenus *Caririchnium* complement the evidence of the ornithopod dinosaurs from these formations provided by bone fossil remains.

Conclusion

The outcrops of the Lower Cretaceous Papo Seco Formation have yielded an important set of fossil remains of aquatic, semiaquatic and terrestrial vertebrates. This association, of early Barremian age, includes dinosaurs, crocodyliforms, pterosaurs, turtles and bony fish. Dinosaurs are represented by theropods, sauropods and ornithopods. Most of the ornithopod fossils from the Papo Seco Formation have been collected from the lower beds of the formation at the base of the cliffs. The material consists of cranial and postcranial remains. Several different individuals are represented in the assemblage. The presence of *Iguanodon* and *Mantellisaurus* in the Papo Seco Formation of Portugal cannot be confirmed based on the available material, despite previously suggested in the literature. The ornithopod remains studied here are classified as Ornithopoda indeterminate, Iguanodontia indeterminate and cf. Styracosterna indeterminate.

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