

Upper Jurassic sauropod record in the Lusitanian Basin (Portugal): Geographical and lithostratigraphical distribution

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ABSTRACT

Sauropod remains are relatively abundant in the Upper Jurassic sediments of the Lusitanian Basin. These dinosaurs are recorded in several sub-basins formed during the third rifting episode related to the evolution of the Lusitanian Basin. The Kimmeridgian-Tithonian sedimentary sequence is dominated by siliciclastic deposits, indicating a continental environment. Sauropods are present all along this mainly terrestrial sequence, being recorded in the Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Freixial, and the Bombarral Formations, ranging from the early Kimmeridgian to the late Tithonian. Sauropoda is the most abundant dinosaur group in the Upper Jurassic fossil record of the Lusitanian Basin and is especially well-represented in the Bombarral and Turcifal Sub-basins. Several new specimens, so far unpublished, are reported here. The sauropod fauna identified mainly includes non-neosauropod eusauropods (including turiasaurs), diplodocoids (some specimens with diplodocine affinities), basal macronarians (non-camarasaurids and camarasaurids), and titanosauriforms (some specimens with brachiosaurid affinities). Macronarians, turiasaurs and diplodocoids are generally present along the entire Kimmeridgian-Tithonian continental to transitional deposits of the Lusitanian Basin, but the known fossil record for some more exclusive groups such as camarasaurids, brachiosaurids, and diplodocines, present a more restricted stratigraphic distribution.

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INTRODUCTION

The Upper Jurassic sediments of the Lusitanian Basin (Portugal) are known to have yielded abundant fossil vertebrates, in particular dinosaurs, turtles, and crocodyliforms (e.g., Sauvage, 1897-98; Lapparent and Zbyszewski, 1957; Dantas, 1990; Antunes and Mateus, 2003; Ortega et al., 2009, 2013). The sauropod fossil record is particularly rich in this basin, and several historical references deal with this clade (e.g., Sauvage, 1897-98; Lapparent and Zbyszewski, 1957).

A systematic revision of the Portuguese taxa of the Late Jurassic was recently performed (for *Dinheirosaurus* see Mannion et al., 2012; Tschopp et al., 2015; *Lusotitan* see Mannion et al., 2013; Mocho et al., 2016c; and for *Lourinhasaurus*, see Mocho et al., 2014b). Several new occurrences have also been reported (Antunes and Mateus, 2003; Mateus, 2005; Royo-Torres et al., 2006; Yagüe et al., 2006; Mateus, 2009; Royo-Torres et al., 2009; Ortega et al., 2010; Mannion et al., 2012; Mocho et al., 2012, 2013a, 2013b; Mateus et al., 2014; Mocho et al., 2014a, 2016b, 2017). This new information suggests a more diverse scenario for sauropod fauna during the Late Jurassic of the

Lusitanian Basin than previously considered, with the identification of a clade previously unidentified in this basin, the non-neosauropod eusauropod group Turiasauria. Royo-Torres et al. (2006) suggested the presence of Turiasauria in the Portuguese Upper Jurassic record, and this hypothesis was subsequently corroborated by the presence of new teeth and postcranial material (Mateus, 2009; Royo-Torres et al., 2009; Ortega et al., 2010; Mocho et al., 2012; Royo-Torres et al., 2014a; Mocho et al., 2016b). Four taxa, so far exclusively, were described in the Upper Jurassic of the Lusitanian Basin: the camarasaurid *Lourinhasaurus alenquerensis* (Lapparent and Zbyszewski, 1957; Dantas et al., 1998; Mocho et al., 2014b); the diplodocid *Dinheirosaurus lourinhanensis* (Bonaparte and Mateus, 1999; Mannion et al., 2012; recently referred as *Supersaurus lourinhanensis* by Tschopp et al., 2015), the basal macronarian and putative brachiosaurid *Lusotitan atalaiensis* (Lapparent and Zbyszewski, 1957; Antunes and Mateus, 2003; Mannion et al., 2013), and the turiasaur *Zby atlanticus* (Mateus et al., 2014).

The relationships between the Portuguese Upper Jurassic record and North American Morrison Formation dinosaur fauna have been widely

discussed. The relatively abundant Portuguese vertebrate fossil record is important in understanding the relationships between North American and European fauna in this period. A combination of shared and exclusive taxa has been used as an argument to justify processes of dispersion and vicariance (Galton, 1980; Pérez-Moreno et al., 1999; Antunes and Mateus, 2003; Escaso et al., 2007a; Ortega et al., 2013). The relationship of the Portuguese Late Jurassic sauropods to taxa from the North American Upper Jurassic Morrison Fm. (e.g., Lapparent and Zbyszewski, 1957) is currently believed to be less close than to other dinosaur groups (Galton, 1980; Pérez-Moreno et al., 1999; Mateus and Antunes, 2003; Escaso et al., 2007a; Malafaia et al., 2007, 2010a, 2010b; Hendrickx and Mateus, 2014; Malafaia et al., 2015) with no species or even genera reported on either side of the Atlantic. Recently, Tschopp et al. (2015) have suggested the presence of the genus *Supersaurus* in the Upper Jurassic of the Lusitanian Basin.

The present study provides a stratigraphic context for the Portuguese Late Jurassic sauropods from the Lusitanian Basin, considering several geological areas, such as the Bombarral (Bombarral-Alcobaça and Consolação), Turcifal, and Arruda Sub-basins. Many specimens are reported and briefly analysed here for the first time, including several specimens found in Torres Vedras, Lourinhã, Peniche, Caldas da Rainha, and Pombal. Several specimens are under preparation for study, but a preliminary systematic evaluation is presented here. This study aims to provide information about the composition of the sauropod fauna in the Upper Jurassic sequence of the Lusitanian Basin.

Geological Context

The Lusitanian Basin is located in the west region of the Iberian Peninsula, and it is related to the opening of the North Atlantic. This N-S elongated basin has a maximum extension of 225 km x 70 km (Kullberg, 2000). It is part of a set of marginal and peri-North Atlantic basins, which began to be differentiated in the Triassic due to the fragmentation of Pangaea, and evolved during the Jurassic and Cretaceous, when this shore of the Atlantic became a passive margin (Ribeiro et al., 1979; Boillot et al., 1978; Kullberg et al., 2006; Pena dos Reis et al., 2011; Kullberg et al., 2013). The Lusitanian Basin sedimentary sequence was deposited from the Middle Triassic (?Ladinian - Carnian) (Rocha et al., 1996) to the Late Cretaceous (Turonian) (Rey, 1999) (Figure 1). The evo-

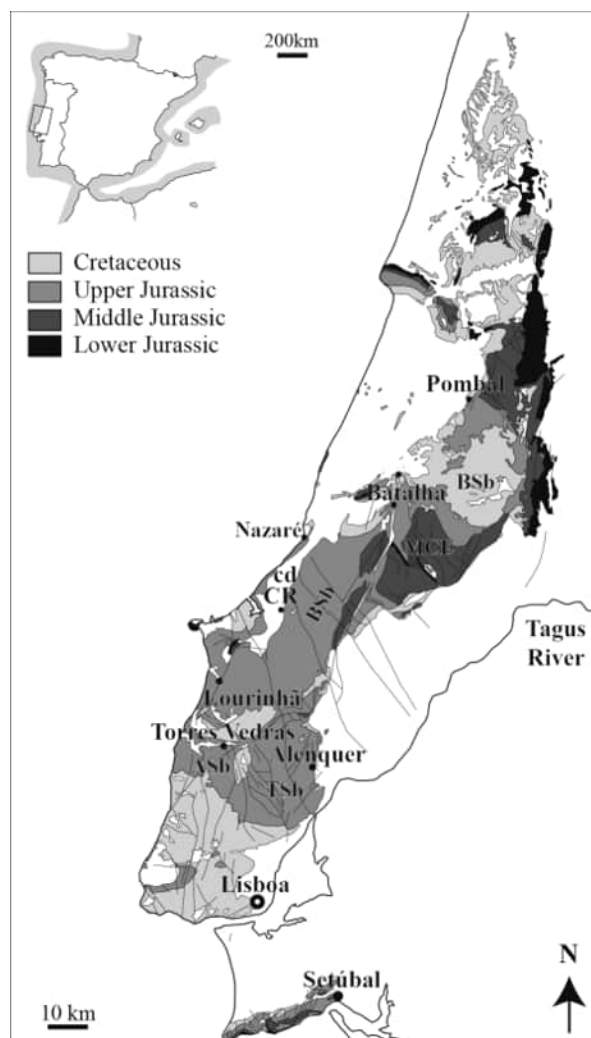


FIGURE 1. Geological map (adapted from Oliveira et al., 1992) showing the Portuguese Mesozoic levels outcropping in the Lusitanian Basin. ASb – Arruda Sub-basin; BSb – Bombarral Sub-basin, cd – Caldas Diapir; CR – Caldas da Rainha town; TSb – Turcifal Sub-basin.

lution of the basin took place mainly in an extensional tectonic context (Kullberg et al., 2006) and in some regions, this sedimentary sequence reaches a thickness of 5000 m (Ribeiro et al., 1979). From the Late Cretaceous onwards, alpine compressive episodes led to the cessation of sedimentation and ultimately the inversion of the basin, with predominant up-lift and the exposure of most of its Mesozoic sequence.

The Upper Jurassic sequence is the focus of this study, and represents the main subsidence phase of the basin, with an accumulation of over 3 km in sedimentary thickness, in a short period, at its main depocenters (Pena dos Reis et al., 1996, 2000). It ranges from the middle Oxfordian to the

boundary with the Lower Cretaceous (Schneider et al., 2009). The Upper Jurassic sedimentary sequence represents a third rifting episode (Rasmussen et al., 1998; Kullberg et al., 2006), marked by intense subsidence and an internal differentiation in three main sectors (Rocha and Soares, 1984). The northern sector extends from Coimbra to the Nazaré fault and is characterized by lower subsidence; the central sector extends from this main tectonic line to the Lisboa area and presents the maximum subsidence; and the southern sector extends from Lisboa to the alpine Arrabida chain, with the lowest subsidence. This episode of rifting was marked by an important sedimentary input into the whole basin, which progressively filled the basin (Guéry, 1984; Hill, 1988; Wilson, 1988; Pena dos Reis et al., 2000; Kullberg et al., 2006, 2013). From the lower Kimmeridgian up to the top of the Upper Jurassic, the sedimentary sequence was dominated by abundant siliciclastic inputs, with a mainly continental and transitional signature (e.g., Hill, 1988; Manuppella et al., 1999; Kullberg et al., 2006). As accommodation space decreased, coastal environments became shallower and siliciclastics prograded into the basin, with the gradual development of fluvial environments, giving origin to a predominantly braided fluvial sedimentation in Berriasian times (Torres Vedras Group). Late Jurassic paleogeographic reconstructions point to a narrow trough developing from NE proximal areas to SW distal areas, with both longitudinal axial drainage and lateral inputs from the eastern and western basement borders (Pena dos Reis et al., 2011). Palaeoenvironments grade from proximal braided fluvial deposits to distal fine-grained meandering, and even deltaic to coastal deposits. Siliciclastics are clearly predominant, but some minor carbonate and shell-rich intercalations may be found, particularly in distal areas (Pena dos Reis et al., 2011).

The central sector corresponds mainly to distal fluvio-deltaic and coastal environments, which produced the richest fossil record of terrestrial vertebrates in the Lusitanian Basin (e.g., Lapparent and Zbyszewski, 1957; Dantas, 1990; Antunes and Mateus, 2003; Ortega et al., 2009). No sauropod osteological remains have yet been identified in the Upper Jurassic of the southern or northern sectors of the Lusitanian Basin. The Central Sector of the Lusitanian Basin has been divided into three Upper Jurassic sub-basins, the Turcifal, Arruda, and Bombarral (Figure 2.1), based on isopachs and facies distribution (Pena dos Reis et al., 1996, 2000). The stratigraphy of the Upper Jurassic

sequence of the Lusitanian Basin is complex, due the profuse lateral heterogeneity and the proposal of several and different stratigraphic approaches (e.g., Hill, 1988; Leinfelder, 1993; Manuppella et al., 1999; Kullberg et al., 2006; Schneider et al., 2009; Martinus and Gowland, 2011; Taylor et al., 2014). Figure 3 presents the stratigraphic correlations between the nomenclature proposed for the areas considered in this manuscript: *i)* Turcifal Sub-basin (stratigraphy based on Pereda-Suberbiola et al., 2005; Kullberg et al., 2006; Schneider et al., 2009); *ii)* Arruda Sub-basin (stratigraphy based on Kullberg et al., 2006); *iii)* Consolação Sub-basin areas: Torres Vedras-Lourinhã-Peniche (stratigraphy based on Manuppella et al., 1999), Foz do Arelho-Nazaré coastal sector (stratigraphy based on Kullberg et al., 2006; Azerêdo et al., 2010); *iv)* Bombarral-Alcobaça Sub-basin (stratigraphy based on Kullberg et al., 2006; Azerêdo et al., 2010); *v)* Batalha-Leiria region (stratigraphy based on Manuppella et al., 2000; Kullberg et al., 2006; Escaso et al., 2007a), and *vi)* Pombal region (stratigraphy based on Kullberg et al., 2006; Malafaia et al., 2010a). This nomenclature will be used in the present study. The term Lourinhã Formation was proposed by Hill (1988) and has been widely used in vertebrate paleontological literature. This formation was defined on the coastal sections south of São Bernardino (Peniche) to Porto da Calada (Mafra). This formation seems to be coincident with the upper part of the Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Freixial, and Bombarral Formations referenced by other authors, including the Portuguese Geological Surveys (e.g., Manuppella et al., 1999). The use of this unit outside the area corresponding to the Consolação Sub-basin of Taylor et al. (2014) is not completely established in literature (e.g., Hill, 1988; Kullberg et al., 2006; Schneider et al., 2009; Ribeiro and Mateus, 2012; Kullberg et al., 2013; Mateus et al., 2013). Yagüe et al. (2006) therefore incorporate the entire Alcobaça Formation and the previously defined Lourinhã Formation into a new lithostratigraphic unit, the Lourinhã Group. The stratigraphic proposals of Hill (1988) and Yagüe et al. (2006) are also presented in the Figure 3.

MATERIAL AND METHODS

The studied material is mainly deposited in Portuguese institutions, excluding one specimen found in the Muséum National d'Histoire Naturelle (Paris, France) (see list in Appendix 1). All the specimens are described and discussed based on direct observations. We use "Romerian" terms for

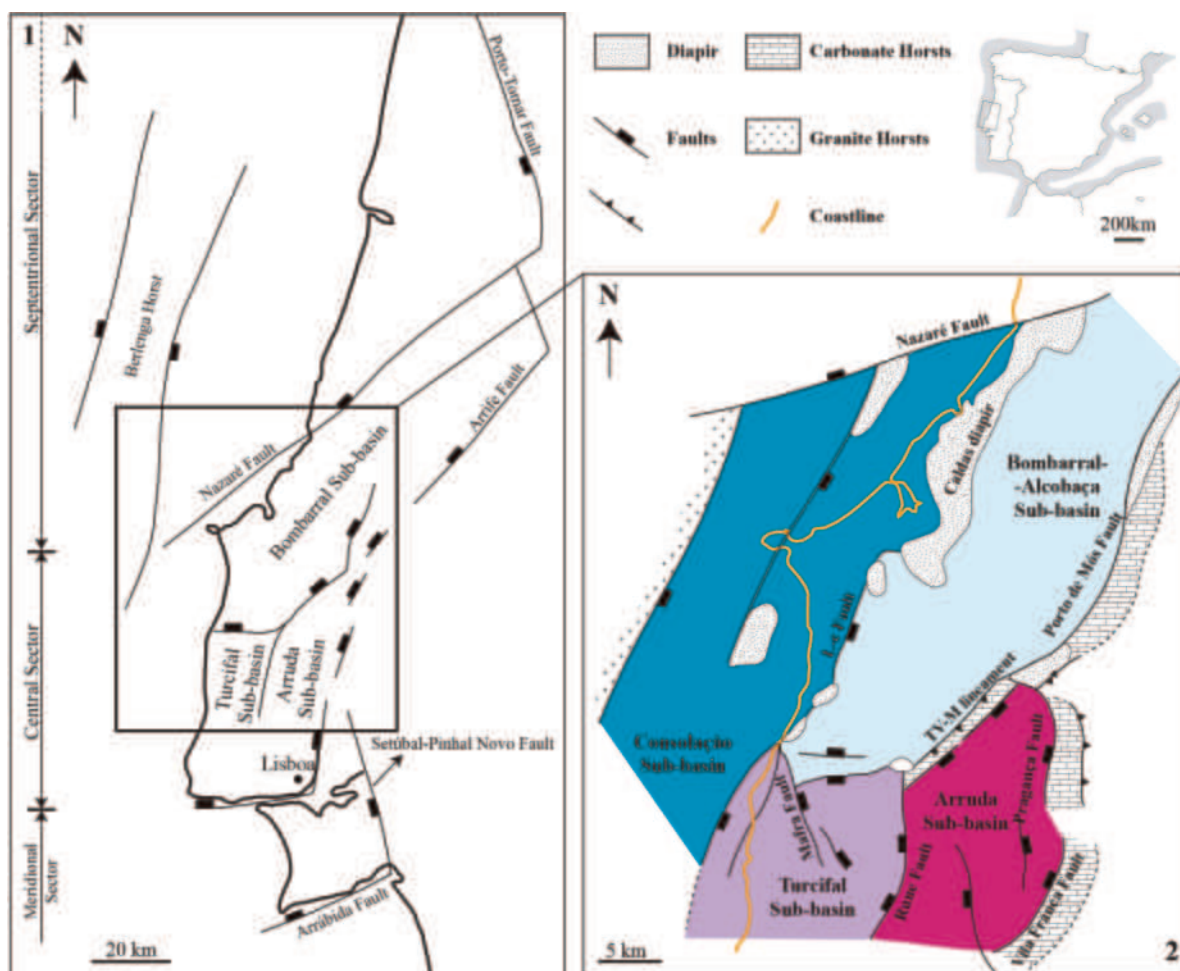


FIGURE 2. Lusitanian Basin (divided into three sectors following Ribeiro et al., 1996) with the location of the Upper Jurassic sub-basins following two different interpretations: (1) location of Bombarral, Turcifal and Arruda Sub-basins (Guery, 1984; Kullberg, 2000; Kullberg et al., 2006) (modified from Kullberg, 2000); (2) location of Bombarral-Alcobaça, Consolação, Arruda and Turcifal Sub-basin (modified from Taylor et al., 2014).

anatomical structures for the structures (e.g., “centrum”) and their orientation (e.g., “anterior”) (Wilson, 2006). This study applies the landmark-based terminology of Wilson (1999, 2012) and Wilson et al. (2011) for vertebral laminae and fossae.

Anatomical Abbreviations

aacet, articulation for the acetabulum; **acc**, acromial crest; **acet**, acetabulum; **ant. spdl**, anterior spinodiapophyseal lamina; **asp**, ascending process; **aspa**, articular surface for the ascending process; **awf**, apical wear facet; **br**, bridge; **cc**, cnemial crest; **cml**, camellae; **cpol**, centropostzygapophyseal lamina; **cr**, caudal rib; **cwf**, carina wear facet; **di**, diapophyses; **dpc**, deltopectoral crest; **ec**, epicondyle; **f**, fossa; **fic**, fibular condyle; **ft**, fourth trochanter; **gl**, glenoid; **gr**, groove; **ibi**, incipient bifurcation; **ilped**, iliac peduncle; **isped**,

ischiatric peduncle; **lag**, labial groove; **lb**, lateral bulge; **lf**, lingual facets; **lic**, lingual crest; **lt**, lateral trochanter; **hy**, hyposphene; **lat.spol**, lateral spinopostzygapophyseal lamina; **of**, obturator foramen; **pafo**, posterior astragalar fossa crest; **paf**, posterior astragalar fossa; **pcdl**, posterior centrodiapophyseal lamina; **pcpl**, posterior centroparapophyseal lamina; **pfr**, pneumatic foramen; **podl**, postzygodiapophyseal lamina; **posl**, postspinal lamina; **post. spdl**, posterior spinodiapophyseal lamina; **poz**, postzygapophyses; **prsl**, prespinal lamina; **prdl**, prezygodiapophyseal lamina; **prz**, prezygapophyses; **spof**, spinopostzygapophyseal fossa; **spol**, spinopostzygapophyseal lamina; **sprf**, spinoprezygapophyseal fossa; **spri**, spinoprezygapophyseal lamina; **tap**, triangular all-form process; **tb**, tuberosity; **tia**, tibial articular sur-

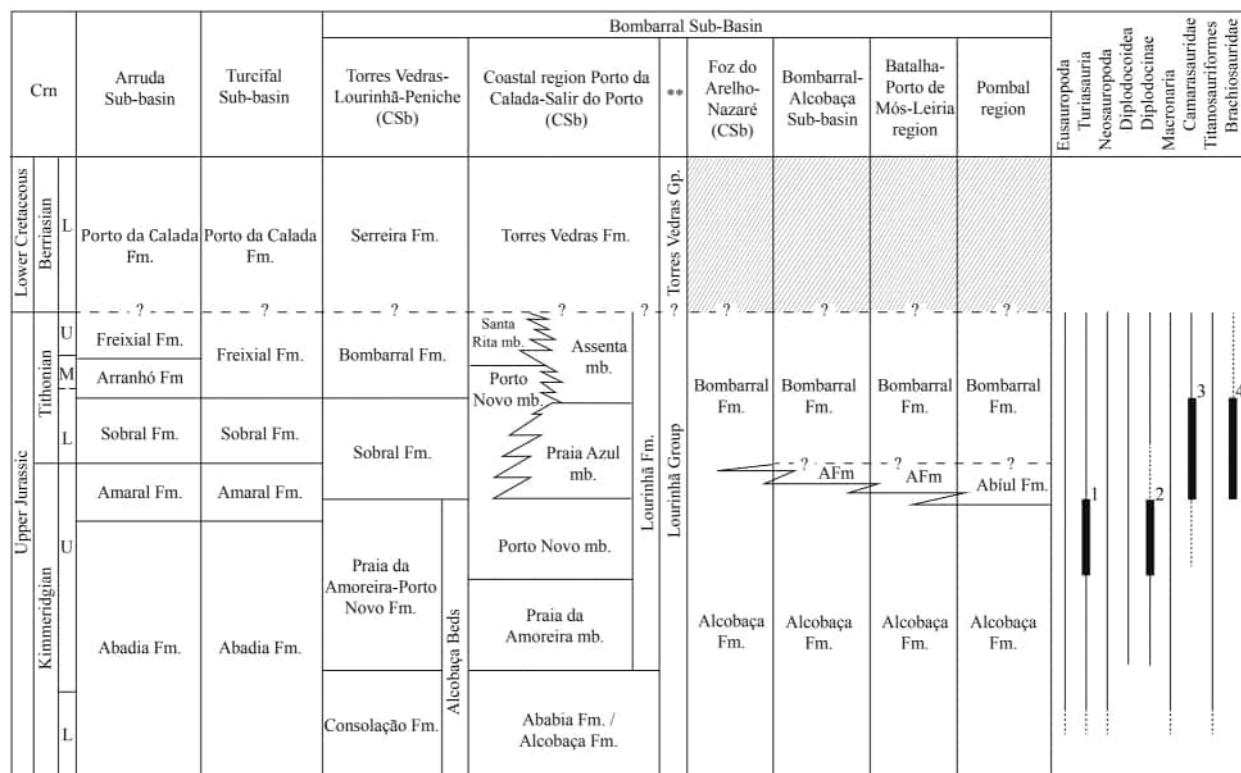


FIGURE 3. Stratigraphic correlation between the nomenclature proposed for the Upper Jurassic sub-basin of the central sector of the Lusitanian Basin [Bombarral Sub-basin is split in several areas: Consolação Sub-basin areas (Torres Vedras-Lourinhã-Peniche and Foz do Arelho-Nazaré coastal sector), Bombarral-Alcobaça Sub-basin area, Batalha-Leiria region and Pombal region], from the left to the right: i) Arruda Sub-basin (Kullberg et al., 2006); ii) Turcifal Sub-basin (Pereda-Suberbiola et al., 2005; Kullberg et al., 2006; Schneider et al., 2009); iii) Arruda Sub-basin (Kullberg et al., 2006); iv) Torres Vedras-Lourinhã-Peniche (Manuppella et al., 1999); v) Foz do Arelho-Nazaré coastal sector (Kullberg et al., 2006; Azerêdo et al., 2010); vi) Bombarral-Alcobaça Sub-basin area (Kullberg et al., 2006; Azerêdo et al., 2010); vii) Batalha-Leiria region (Manuppella et al., 2000; Kullberg et al. 2006; Escaso et al., 2007a) and viii) Pombal region (Kullberg et al., 2006; Malafaia et al., 2010a). The stratigraphy proposed by Hill (1988) for the coastal sector from Porto da Calada to Salir do Porto is also plotted. Cm – Chronostratigraphy; **sensu Yagüe et al., 2006. The right column shows the known stratigraphic distribution of the main sauropod clades along the Kimmeridgian-Tithonian sedimentary sequence in the Lusitanian Basin. The black bar indicates the known stratigraphic distribution of the established sauropod taxa (1, *Zby atlanticus*; 2, *Dinheirosaurus lourinhanensis*; 3, *Lourinhasaurus alenquerensis*; 4, *Lusotitan atalaiensis*); CSb, Consolação Sub-Basin (following Taylor et al., 2014).

face; **tic**, tibial condyle; **vh**, ventral hollow; **vlc**, ventrolateral crest; **vpr**, ventral process.

Institutional Abbreviations

MG, Museu Geológico (Lisboa, Portugal); **ML**, Museu da Lourinhã (Lourinhã, Portugal); **MMPM**, Museu Municipal de Porto de Mós (Porto de Mós, Portugal); **MMB**, Museu Municipal do Bombarral (Bombarral, Portugal); **MLLT**, Museu Municipal Leonel Trindade (Torres Vedras, Portugal); **MNHN**, Muséum National d'Histoire Naturelle (Paris, France); **MNHNUL**, Museu Nacional de História Natural e da Ciência (Lisboa, Portugal); **SHN**, Sociedade de História Natural, plus **JJS** for the

José Joaquim dos Santos collection (Torres Vedras, Portugal).

UPPER JURASSIC SAUROPOD RECORD OF THE LUSITANIAN BASIN

The sauropod record will be presented as following a palaeogeographic distribution, corresponding mainly to the Upper Jurassic sub-basins of the central sector (Figure 2), however, it must be noted that these sub-basins have been defined based on, essentially, geodynamic features, namely the existence of three depocentres separated by main tectonic fault lines and by less subsidiary areas. These areas could eventually

represent paleotopographic highs, which may account for some palaeogeographic differences between sub-basins. Sub-basins could therefore represent low-lands where water, vegetation, and vertebrates would have had better conditions in which to develop and accumulate. If so, these areas might represent different contemporaneous communities, occupying slightly different habitats or palaeoenvironments, more or less open to coastal influences or connections.

Bombarral Sub-basin

The Bombarral Sub-basin is the widest Upper Jurassic sub-basin of the central sector of the Lusitanian Basin. It is also the richest area with respect to fossil sites with vertebrates (e.g., Lapparent and Zbyszewski, 1957; Ortega et al., 2009). This basin is delimited in the north by the Nazaré Fault and in the east and south by the Porto-Tomar, Arrife, and Torres-Vedras-Montejunto Faults (Kullberg, 2000; Kullberg et al., 2006, 2013; Figure 2.1). The Torres Vedras-Montejunto Fault separates the Bombarral Sub-basin from the half-graben Turcifal and Arruda Sub-basins (Kullberg et al., 2006, 2013). Taylor et al. (2014) established two new sub-basins replacing the Bombarral Sub-Basin, called the Consolação and Bombarral-Alcobaça Sub-basins (Figure 2.2).

The Consolação Sub-basin is located on the west of the Lourinhã Fault and the Caldas Diapir, and is bounded in the north by the Nazaré Fault (Figure 2.2). This sub-basin includes the Upper Jurassic coastal sector from Praia da Consolação (Peniche) to Santa Cruz (Torres Vedras) and some Upper Jurassic cliffs north of Peniche, and from Nazaré to Foz do Arelho. The remaining area of the previously defined Bombarral Sub-basin, and that on the east of the Lourinhã Fault and the Caldas Diapir, is now included in the Bombarral-Alcobaça Sub-basin (Figure 2.2; Taylor et al., 2014). We follow the sub-division of the Lusitanian Basin Central Sector proposed by Kullberg et al. (2006, 2013) always referring to the correspondent nomenclature proposed by Taylor et al. (2014).

The presence of several dinosaur remains in the Bombarral Sub-basin has been reported since the end of the nineteenth century (e.g., Sauvage, 1897-98; Lapparent and Zbyszewski, 1957; Dantas, 1990; Antunes and Mateus, 2003), most notably those from Upper Jurassic sediments outcropping in the Lourinhã, Peniche, and Pombal municipalities (e.g., Lapparent and Zbyszewski, 1957; Pérez-Moreno et al., 1999; Antunes and Mateus, 2003). Several occurrences of non-sauro-

pod dinosaurs (theropods, ornithopods, and thyreophorans) were also reported. Theropod fauna are comprised of basal forms representing Ceratosauria (*Ceratosaurus* sp.), Megalosauroida (*Torvosaurus gurneyi*), and Allosauroida, such as *Allosaurus* and *Lourinhanosaurus antunesi* (e.g., Dantas, 1987; Mateus et al., 1997; Mateus, 1998; Dantas et al., 1999; Pérez-Moreno et al., 1999; Mateus and Antunes, 2000a, 2000b; Rauhut, 2000; Mateus, 2005, 2006; Mateus et al., 2006; Malafaia et al., 2007, 2008, 2010a, 2010b; Hendrickx and Mateus, 2012, 2014; Malafaia et al., 2015, 2016, 2017). Derived theropods are also represented by mostly isolated specimens related to the clade Coelurosauria, including the basal tyrannosauroid *Aviatyrannis*, indeterminate dromaeosaurids, and several teeth attributed to cf. *Archaeopteryx* (Weigert, 1995; Zinke, 1998; Zinke and Rauhut, 1994; Antunes and Mateus, 2003; Mateus, 2005; Malafaia et al., 2007, 2010a, 2014). The most important Bombarral Sub-basin theropod fossil sites are reported from Andrés in Pombal (Dantas et al., 1999; Pérez-Moreno et al., 1999; Malafaia et al., 2007, 2010a), Paimogo in Lourinhã (Dantas, 1987; Mateus et al., 1997), Vale de Pombas-Praia Vermelha coastal cliffs in Lourinhã-Peniche (Mateus, 2005; Hendrickx and Mateus, 2014), and the Guimarota mine in Leiria (Zinke, 1998; Rauhut, 2000, 2003; Rauhut and Fechner, 2005).

The Bombarral Sub-basin is also rich in ornithischian remains, with the presence of at least four ornithopod and three thyreophoran forms. Several historical specimens were referred to the genus *Omosaurus* (Zbyszewski, 1946; Lapparent and Zbyszewski, 1957), but some part of this material, as well as new specimens, were later assigned to the genus *Dacentrurus* (e.g., Galton, 1991; Maidment et al., 2008; Ortega et al., 2009). This genus is also present in the Spanish Villar del Arzobispo Formation (Kimmeridgian-Berriasian in age), as the only known shared dinosaur genus between these territories for the Late Jurassic (Cobos et al., 2010; Cobos and Gascó, 2013). More recently, two other stegosaurian forms were identified in the Upper Jurassic levels of the Bombarral Sub-basin. Escaso et al. (2007a) referred a partial individual found in Casal Novo (Alcobaça Fm., Leiria) to the North American Morrison Fm. genus *Stegosaurus*, proposing a Late Jurassic contact for the Iberian and North American fauna. Mateus et al. (2009) established a new stegosaurian taxon, *Miragaia longicollum*, a form closely related to *Dacentrurus*. Cobos et al. (2010) proposed *Miragaia* as synonymous with of *Dacentru-*

rus, a hypothesis followed by Escaso (2014) and Maidment et al. (2015).

The Upper Jurassic ornithopod record of the Bombarral Sub-basin is represented by the dryosaurid *Eousdryosaurus* (Escaso et al., 2014) and two styracosternans: *Camptosaurus* (= *Uteodon*) *aphanoecetes*, previously identified in the Morrison Formation (Escaso et al., 2010a, 2010b) and the exclusive Portuguese form *Draconyx loureiroi* (Mateus and Antunes, 2001). Another ornithopod, based on teeth from the Guimarães mine, was described as *Phyllodon henkeli* (Thulborn, 1973). Rauhut (2001) referred some additional teeth as well as three partial dentaries to this taxon.

Other vertebrate groups have been reported, such as fishes (Sauvage, 1897-98; Kriwet, 2000; Balbino, 2003), amphibians (Wiechmann, 2000), turtles (Sauvage, 1897-98; Bräm, 1973; Antunes et al., 1988; Gassner, 2000; Pérez-García and Ortega, 2011; Pérez-García, 2015); sphenodonts (Ortega et al., 2006; Malafaia et al., 2010a), squamates (Seiffert, 1973; Broschinski, 2000; Caldwell et al., 2015), pterosaurs (Dantas, 1987; Wiechmann and Gloy, 2000), crocodyliforms (Sauvage, 1897-98; Krebs and Schwarz, 2000; Schwarz and Fechner, 2004; Schwarz and Salisbury, 2005; Tennant and Mannion, 2014; Russo et al., 2017), mammals (e.g., Hahn, 1971; Krusat, 1980; Hahn and Hahn, 2000; Krebs, 2000; Martin, 2000; Martin and Nowotny, 2000; Martin, 2005), and possible plesiosaurs (Castanhinha and Mateus, 2007).

The sauropods are well represented in this sub-basin, being recognised in many fossil sites, with numerous occurrences (e.g., Lapparent and Zbyszewski, 1957; Dantas, 1990; Antunes and Mateus, 2003; Mateus, 2005; Mocho et al., 2013a, 2013b, 2014a, 2016a, 2017). We will report the sauropod record in the following different areas of the Bombarral Sub-basin: *i*) northern region of Maciço Calcário Estremenho; *ii*) coastal sector from Foz do Arelho to Nazaré; *iii*) Alcobaça, Bombarral and A-dos-Cunhados; *iv*) North Peniche; and *v*) Praia da Consolação-Lourinhã-Torres Vedras coastal sector. This subdivision seems useful considering the profuse lateral lithological heterogeneity and the proposal of several stratigraphic approaches for each area within this sub-basin, and also to provide a more accurate overview of the abundant sauropod fossil record in the Bombarral Sub-basin.

Northern region of Maciço Calcário Estremenho (Figures 4, 5). The region north of the Maciço Calcário Estremenho (MCE) is rich in transitional to continental Upper Jurassic deposits

(Camarate França and Zbyszewski, 1963; Teixeira et al., 1966; Manuppella et al., 2000), including several fossil sites in the Pombal, Leiria, Batalha, and Porto-de-Mós municipalities. Several important vertebrate sites are identified in this area, notably the Guimarães mine (Leiria), and Andrés (Pombal) and Casal Novo (Batalha) quarries (e.g., Pérez-Moreno et al., 1999; Rauhut, 2000; Escaso et al., 2007a; Malafaia et al., 2007, 2010a). The sauropod record is relatively poor in this sector of the Bombarral Sub-basin and is mainly based on incomplete specimens (Figure 5). Samples come from sediments in the Alcobaça and Bombarral Formations (Figures 4.2-3, 5), and there is published and unpublished material (e.g., Malafaia et al., 2010a; Mocho et al., 2016a, 2017). The Alcobaça Fm. is interpreted as having been deposited in marine environments, transiting to fluvio-lacustrine deposits at the top of the formation. In this area, the Alcobaça Fm. is lower Kimmeridgian-lower Tithonian in age, being considered as laterally correlated with the marine Abadia Fm., present in the south of the Lusitanian Basin Central Sector (Manuppella et al., 2000). Some important fossil sites found in the Alcobaça Fm. correspond to fluvial (Escaso et al., 2007a) and lagoonal deposits (Schudack, 2000). The Bombarral Fm. is composed of fluvio-lacustrine deposits, dated to the late Kimmeridgian-Tithonian (Manuppella et al., 2000).

Near Pombal, sauropod fossils were only identified in the sediments of the Bombarral Formation. A great accumulation of fossils representing a relatively diverse vertebrate fauna was identified at the Andrés locality in the Tithonian levels of the Bombarral Fm. (Dantas et al., 1999; Pérez-Moreno et al., 1999; Malafaia et al., 2007, 2009a, 2010a). Several teeth and postcranial material assigned to Sauropoda were collected at this fossil site (Figure 5.5). A preliminary analysis of the teeth allowed the recognition of four different morphotypes: spatulate, heart-, compressed cone-chisel-, and peg-shaped, which led Malafaia et al. (2010a) to suggest the presence of forms related to Diplodocoidea, Turiasauria, and Titanosauriformes. However, the presence of compressed cone-chisel-shaped teeth in *Europasaurus* (Sander et al., 2006), which was recently considered as a non-titanosauriform macronarian (Carballido and Sander, 2014), might indicate that this tooth morphology was already present in non-titanosauriform macronarians. More teeth and postcranial elements from the Andrés site are being prepared (EM, personal commun., 2015).

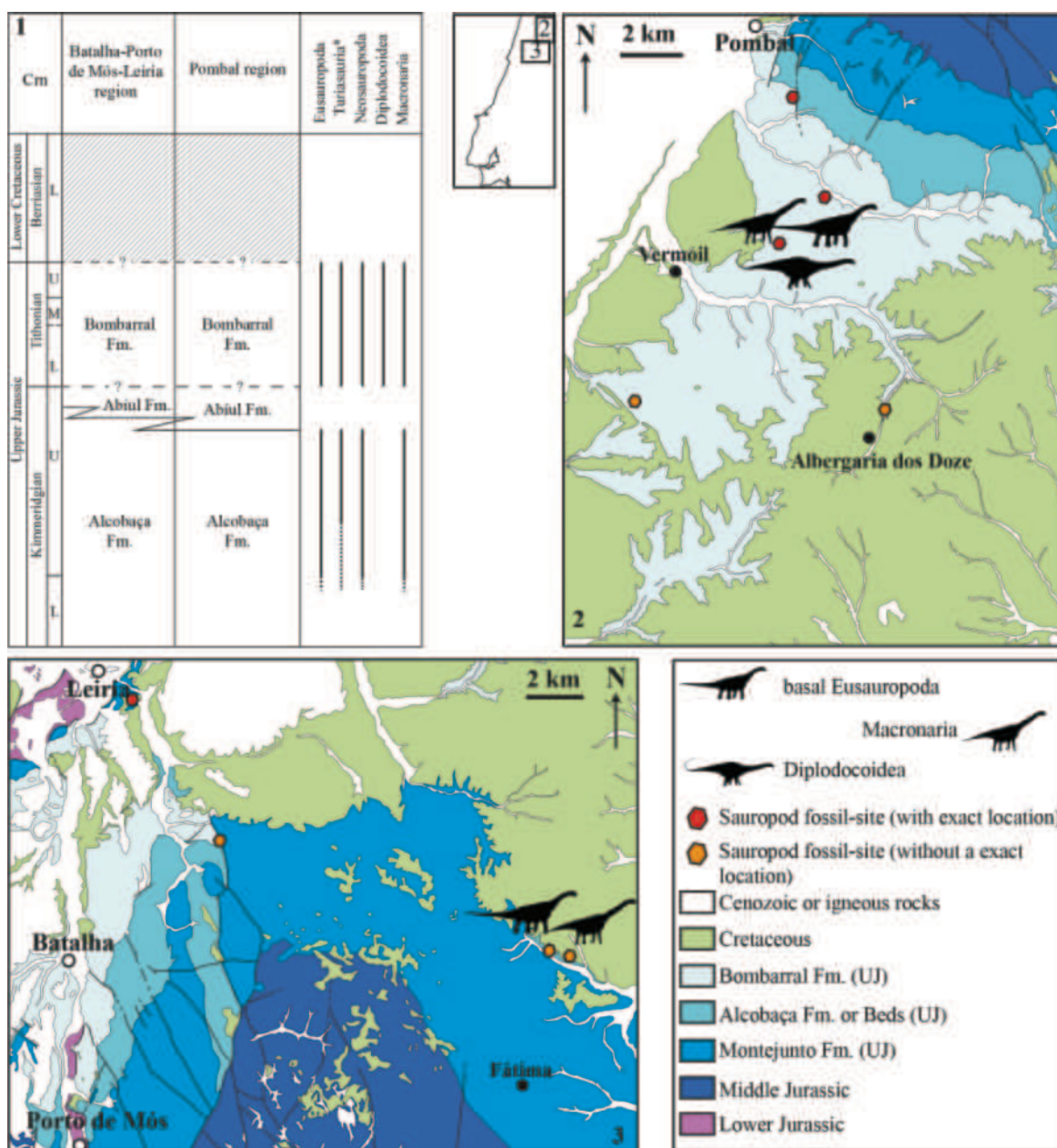


FIGURE 4. 1, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence in the Pombal, Leiria, and Batalha areas (located on the Bombarral Sub-basin) (Manuppella et al., 2000; Kullberg et al., 2006; Escaso et al., 2007a; Malafaia et al., 2010a) with distribution of the main sauropod clades identified in this area. **2-3**, Geological map of Pombal (**2**) and Leiria and Batalha (**3**) areas with localities yielding fossil remains referred to Sauropoda (modified from Teixeira et al., 1966; Zbyszewski et al., 1974; Zbyszewski and Ferreira, 1978; Manuppella et al., 2000). Crn – Chronostratigraphy. *the presence of Turiasauria is only supported by the presence of heart-shaped teeth.

Also in the Pombal area, a middle/posterior caudal vertebra (Figure 5.4, MG 4811) was found in Albergaria dos Doze (Pombal), probably from the Bombarral Formation (Figure 4.2). Lapparent and Zbyszewski (1957) attributed this element to the theropod *Megalosaurus pombali*. Subse-

quently, Mateus (2005) considered this vertebra to belong to an indeterminate theropod. This vertebra probably corresponds to an indeterminate sauropod based on its general morphology, transversely convex ventral face and an anteroposteriorly short neural arch. A middle or posterior dorsal neural

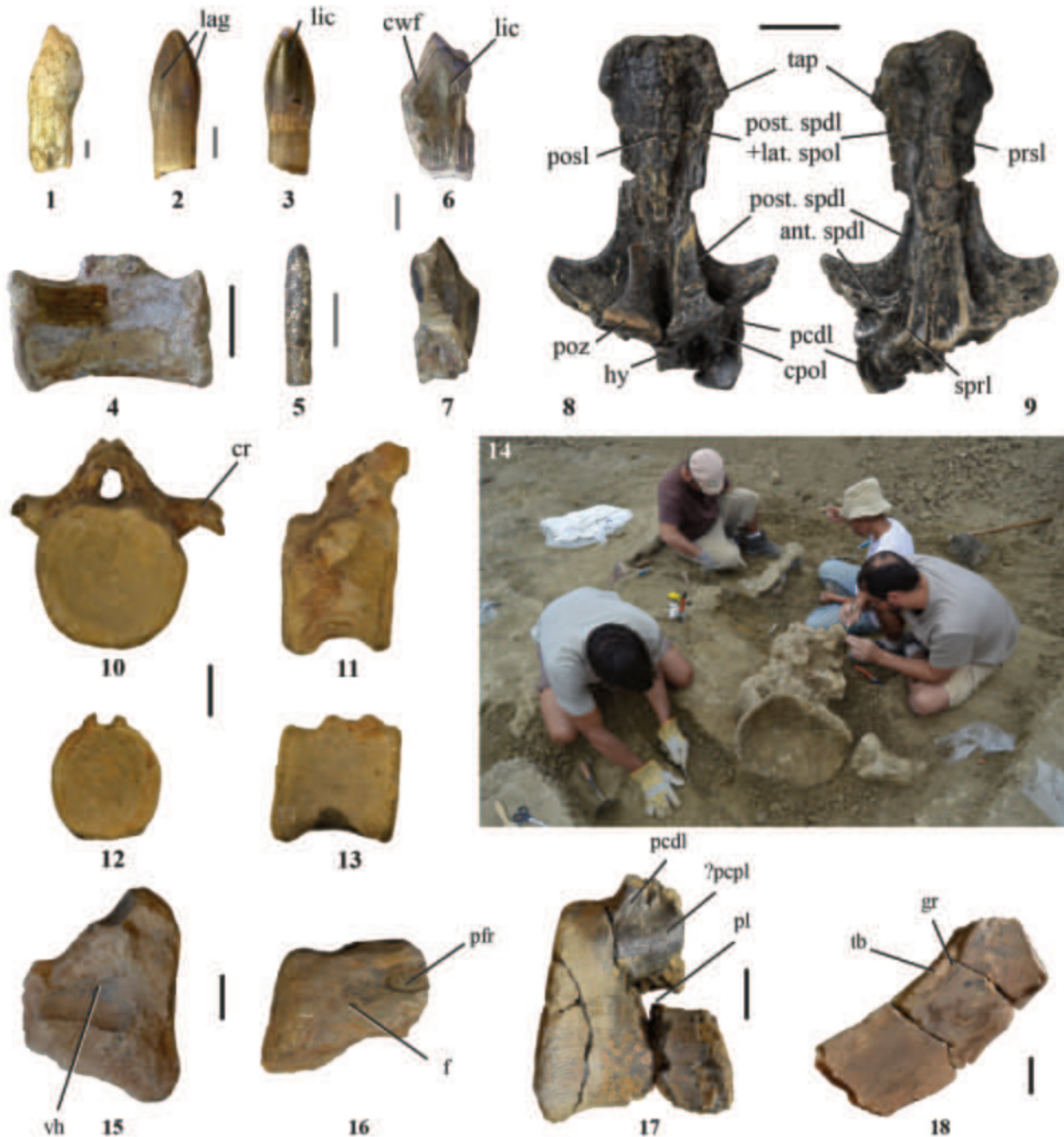


FIGURE 5. Cranial and postcranial sauropod remains from Pombal, Leiria, and Batalha areas: **1**, *Macronaria* indet., compressed cone-chisel-shaped tooth (MG 8779, Ourém) in labial view; **2-3**, *Macronaria* indet., compressed cone-chisel-shaped tooth (MG 27891, Guimarães) in labial (**2**) and lingual (**3**) views; **4**, *Sauropoda* indet., middle or posterior caudal vertebra (MG 4811, Albergaria dos Doze) in right view; **5**, *Diplodocoidea* indet., pencil-shaped teeth (MNHNUL.P.AND303, Andrés) in labial view; **6-7**, *?Turiasauria* indet., heart-shaped tooth (MG 16, Ourém) in lingual (**6**) and labial (**7**) views; **8-9**, *Eusauropoda* indet., posterior or middle dorsal neural spine (MNHN.unnumbered, Vermoill) in posterior (**8**) and anterior (**9**) views; **10-13**, *Sauropoda* indet., anterior, and middle caudal vertebra from a partial caudal series (MG 4974, Abadia) in posterior (**10**, **12**) and right (**11**, **13**) views; **14**, sauropod fossil-site in Junqueira locality (Pombal); **15-18**, sauropod material from near Batalha (MG 30389) that might represent an indeterminate diplodocine, middle caudal vertebra in ventral (**15**) and right (**16**) views, partial posterior (?) dorsal centrum in right view (**17**), and partial ischiatic peduncle in lateral view (**18**). Black scale bar: 10 cm; Gray scale bar: 0.5cm. See Anatomical abbreviations for abbreviations.

spine was also found in this area, near Vermoil (Bombarral Fm., Figure 5.8-9, MNHN.unnumbered). This neural spine probably represents a eusauropod due the presence of a transversely expanded neural spine and a well-defined prespinal lamina (Mocho et al., 2017). More recently, a new fossil site containing a partial sauropod skeleton (dorsal vertebrae and ribs) was found in Pombar (Figure 5.14) during fieldwork carried out by the Museu Nacional de História Natural e da Ciência (Lisboa, Portugal).

A large area with Upper Jurassic continental sediments from the Alcobaça and Bombarral Formations is located across the localities of Batalha, Vila Nova de Ourém, Leiria, and Porto-de-Mós. In the Alcobaça Fm., one of the most important accumulations was found in the Guimarães mine, in Leiria (e.g., Rauhut, 2000). The Guimarães fossil record is relatively poor in sauropod remains, but some small teeth referred to Brachiosauridae (Rauhut, 2000), or to cf. *Lusotitan atalaiensis* (Mateus, 2005) were found (Figure 5.2-3). Sauvage (1897-98) and Lapparent and Zbyszewski (1957) also reported some localities with dinosaur remains near Vila Nova de Ourém and Porto de Mós (probably from the Alcobaça Fm.). Two teeth, one had a heart-shaped morphology probably referable to Turiasauria (Figure 5.6-7, MG 16; Mocho et al., 2012, 2016b) and other had a compressed cone-chisel-shaped morphology (Figure 5.1, MG 8779) common in Titanosauriformes, but also found in the basal macronarian *Europasaurus* (Sander et al., 2006; Carballido and Sander, 2014). A posterior caudal vertebra (MMPM.P/554) from an indeterminate sauropod was also found in Fonte do Oleiro (Alcobaça Fm.), south of the town of Porto de Mós (Mocho et al., 2017).

Mocho et al. (2017) described some sauropod specimens found close to the town of Batalha, and they are deposited in the collections of the Museu Geológico and Museu Municipal de Porto-de-Mós, including: *i*) a partial dorsal centrum and a partial caudal series collected in Abadia (Figure 5.10-13, MG 4974), and *ii*) a set of sauropod bones including dorsal and caudal vertebrae and a fragmentary ischium from Batalha, which might represent a member of Diplodocinae (Figure 5.15-18, MG 30389). The stratigraphic and geographic context of these specimens is not clear, and they might pertain to the Alcobaça Fm. or to the Bombarral Fm.

The presence of non-neosauropod eusauropods, probably turiasaurs, indeterminate diplodocoids (including members of Diplodocinae), and

macronarians, was identified in the area located in the north of the Maciço Calcário Estremenho (Figure 4.1).

Coastal sector from Foz do Arelho to Nazaré (Figures 6, 7). An extensive sector with Upper Jurassic sediments in the Bombarral (following Kullberg et al., 2006, 2013; Azerêdo et al., 2010), or Consolação Sub-basin (following Taylor et al., 2014), crops westwards out of the Caldas Diapir (Figure 6.1). This sequence extends from the coastal cliffs of Foz do Arelho to Nazaré (e.g., Hill, 1988; Kullberg et al., 2006), and includes sediments of the Alcobaça (Kimmeridgian to basal Tithonian) and Bombarral (Tithonian) Formations (Figure 6.2) (Kullberg et al., 2006, 2013; Schneider et al., 2009; Azerêdo et al., 2010). Both formations are particularly rich in fossil vertebrate finds. One of the most important fossil sites is the historical site in Murteiras (Caldas da Rainha) (Lapparent and Zbyszewski, 1957), due the presence of several specimens referred to *Dacentrurus* (Galton, 1991; Antunes and Mateus, 2003; Maidment et al., 2008; Escaso, 2014). No sauropod remains were reported there, however (Lapparent and Zbyszewski, 1957).

Sauropod remains collected in the Alcobaça Formation (following Camarate França and Zbyszewski, 1963; Azerêdo et al., 2010), outcropping in this sector of the Bombarral Sub-basin, (Figure 6.1) include axial elements (Figure 7.1-3, MMPM.P/551) found close to São Martinho do Porto (Mocho et al., 2017), and some unpublished caudal vertebrae and pelvic fragments (Figure 7.18, SHN 537) found in Salir do Porto. An anterior dorsal neural spine (Figure 7.8, MG 4920; Lapparent and Zbyszewski, 1957) of an indeterminate eusauropod from Foz do Arelho (Caldas da Rainha) was collected from sediments of the Bombarral Fm.

Several teeth were collected in this coastal area, corresponding to different morphotypes: *i*) heart-shaped teeth (Figure 7.4-7, 7.11-15, 7.16-17), tentatively referred to Turiasauria (see Royo-Torres and Upchurch, 2012; Royo-Torres et al., 2009; Mocho et al., 2012, 2016b); *ii*) spatulate teeth (Figure 7.9-10; unpublished material housed in MG and SHN) referred to an indeterminate eusauropod (probably a macronarian); and *iii*) compressed cone-chisel-shaped teeth (unpublished material housed in the SHN), referred to Macronaria. The first of these morphotypes is the most abundant in this coastal sector.

The known and the new occurrences put in evidence a relatively high potential for future dis-

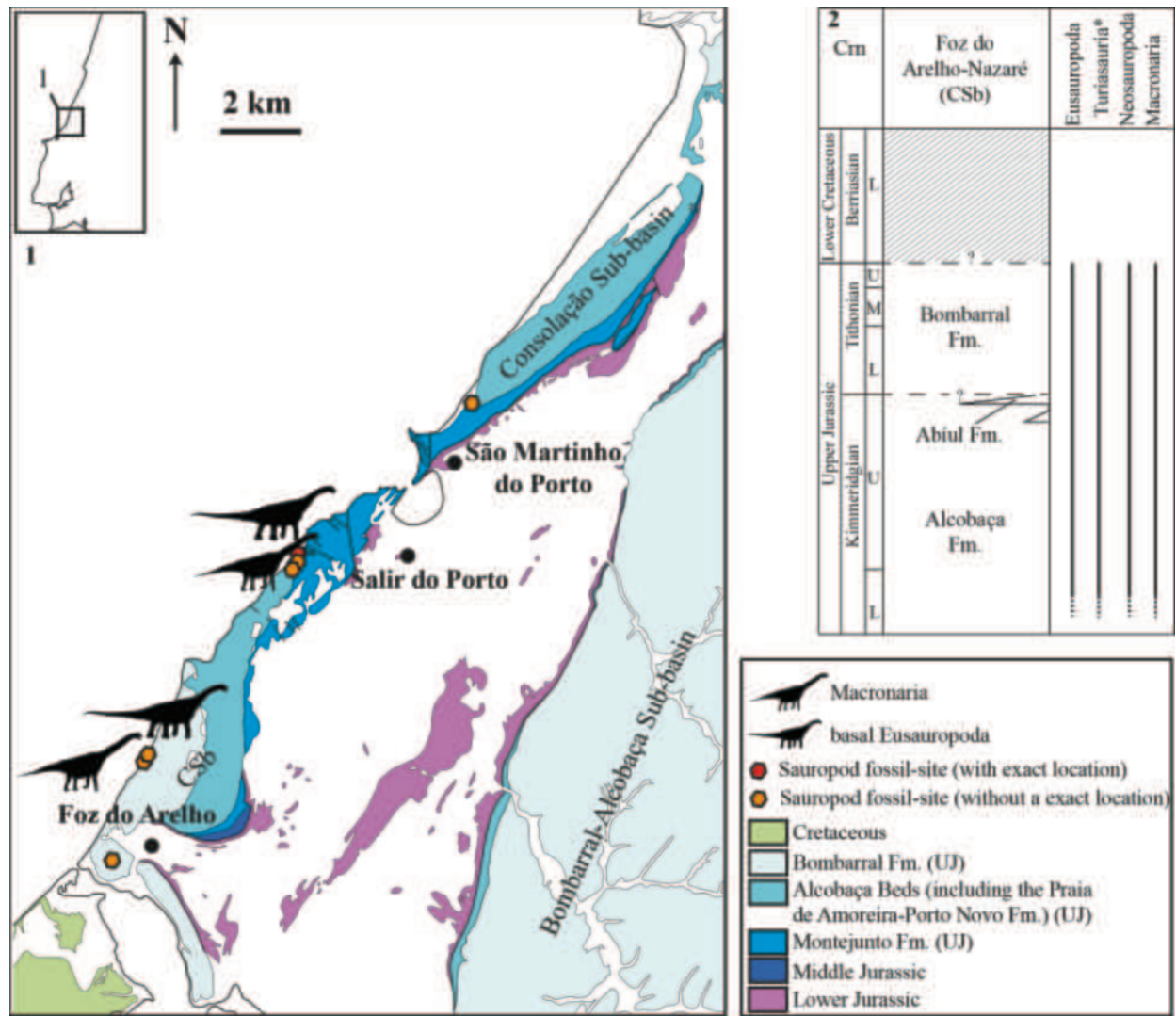


FIGURE 6. 1, Geological map of the coastal sector from Foz do Arelho to Nazaré area (located on the Bombarral Sub-basin, and considered part of the Consolação Sub-basin following Taylor et al., 2014) (modified from Zbyszewski and Moitinho de Almeida, 1960; Camarate França and Zbyszewski, 1963; Azerêdo et al., 2010) with the localities yielding fossil remains referred to Sauropoda. 2, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for the coastal sector from Foz do Arelho to Nazaré sector based on Azerêdo et al. (2010) with the stratigraphic distribution of the main sauropod clades identified in this area. Crn – Chronostratigraphy; *the presence of Turiasauria is only supported by the presence of heart-shaped teeth.

coveries in this area. However, the so far published (Mocho et al., 2012, 2016b, 2017) and unpublished material of sauropods only allows identification of indeterminate sauropods and eusauropods, possibly members of Turiasauria, and indeterminate macronarians. The presence of several compressed cone-chisel teeth in the sedimentary sequence suggests the presence of macronarian forms within the clade formed by *Europasaurus* + *Titanosauriformes* (Figure 6.2).

Alcobaça, Bombarral, and A-dos-Cunhados (Figures 8, 9). A large area with Upper Jurassic

sediments, included within the Bombarral Sub-basin, is found east of the Lourinhã Fault and the Caldas Diapir, defined as the Bombarral-Alcobaça Sub-basin by Taylor et al. (2014) (Figure 8.1). This area is poorly prospected when compared with other areas, such as the coastal sector from Praia da Consolação to Torres Vedras. In fact, this area is generally covered by soil with natural vegetation or agriculture, resulting in only a few outcrops that could produce vertebrate fossils. The most important localities are Moita dos Ferreiros (Mateus, 2005; Mannion et al., 2012) and Miragaia, where



FIGURE 7. Cranial and postcranial sauropod remains from the coastal sector from Foz do Arelho to Nazaré: **1-3**, Eusauropod material (MMPM.P/551) found near the São Martinho do Porto locality, middle caudal vertebra in anterior (**1**) and right (**2**) views and a partial anterior or middle chevron in posterior view (**3**); **4-5**, ?*Turiasauria* indet., heart-shaped tooth (MG 4832, São Martinho do Porto) in lingual (**4**) and labial (**5**) views; **6-7**, ?*Turiasauria* indet., heart-shaped tooth (SHN 501, Praia da Gralha) in labial (**6**) and lingual (**7**) views; **8**, Eusauropoda indet., anterior dorsal neural spine (MG 4920, Foz do Arelho) in anterior view; **9-10**, ?*Macronaria* indet., spatulate tooth (SHN 517, Foz do Arelho) in lingual (**9**) and labial (**10**) views; **11-13**, ?*Turiasauria* indet., heart-shaped tooth (SHN 508, Serra do Bouro) in lingual (**11**), labial (**12**) and distal (**13**) views; **14-15**, ?*Turiasauria* indet., heart-shaped tooth (SHN 512, Foz do Arelho) in lingual (**14**) and labial (**15**) views; **16-17**, ?*Turiasauria* indet., heart-shaped tooth (SHN (JJS) 146, Salir do Porto) in lingual (**16**) and labial (**17**) views; **18**, Sauropoda indet., middle caudal vertebra (SHN 537, Salir do Porto) in left view. Black scale bar: 5 cm; Grey scale bar: 0.5 cm. See Anatomical abbreviations for abbreviations.

the type material for *Miragaia longicollum* was found (Mateus et al., 2009). Sauropod remains are scarce in this area (Figure 8.1), although there are also some specimens housed in private collections (e.g., Mateus, 2005; pers. observ., PM), such as a partial tail of an indeterminate sauropod, collected near the town of Bombarral.

Some older occurrences from the Alcobaça Formation were found in the Alcobaça, Bombarral, and A-dos-Cunhados regions (Bombarral-Alcobaça Sub-basin) and referred to Sauropoda (Lapparent and Zbyszewski, 1957): *i*) an heart-shaped tooth (Figure 9.6-7) from Fervença (Sauvage, 1897-98; Lapparent and Zbyszewski, 1957), tentatively referred to an indeterminate eusauropod probably related to *Turiasauria* (Mocho et al.,

2016b); and *ii*) a posterior caudal vertebra from Chiqueda de Cima (Lapparent and Zbyszewski, 1957), representing an indeterminate sauropod. Some elements were found in the Bombarral Fm.: *i*) an anterior caudal vertebra (Figure 9.5, MG 4804) of an indeterminate eusauropod from Salir de Matos; *ii*) a middle caudal vertebrae (Figure 9.3-4, MG 4819, 4821, 4826) of an indeterminate diplodocine from São Gregório da Fanadia; and *iii*) a large left astragalus (Figure 9.1-2, MMPM.P/75) attributed to an indeterminate eusauropod was found in Imaginário (Caldas da Rainha) (Mocho et al., 2016a, 2017).

An incomplete skeleton composed of axial elements (cervical and dorsal vertebrae; Figure 9.8, ML 418), considered as aff. *Dinheirosaurus*

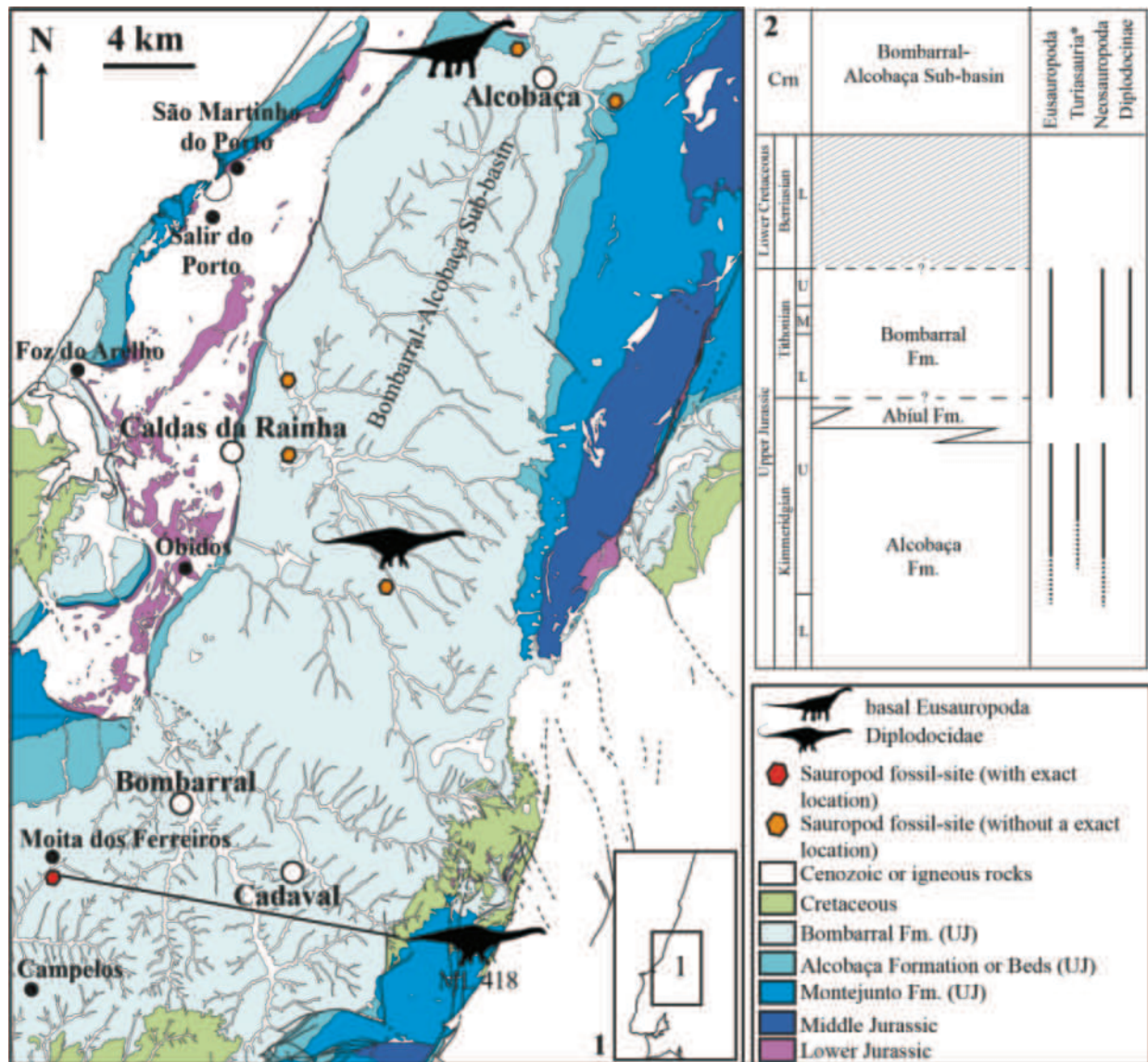


FIGURE 8. 1, Geological map of the Alcobaça, Bombarral and A-dos-Cunhados region (located on the Bombarral Sub-basin, and considered part of the Bombarral-Alcobaça Sub-basin following Taylor et al., 2014) (modified from Camarate França et al., 1960; Zbyszewski and Moitinho de Almeida, 1960; Camarate França and Zbyszewski, 1963; Zbyszewski and Torre de Assunção, 1965; Zbyszewski et al., 1966; Azerêdo et al., 2010) with the localities yielding fossil remains referred to Sauropoda. **2,** Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for Bombarral-Alcobaça Sub-basin (stratigraphy based on Kullberg et al., 2006 and Azerêdo et al., 2010) with the stratigraphic distribution of the main sauropod clades identified in this area. Crn – Chronostratigraphy. *the presence of Turiasauria is only supported by the presence of heart-shaped teeth.

(Antunes and Mateus, 2003) and *Apatosaurus* sp. (Mateus, 2005), was found close to Moita dos Ferreiros (Lourinhã, Bombarral Formation). These elements are poorly preserved. Mannion et al. (2012) distinguished this specimen from *Dinheirosaurus lourinhanensis* and suggested that it might represent a second diplodocid taxon from the Upper Jurassic of the Lusitanian Basin. Tschoop et al. (2015) suggested that it represents an indetermi-

nate diplodocine different from *Dinheirosaurus*. The full preparation of the dorsal vertebrae of *Dinheirosaurus lourinhanensis* will be important to test this hypothesis.

In summary, the dinosaur fauna in the Alcobaça, Bombarral and A-dos-Cunhados area are poorly understood. The recorded sauropod fauna in this area is composed of indeterminate taxa, and indeterminate eusauropods (some tentatively

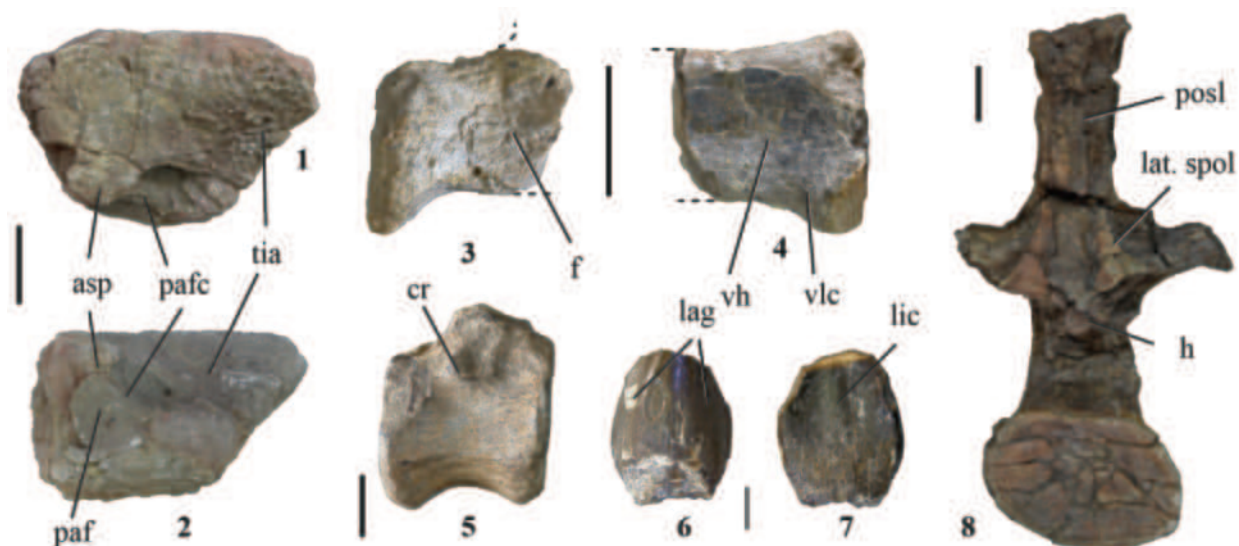


FIGURE 9. Cranial and postcranial sauropod remains from the Alcobaça, Bombarral and A-dos-Cunhados region: **1-2**, Eusauropoda indet., left astragalus (MMPM.P/75, Imaginário) in proximal (**1**) and posterior (**2**) views; **3-4**, Diplodocinae indet., middle caudal vertebra (MG 4819, São Gregório da Fanadia) in right (**3**) and ventral (**4**) views; **5**, Sauropoda indet., anterior caudal vertebra (MG 4804, Salir de Matos) in right view; **6-7**, ?Turiasauria indet., heart-shaped tooth (MG 277, Fervença) in labial (**6**) and lingual (**7**) views; **8**, Diplodocinae indet., middle or posterior dorsal vertebra (ML 418, Moita dos Ferreiros) in posterior view. Black scale bar: 10 cm; Grey scale bar: 0.5cm. See Anatomical abbreviations for abbreviations.

assigned to Turiasauria), and indeterminate diplodocines. One of the diplodocine specimens (ML 418) might represent a diplodocine different from *Dinheirosaurus lourinhanensis* (Mannion et al., 2012; Tschopp et al., 2015).

North Peniche (Figures 10, 11). An Upper Jurassic section, including the Praia da Amoreira-Porto Novo and Bombarral Formations, crops out north of the town of Peniche (Manuppella et al., 1999; Azerêdo et al., 2010) (Figure 10). Some stratigraphic approaches have suggested the presence of the Sobral Fm. along this sequence (e.g., Hill, 1988; Martinus and Gowland, 2011) (Figure 10.2). This section is not very large (its maximum length is about 2 km), but it is rich in fossil sites, some of them known since the first half of the twentieth century. The most important dinosaur site is located in Pedras Muiatas (Peniche) where remains of sauropods and stegosaurs have been collected (Zbyszewski, 1946; Lapparent and Zbyszewski, 1957). Their precise location is not clear. According to the available stratigraphic information (e.g., Lapparent and Zbyszewski, 1957; Camarate França et al., 1960; Hill, 1988; Bernardes, 1992; Schneider et al., 2009; Azerêdo et al., 2010; Martinus and Gowland, 2011; Taylor et al., 2014), these elements probably came from sediments of the Praia da Amoreira-Porto Novo Fm. Some partial middle and

posterior sauropod cervical vertebrae (MG 4915, 4916, 4917 and 4919) were found in Pedras Muiatas. These remains include a misidentified cervical vertebra, previously considered part of an *Omosaurus* individual (Zbyszewski, 1946, pl. I, figure 1). This specimen includes middle and posterior cervical vertebrae (Figure 11.5-6), which have been subject to a systematic revision and might represent a neosauropod form due the presence of polycamerate cervical vertebrae with bifurcated neural spine.

Other sauropod remains were also identified to the north of Peniche. Most of these specimens are deposited in the collections of the MG, ML and SHN. A currently unpublished, partial spatulate tooth (Figure 11.1, MG 8783), bearing lingual facets, was found in Baleal. It can be attributed to an indeterminate eusauropod, possibly a basal macronarian. This tooth morphology is common in mamenchisaurids (Ouyang and Ye, 2002), basal macronarians (Osborn and Mook, 1921; Gilmore, 1925; Ostrom and McIntosh, 1966), and in the euhelopodid *Euhelopus* (Wilson and Upchurch, 2009). Heart-shaped teeth (Figure 11.2-3) are also reported from this area (Mocho et al., 2012, 2016b), which indicate the presence of turiasaurian eusauropods in the outcropping sediments north of Peniche. The SHN houses several specimens from

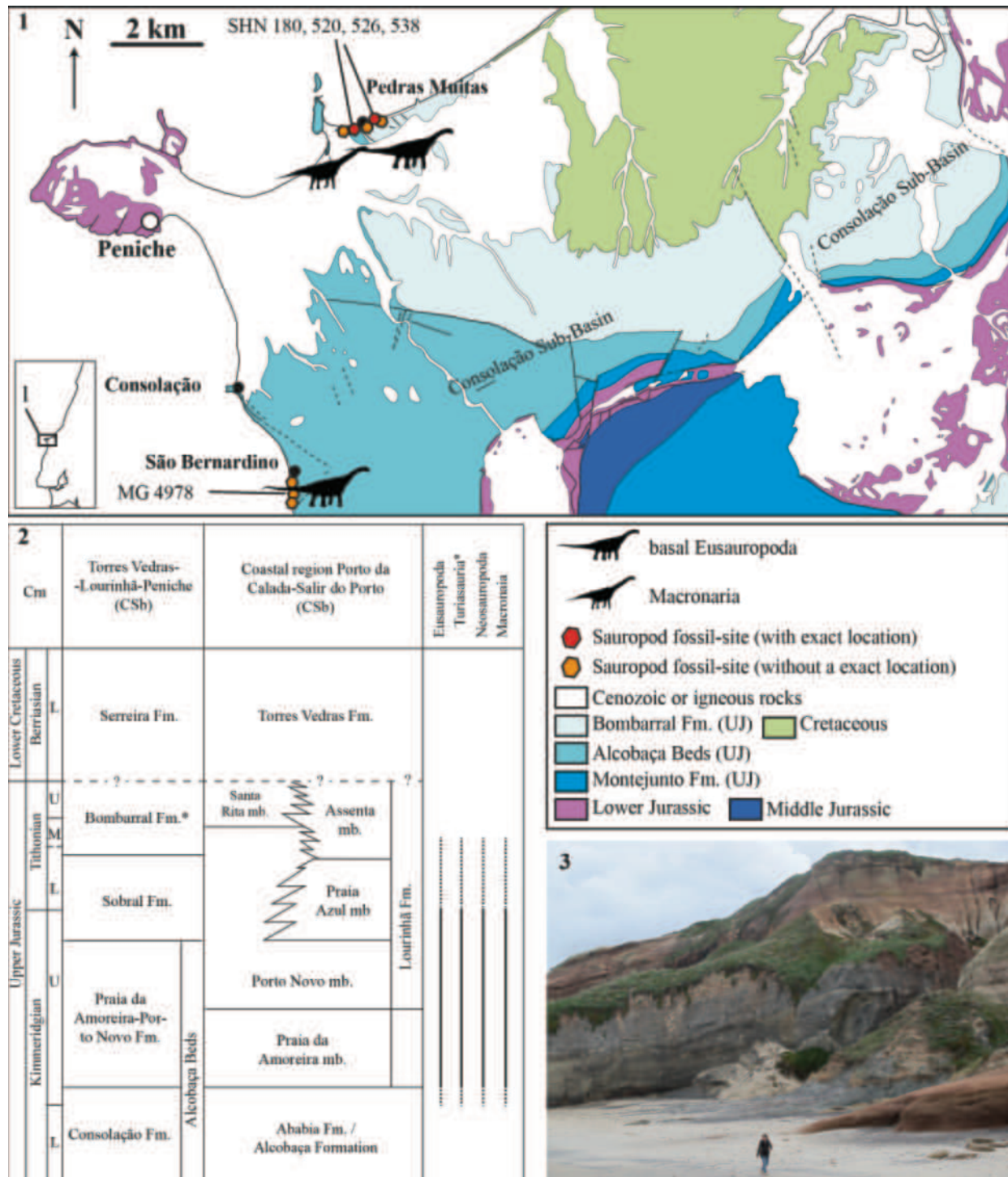


FIGURE 10. 1, Geological map of the Peniche area (located on the Bombarral Sub-basin, and considered part of the Consolação Sub-basin following Taylor et al., 2014) (modified from Camarate França et al., 1960; Zbyszewski and Moitinho de Almeida, 1960; Azerêdo et al., 2010) with the localities yielding fossil remains referred to Sauropoda. **2**, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for the Peniche area based on Manuppella et al. (1999, first column) and Hill (1988, second column) with the stratigraphic distribution of the main sauropod clades identified in this area. **3**) Sediments of the Bombarral Formation in the Almagreira Cliffs. Crn – Chronostratigraphy; *the presence of Turiasauria is only supported by the presence of heart-shaped teeth.

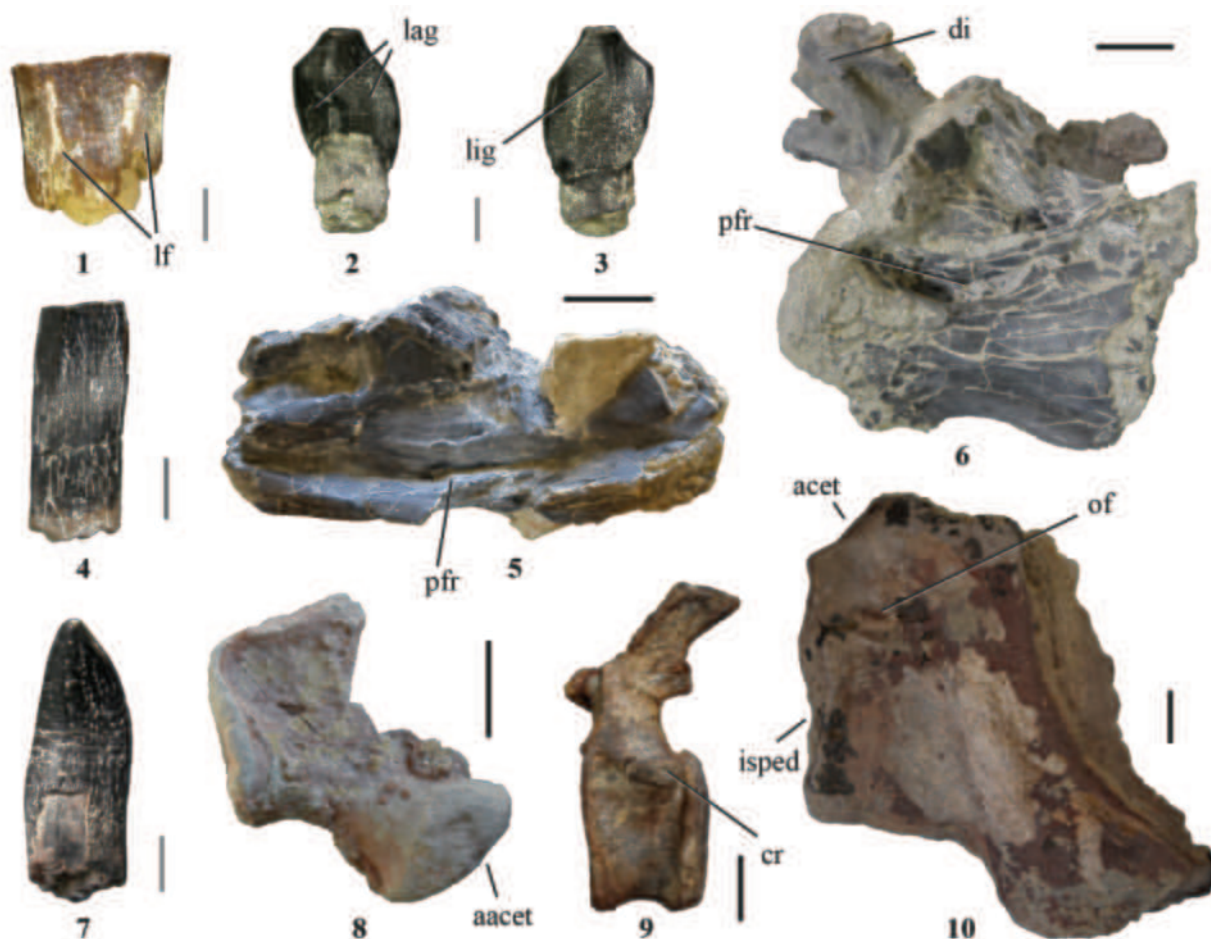


FIGURE 11. Cranial and postcranial sauropod remains from the cliffs located on North of Peniche: **1**, ?*Macronaria* indet., partial spatulate tooth (MG 8783, Baleal) in lingual view; **2-3**, ?*Turiasauria* indet., heart-shaped tooth (SHN (JJS) 141, Baleal) in labial (**2**) and lingual (**3**) views; **4**, *Macronaria* indet., compressed cone-chisel-shaped tooth (SHN 547, Pedras Muitas) in lingual view; **5-6**, *Eusauropoda* indet., middle (MG 4917) and posterior cervical vertebrae from Pedras Muitas in right (**5**) and left (**6**) views, respectively; **7**, *Macronaria* indet., compressed cone-chisel-shaped tooth (SHN 543, Baleal) in lingual view; **8**, sacral rib (SHN, 538, Almagreira) in posterior or anterior view; **9**, *Eusauropoda* indet., anterior caudal vertebra (SHN 180, Baleal) in left view; **10**, *Macronaria* indet., right pubis (SHN 526, Almagreira) in lateral view. Black scale bar: 10 cm; Grey scale bar: 1 cm. See Anatomical abbreviations for abbreviations.

Baleal, Pedras Muitas, and Almagreira (Figure 10.3), which still need preparation, including several axial and appendicular elements (e.g., Figure 11.8-10). One of those specimens is an anterior caudal vertebra with a slightly procoelous centrum (Figure 11.9, SHN 180). The overall morphology (e.g., slightly procoelous centrum and short neural spine with distal rugosities) resembles that of the anterior caudal vertebrae collected from the Spanish sediments of the Villar de Arzobispo Formation, in San Lorenzo (Riodeva), attributed by Cobos et al. (2011) to *Turiasauria*. The procoelous condition is shared with several clades within *Eusauropoda* (e.g., Wilson, 2002; Upchurch et al., 2004). Some compressed cone-chisel-shaped teeth (Figure

11.4, 11.7) collected in the Baleal-Pedras Muitas coastal section are deposited in the SHN collections.

The systematic affinities of the sauropod remains collected north of Peniche still need to be established in a detailed study. However, the currently available information allows the identification of possible *turiasaurs* and basal *macronarians*, including members of the clade that includes *Titanosauriformes* and *Europasaurus* (Figure 10).

Praia da Consolação-Lourinhã-Torres Vedras coastal sector (Figures 12-15). This is the richest area in the Lusitanian Basin concerning Upper Jurassic dinosaur remains (e.g., Lapparent and Zbyszewski, 1957; Dantas, 1990; Antunes and

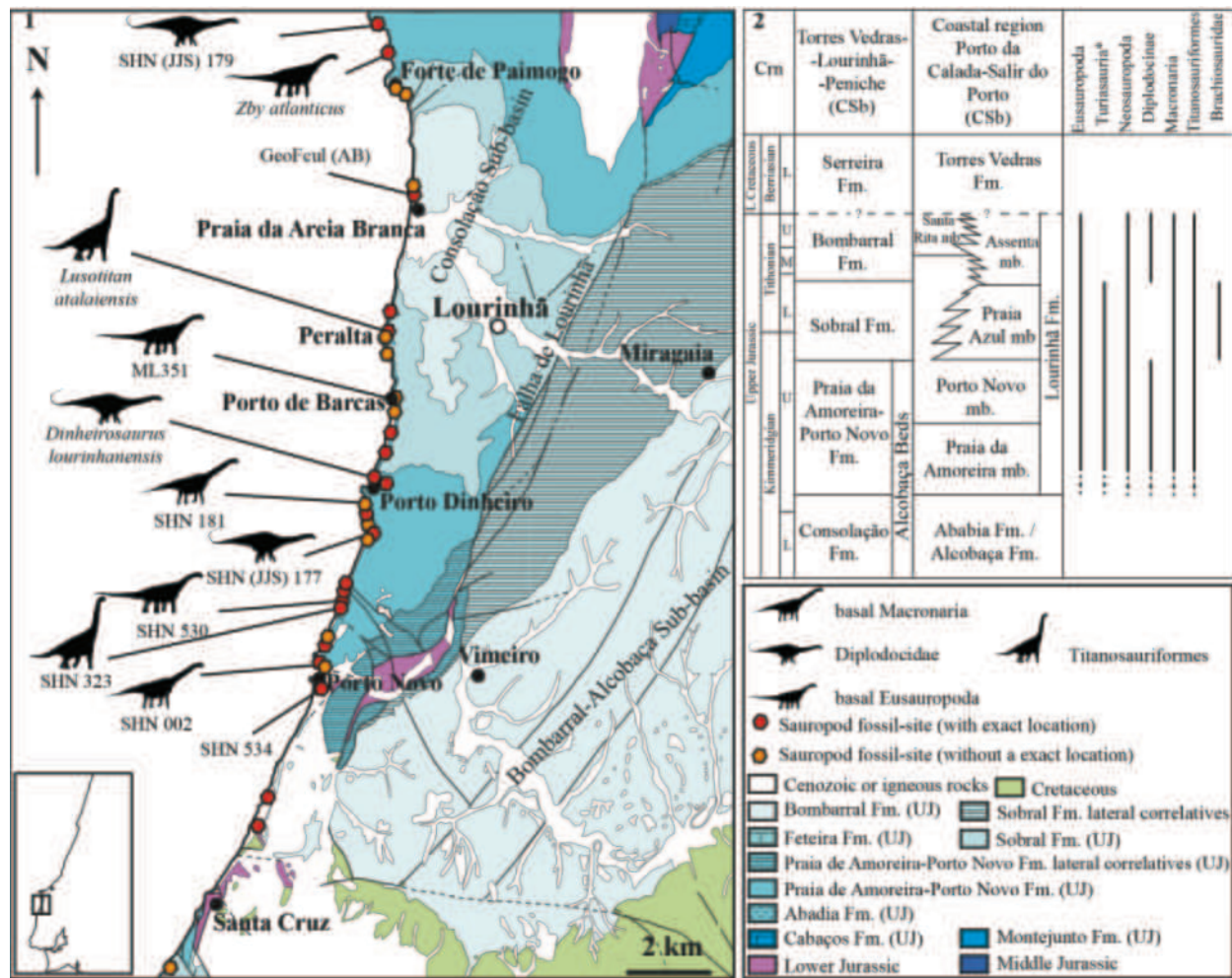


FIGURE 12. 1, Geological map of the coastal sector of Praia da Consolação-Lourinhã-Torres Vedras (located on the Bombarral Sub-basin, and considered part of the Consolação Sub-basin following Taylor et al., 2014) (modified from Manuppella et al., 1999) with the localities yielding fossil remains referred to Sauropoda. **2**, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for the coastal sector of Praia da Consolação-Lourinhã-Torres Vedras based on Manuppella et al. (1999, first column) and Hill (1988, second column) with the stratigraphic distribution of the main sauropod clades identified in this area. Crn – Chronostratigraphy. *the presence of Turiasauria is only supported by the presence of heart-shaped teeth and the holotype of *Zby atlanticus*.

Mateus, 2003; Ortega et al., 2009, 2013) (Figure 12.1). A thick Upper Jurassic sedimentary sequence crops out in this sector and includes deposits of the Praia da Amoreira-Porto Novo, Sobral and Bombarral Formations. This continental sedimentary sequence was deposited above the marine Abadia Fm. (Manuppella et al., 1999) (Figure 12.2). The type specimens of *Lusotitan atalaiensis*, *Dinheirosaurus lourinhanensis* and *Zby atlanticus* (Lapparent and Zbyszewski, 1957; Dantas et al., 1992; Bonaparte and Mateus, 1999; Antunes and Mateus, 2003; Mannion et al., 2012, 2013; Mateus et al., 2014) were found in this area of the Bombarral Sub-basin (Consolação Sub-

basin following Taylor et al., 2014). In addition, many published and unpublished specimens, most of them housed in the palaeontological collections of the MG, ML, and SHN, were also collected in this area (Bonaparte and Mateus, 1999; Mateus, 2005; Yaguë et al., 2006; Mannion et al., 2012; Mocho et al., 2013a, 2013b, 2014a).

The Praia da Amoreira-Porto Novo Formation crops out in several areas along this sector, especially in the sedimentary sections from São Bernardino to Paimogo and from Porto Dinheiro to Praia de Santa Rita (Hill, 1988; Manuppella et al., 1999; Mateus et al., 2013). This late Kimmeridgian-basal Tithonian formation (Fürsich, 1981; Manup-

ella et al., 1999) is well-known for its abundant dinosaur fossil remains, including several sauropod specimens (Lapparent and Zbyszewski, 1957; Dantas, 1990; Manuppella et al., 1999; Antunes and Mateus, 2003; Ortega et al., 2009). This formation is interpreted as having been deposited in a distal alluvial to fluvial meandriform environment (Hill, 1988, 1989).

The holotype of *Zby atlanticus* (Figure 13.13-16, ML 368) was found in the Vale de Pombas cliffs (north of Forte de Paimogo), in the Praia da Amoreira-Porto Novo Formation. This partial skeleton includes a tooth, a chevron, a right partial scapula, and coracoid, an almost complete right forelimb, and some indeterminate elements (Mateus, 2005, 2009; Mateus et al., 2014; pers. observ. PM). The material of *Zby atlanticus* was first attributed to the North American Morrison genus *Camarasaurus* (Mateus, 2005), and subsequently to *Turiasaurus riodevensis* (Mateus, 2009). Mateus et al. (2014) described the species *Zby atlanticus* as a member of Turiasauria. The affinities between *Zby* and the members of the Turiasauria clade were previously noted by other authors (Mateus, 2009; Mocho et al., 2012; Royo-Torres and Upchurch, 2012).

Lapparent and Zbyszewski (1957) reported the presence of some specimens collected north of the Forte de Paimogo (Praia da Amoreira-Porto Novo Formation). Non-sauropod dinosaurs were also found in this locality (Lapparent and Zbyszewski, 1957; Escaso et al., 2008; Hendrickx and Mateus, 2014). A partial caudal series (MG 4978), with 15 caudal vertebrae, was found in São Bernardino (Peniche). A partial right humerus (Figure 13.25, MG 4976) of a sauropod was found in Praia dos Frades (Peniche) and was attributed to *Apatosaurus alenquerensis* (Lapparent and Zbyszewski, 1957). This humerus has a crest on the posterior face of the proximal end, which is here identified as a shared feature with the humerus of *Duriatitan humerocristatus*, from the British lower Kimmeridge Clay Fm. (Barrett et al., 2010), being considered as cf. *Duriatitan humerocristatus* (Mocho et al., 2016a). An unpublished metacarpal I (SHN 583) found in Praia dos Frades (Peniche) shares the morphology of metacarpal I of *Turiasaurus riodevensis* and *Zby atlanticus* with the presence of a rough platform on the laterodorsal border of the distal end. It is thus tentatively considered as cf. Turiasauria.

A so far unprepared diplodocid specimen (Figure 13.27, SHN (JJS) 179) from Praia da Vermelha (Peniche, Praia da Amoreira-Porto Novo Forma-

tion), comprises axial and appendicular elements (Peniche; Mocho et al., 2014a). The morphology of the neural spines (posterior dorsal or anterior caudal), with a well-defined prespinal lamina, a rectangular shape (anteroposteriorly compressed), and with a slight dorsal bifurcation, is similar to the apomorphic morphology in the posterior dorsal and anterior caudal neural spines of diplodocids, such as *Supersaurus*, *Dinheirosaurus*, *Diplodocus*, and *Barosaurus* (e.g., Hatcher, 1901; Lull, 1919; McIntosh, 2005; Mannion et al., 2012; pers. observ., PM). Other unprepared sauropod specimens from this sector, also from the Praia da Amoreira-Porto Novo Fm., are housed in the collections of the SHN and ML (see list of Mateus, 2005, for ML specimens; pers. observ., PM). Several teeth have also been found between Forte de Paimogo and Praia da Consolação, including heart-shaped teeth, probably referable to Turiasauria (Mocho et al., 2012, 2016b), spatulate teeth (e.g., SHN 516, SHN 540), attributed to indeterminate eusauropods, probably basal macronarians, and compressed cone-chisel-shaped teeth (e.g., SHN 546), a morphology shared with titanosauriforms and the basal macronarian *Europasaurus*. A skull fragment bearing heart-shaped teeth was found in Praia dos Frades (Figure 13.7-8, SHN 582) and probably represents a turiasaurian sauropod.

To the south of Porto Dinheiro, the type locality of *Dinheirosaurus lourinhanensis* (Dantas et al., 1992; Bonaparte and Mateus, 1999; Mannion et al., 2012), an extensive section of the Praia da Amoreira-Porto Novo Formation crops out. The border between the municipalities of Torres Vedras and Lourinhã is located in this relatively poorly prospected area. New discoveries reveal a rich dinosaur fauna, including theropods, ornithopods, thyreophorans, and sauropods, as well as other vertebrate groups, such as turtles and crocodyli-forms (e.g., Malafaia et al., 2008; Escaso et al., 2010a, 2010b; Pérez-García and Ortega, 2011). Several fossil sites containing sauropods were found in this area, including some partial skeletons.

The first remains of the holotype of *Dinheirosaurus lourinhanensis* were identified in 1987, in the cliffs of Porto Dinheiro. Consequently, in 1988 and 1991, a team composed of members of the Museu Nacional de História Natural e da Ciência (Lisboa, Portugal), Salamanca University (Salamanca, Spain) and GEAL (Lourinhã, Portugal) proceeded to the extraction of a series of partially articulated cervical and dorsal vertebrae, with associated dorsal ribs, as well as caudal vertebrae and pelvic elements (Figures 13.28-30, 14.1) (Dan-



FIGURE 13 (caption on next page).

tas et al., 1992). Bonaparte and Mateus (1999) defined a new diplodocid taxon, *Dinheirosaurus alenquerensis*, considered as a diplodocine form closely related to the North American Late Jurassic *Supersaurus* (Rauhut et al., 2005; Whitlock, 2011; Mannion et al., 2012; Tschopp and Mateus, 2013; Tschopp et al., 2015). In fact, Tschopp et al. (2015) suggested that *Dinheirosaurus lourinhanensis* might represent a species of *Supersaurus*, proposing the new combination *Supersaurus lourinhanensis*. Several remains of the type specimen (ML 414), including several caudal vertebrae (pers. observ., FO and PM), need to be prepared for the confirmation or refutation of this hypothesis. The *Dinheirosaurus* type locality is stratigraphically close to the boundary between the Praia da Amoreira-Porto Novo and Sobral Formations (Manuppella et al., 1999; field observations, PM).

Another partial diplodocid individual was found in Valmitão (Lourinhã), south of Porto Dinheiro (Mocho et al., 2014a). This specimen and the *Dinheirosaurus* holotype are the most complete diplodocids of the European Upper Jurassic record. The Valmitão specimen (SHN (JJS) 177) comprises elements of the axial skeleton (dorsal?, sacral, and anterior caudal vertebrae; ribs and chevrons) and pelvic girdle (ilia, ischia, and pubis) (Figure 13.10-12). SHN (JJS) 177 can be referred to Flagellicaudata on the basis of the presence of an expanded distal end of the ischia (following Whitlock, 2011). Rectangular anterior caudal neural spines in anterior view and the presence of diapophyseal laminae on the anterior caudal ribs

support the assignation of SHN (JJS) 177 to Diplodocidae (*sensu* Whitlock, 2011). The presence of wing-like, anterior caudal ribs, dorsal concavity in the neural spines (slightly bifurcated), and ventral and lateral pneumaticity, suggest that the SHN (JJS) 177 is closely related to diplodocines, such as *Diplodocus*, *Barosaurus*, and *Tornieria* (Osborn, 1899; Hatcher, 1901; Lull, 1919; McIntosh, 2005; Remes, 2006; Whitlock, 2011; Tschopp et al., 2015).

Many sauropod specimens from the coastal cliffs between Porto Dinheiro and Santa Rita are housed in the SHN, and most still require preparation. Mateus (2005) also reported an appreciable number of specimens from this area and deposited in the ML. In 2003 and 2009, the SHN excavated a partial and articulated skeleton (Figure 14.2-3) in Santa Rita (Torres Vedras), including a partial tail and pelvis, associated with limb bones (Figure 13.26, SHN 534). The systematic affinities of this specimen still need to be clarified. Close to this quarry is the type locality of the pleurosternid turtle *Selenemys lusitanica*, also from the Praia da Amoreira-Porto Novo Formation (Pérez-García and Ortega, 2011). Another fossil site prospected by the SHN is located in Porto Novo (Torres Vedras). Several axial and appendicular sauropod bones were recovered there. This specimen (SHN 002) shares the general morphology of the forelimb bones with the camarasaurid *Lourinhasaurus alenquerensis*; nevertheless, no diagnostic features can be identified. These two fossil sites are stratigraphically close to the upper boundary of the

FIGURE 13. (Figure on previous page.) Cranial and postcranial sauropod remains from sediments of the Praia da Amoreira-Porto Novo Fm. of the coastal sector of Praia da Consolação-Lourinhã-Torres Vedras: **1-2**, ?Turiasauria indet., heart-shaped tooth (SHN (JJS) 142, Praia da Corva) in lingual (**1**) and labial (**2**) views; **3-4**, ?Macronaria indet., spatulate tooth (SHN 513, Porto Novo) in labial (**3**) and lingual (**4**) views; **5-6**, Macronaria indet., compressed cone-chisel-shaped tooth (SHN 578, Valmitão) in lingual (**5**) and labial (**6**) views; **7-8**, Eusauropoda indet., partial left maxilla (SHN 582, Praia dos Frades) in lateral (**7**) and posterior (**8**) views; **9**, Titanosauriformes indet., posterior caudal vertebra (SHN 523, Praia da Corva) in right view; **10-12**, Diplodocinae indet., partial skeleton (SHN (JJS) 177, Valmitão), anterior caudal neural spine in posterior view (**10**), anterior caudal centrum in right view (**11**) and left ischium in medial view (**12**); **13-16**, holotype material of *Zby atlanticus* (ML 368, Vale de Pombas), right ungual I in lateral view (**13**), right humerus in anterior view (**14**), right radius in posterior view (**15**), right ulna in lateral view (**16**); **17**, Eusauropoda indet., partial distal forked-chevron (SHN 587, Praia da Corva) in medial view; **18**, Sauropoda indet., pedal ungual I (SHN 524, Praia de Pedrogãos) in lateral view; **19-22**, Macronarian indet., partial skeleton (SHN 181, Valmitão), right astragalus in proximal view (**19**), anterior caudal vertebra in anterior view (**20**), right tibia in lateral view (**21**) and right fibula in medial view (**22**); **23-24**, Eusauropoda indet., partial skeleton (SHN 530, Praia da Corva), anterior chevron in anterior view (**23**) and anterior caudal vertebra in posterior view (**24**); **25**, cf. *Duriantitan humerocristatus*, humerus (MG 4976, Praia dos Frades) in anterior view; **26**, Sauropoda indet., partial skeleton (SHN 534, Santa Rita), middle chevron in posterior view; **27**, Diplodocidae indet., partial skeleton (SHN (JJS) 179, Praia Vermelha), dorsal/caudal (?) neural spine in posterior view; **28-30**, holotype material of *Dinheirosaurus lourinhanensis* (ML 414, Porto Dinheiro), proximal end of a dorsal rib in anterior view (**28**), anterior caudal neural spine in posterior view (**29**) and articulated dorsal vertebrae in right view (**30**). Black scale bar: 10 cm; Grey scale bar: 5 cm; Brown scale bar: 1 cm. See Anatomical abbreviations for abbreviations.



FIGURE 14. 1, *Dinheirosaurus lourinhanensis* dorsal series (ML 414) in Porto Dinheiro with the palaeontologist Pedro Dantas in 1991. 2-3, A partial skeleton in the field (SHN 534) collected in Santa Rita, including a partial tail, in 2003 (2) and several appendicular bones, in 2009 (3).

Praia da Amoreira-Porto Novo Fm. with the Sobral Fm. (Manuppella et al., 1999; field observations, PM). Another specimen (SHN 530), including sacral and caudal vertebrae, and appendicular bones (Figure 13.23-24), was found in the cliffs of Praia da Corva (Torres Vedras). The anterior caudal vertebrae (Figure 13.24) resemble the morphology present in Iberian turiasaurs (e.g., Casanovas et al., 2001), with slightly procoelous centra and fan-like caudal ribs, lacking the lateral and ventral pneumaticity and dorsalised neural spine, which would be typical of diplodocids (e.g., Hatcher, 1901; McIntosh, 2005; Remes, 2006). This specimen also preserves long and bridged anterior chevrons. An unpublished set of anterior, middle, and posterior caudal vertebrae (Figure 13.9), probably belonging to a single individual, was also found at Praia da Corva (SHN 523). It might represent an indeterminate titanosauriform, based on the presence of anteriorly displaced neural arches, pneumatic fossae (as occur in *Giraffatitan* or *Andesaurus*, Mannion and Calvo, 2011; Wedel and Taylor, 2013), and dorsoventrally compressed centrum. Finally, an also unpublished medium-sized individual (SHN 181) found in Valmitão is cur-

rently being prepared and described. It includes caudal vertebrae, and pectoral, pelvic, and hind-limb elements (Figure 13.19-22). This specimen presents several peculiar features and probably represents a new sauropod taxon. Furthermore, several teeth belonging to different morphotypes were recovered from the area between Porto Dinheiro and Santa Rita. These specimens include spatulate (Figure 13.3-4, SHN 513), and heart- (Figure 13.1-2, see Mocho et al., 2012, 2016b), and compressed cone-chisel-shaped teeth (Figure 13.5-6, SHN 574, 575, 578).

The Sobral Formation is a lateral equivalent of the lowest part of the Bombarral Fm., representing a regional transgression (e.g., Hill, 1988). The Sobral Fm. was deposited in a deltaic to marginal marine environment (Hill, 1988; Manuppella et al., 1999). In the western part of the Bombarral Sub-basin (i.e., Consolação Sub-basin, following Taylor et al., 2014), this formation crops out in the coastal section from Peralta to Porto Dinheiro. Several sauropod specimens from the Sobral Fm. were reported, most notably the lectotype of *Lusotitan atalaiensis*. It was found in the Peralta cliffs, close to the Atalaia locality (Lourinhã). Lapparent and

Zbyszewski (1957) originally considered this specimen to represent a new species of *Brachiosaurus* (at that time the genus *Brachiosaurus* included two species, the North American *B. altithorax* and the African *B. brancai*). Subsequently, Antunes and Mateus (2003) established the new genus, *Lusotitan*, to denominate this specimen. Mannion et al. (2013) presented a systematic revision of the Peralta specimen, considering it a basal macronarian, and, possibly, a brachiosaurid. The brachiosaurid affinities were recently supported by Mocho et al. (2016c). This specimen includes dorsal, sacral, and caudal vertebrae, dorsal ribs, chevrons, pelvic, forelimb, and hindlimb elements (Figure 15.9-14; Lapparent and Zbyszewski, 1957; Antunes and Mateus, 2003; Mannion et al., 2013; Mocho et al., 2016c). Several sauropod teeth were found at Peralta, including spatulate (Figure 15.1-2, Mocho et al., 2011) and heart- (Mocho et al., 2012, 2016b), and compressed cone-chisel-shaped teeth (Figure 15.3-6). Some isolated bones were also found in this region (Figure 15.7).

Porto das Barcas is another relevant locality concerning dinosaur remains. The holotype of the ornithomimid *Eousdryosaurus* (Dantas et al., 2000; Escaso et al., 2014) and nests with theropod eggs tentatively referred to *Torvosaurus* (Castanhinha et al., 2009; Araújo et al., 2013), were found there. Several sauropod specimens from Porto das Barcas were referred to *Apatosaurus alenquerensis* by Lapparent and Zbyszewski (1957), including caudal vertebrae (MG 8800, 8805). MG 30390 is an unpublished partial skeleton that represents an indeterminate eusauropod, according to the presence of procoelous anterior caudal vertebrae, which are only known in Eusauropoda, such as mamenchisaurids, turiasaurs, diplodocids, and titanosaurs (e.g., Salgado, 1997; Wilson, 2002; Upchurch et al., 2004; Carballido and Sander, 2014). Another partial skeleton from Porto das Barcas is housed in the ML (ML 351), including a partial caudal series, sacrum and fibula (Antunes and Mateus, 2003; Mateus, 2005). Antunes and Mateus (2003) and Mateus (2005) referred this specimen to *Lourinhasaurus alenquerensis*, but this specimen does not bear diagnostic features that support this taxonomic assignment. The detailed preparation and study of this material is in process (RC, personal commun., 2015). Other specimens from this locality are housed in the ML and SHN (Mateus, 2005, pers. observ., PM), including heart-shaped (Mocho et al., 2012, 2016b), and compressed cone-chisel-shaped teeth (e.g., SHN 576). From Lage Fria (Porto das Barcas), Tschopp,

and Mateus (2012) described a sternal plate (ML 684), suggesting that it might pertain to *Turiasaurus riodevensis* or *Lusotitan atalaiensis*. Lapparent and Zbyszewski (1957, pl. XIII, figure 31-33) identified one vertebra from Porto das Barcas (MMLT 602528) as a posterior dorsal vertebra of *Megalosaurus pombali*. However, it represents an anterior caudal vertebra of an indeterminate sauropod. Another sauropod caudal vertebra (MMLT 602529) from Porto das Barcas was found in the collections of the MMLT, and probably corresponds to a vertebra mentioned by Lapparent and Zbyszewski (1957, pg. 38). This vertebra represents an indeterminate sauropod.

The Tithonian Bombarral Formation crops out in the coastal section from Praia da Areia Branca to Paimogo (including Vale de Frades) (Figure 12.1). This formation lies above the Sobral Fm. (on the Forte de Paimogo locality) and Praia da Amoreira-Porto Novo Fm. (Hill, 1988; Manuppella et al., 1999). Furthermore, the Bombarral Fm. crops out in a wide area to the east of the Lourinhã Fault, from A-dos-Cunhados to Alcobaça (an area included in the Bombarral-Alcobaça Sub-basin by Taylor et al., 2014). The Bombarral Fm. was deposited in a coastal lagoonal to meandering fluvial environment (Manuppella et al., 1999).

West of the Lourinhã Fault, the Bombarral Formation crops out between Peralta and Vale de Frades (south of Paimogo), and from south of Santa Rita to the town of Santa Cruz. Some bones from the Bombarral Fm. were reported by Lapparent and Zbyszewski (1957). A partial left femur (Figure 15.15, MG 4986) was found in Praia da Areia Branca and was originally referred to *Brachiosaurus atalaiensis* (Lapparent and Zbyszewski, 1957). It has recently been reinterpreted as an indeterminate titanosauriform (Mannion et al., 2013). Two caudal vertebrae housed in the palaeontological collections of the Museu Nacional de História Natural e da Ciência (Lisboa) were recovered in Areia Branca: an anterior caudal vertebra previously referred to *Brachiosaurus atalaiensis* (Lapparent and Zbyszewski, 1957), and a procoelous anterior caudal centrum (Figure 15.8, MNHNUL.P.R27) referred to *Apatosaurus alenquerensis* (Lapparent and Zbyszewski, 1957). The first element can only be identified as an indeterminate sauropod. The second bone is recognised as belonging to an indeterminate eusauropod, based on the procoelous condition, a feature present in several eusauropod groups (e.g., Salgado et al., 1997; Wilson, 2002; Upchurch et al., 2004; Carballido and Sander, 2014). Lapparent and Zbyszewski



FIGURE 15. Cranial and postcranial sauropod remains from sediments of the Sobral Fm. and Bombarral Fm. of the coastal sector of Praia da Consolação-Lourinhã-Torres Vedras: **1-2**, ?*Macronaria* indet., spatulate tooth (SHN 122, Peralta) in labial (**1**) and lingual (**2**) views; **3-6**, *Macronaria* indet., compressed cone-chisel-shaped teeth (SHN 550 and 551, Peralta) in labial (**3**, **5**) and lingual (**4**, **6**) views; **7**, *Sauropoda* indet., left dorsal transverse process (MG 8809, Atalaia) in dorsal view; **8**, *Eusauropoda* indet., anterior caudal vertebra (MNHNUL.P.R27) in posterior view (Praia da Areia Branca); **9-14**, lectotype material of *Lusotitan atalaiensis* (Peralta), anterior caudal vertebra MG 4985-2 (**11**) and MG 4985-4 (**9**) in posterior view, left astragalus (MG 4803) in posterior view (**10**), right humerus (MG 4989) in anterior view (**12**), right radius (MG 4958) in anterior view (**13**), right tibia (MG 4981) in posterior view (**14**); **15**, *Titanoosauriformes* indet., a proximal end of left femur (MG 4986, Praia da Areia Branca) in anterior view; **16-19**, *Eusauropoda* indet., partial tail (GeoFCUL(AB), Areia Branca), middle chevron in posterior view (**16**), middle caudal vertebra GeoFCUL(AB) 22 in anterior view (**17**), GeoFCUL(AB) 21 in left view (**18**), GeoFCUL(AB) 20 in posterior view (**19**). Black scale bar: 10 cm; Grey scale bar: 1 cm. See Anatomical abbreviations for abbreviations.

(1957, pg. 17) reported the occurrence of a small femur from a sauropod from Vale de Frades, but its present whereabouts are unknown.

Yagüe et al. (2006) published a partial tail found in Praia de Areia Branca (GeoFCUL (AB), Lourinhã), recovered by members of the Department of Geology of the Sciences Faculty of Lisboa University (GeoFCUL). This specimen comprises several middle caudal vertebrae and chevrons (Figure 15.16-19), and was tentatively attributed to a basal macronarian (Yagüe et al., 2006). Comparisons with more complete caudal series (e.g., Osborn and Mook, 1921; McIntosh et al., 1996a, 1996b; Mannion et al., 2013) indicate that the most anterior preserved vertebra probably corresponds to the thirteenth or fourteenth caudal element. The reduction of the caudal ribs before reaching the twentieth caudal vertebra is common in eusauropods (Upchurch et al., 2004). The absence of middle chevrons without anterior and posterior process led Yagüe et al. (2006) to refer this sauropod to *Macronaria*. Nevertheless, this feature is also present in the non-neosauropod *Jobaria* (Serenó et al., 1999). The available elements do not present features supporting its placement within *Macronaria*, so that we prefer an identification of this material as *Eusauropoda* indet. A procoelous anterior caudal vertebra (MMPM.P/73) of an indeterminate eusauropod was collected in Paimogo (Mocho et al., 2016b). No precise location was given for this element. As a result, and taking into account that in this locality sediments of both the Bombarral and Sobral Formations crop out (Hill, 1988; Mannupella et al., 1999), its precise stratigraphic context is not known. An important section of the Bombarral Fm. crops out south of Santa Rita and several unpublished elements were collected there, including some presacral vertebrae preserved in the SHN (e.g., SHN 006, 535).

In conclusion, the Praia da Consolação-Lourinhã-Torres Vedras coastal sector presents the most diverse Portuguese Upper Jurassic fossil record for sauropods, including non-neosauropod eusauropods, such as turiasaurs (e.g., *Zby atlanticus*), diplodocines (e.g., *Dinheirosaurus lourinhanensis* and SHN (JJS) 177), basal macronarians (e.g., SHN 181), and titanosauriforms, including brachiosaurids (e.g., *Lusotitan atalaiensis*). The presence of camarasaurid macronarians cannot be confirmed in this area, but the systematic study of SHN 002 will allow the testing of its affinities with *Lourinhasaurus alenquerensis* and other camarasaurids.

Arruda Sub-Basin

The Arruda Sub-basin is located in the SE part of the central sector of the Lusitanian Basin and has few known dinosaur fossil sites (Figures 16, 17), a fact that may in part be related to the absence of a wide area of exposed Upper Jurassic outcrops. This half-graben basin has a similar Upper Jurassic stratigraphy to that of the Turcifal Sub-basin (Kullberg et al., 2006, 2013; Figure 2). The vertebrate fossil record from this sub-basin is mainly composed of sauropod dinosaurs (Lapparent and Zbyszewski, 1957; Antunes and Mateus, 2003; Ortega et al., 2009).

One of the most complete sauropod individuals from the European Upper Jurassic record was discovered in the Arruda Sub-basin. The sole specimen identified was used to define a new species of *Apatosaurus*: *Apatosaurus alenquerensis* (Lapparent and Zbyszewski, 1957). Dantas et al. (1998) proposed a new genus for this taxon, *Lourinhasaurus*, resulting in the new combination *Lourinhasaurus alenquerensis*. The specimen includes cervical, dorsal, sacral, and anterior caudal vertebrae, dorsal and sacral ribs, scapular and pelvic elements, and bones of the hindlimb and forelimb (Figure 17.1-6, 17.8-17; Lapparent and Zbyszewski, 1957; Mocho et al., 2014b). The recent systematic revision of the *Lourinhasaurus* lectotype confirmed the placement of this taxon within *Camarasauridae* (Mocho et al., 2014b), a hypothesis previously suggested by other authors (McIntosh, 1990a, 1990b; Wilson and Sereno, 1998). A partial opisthocoelous dorsal centrum (Figure 17.7, MG 4799) was found in Castanheira (Vila Franca de Xira), in coarse sandy arkosic sediments of the Abadia Formation (Leinfelder and Wilson, 1989). This element was originally described as a metatarsal V by Lapparent and Zbyszewski (1957). There are some unpublished fossils deposited in the MG collections that might come from Alenquer or even from Moinho do Carmo, but these specimens show different preservation and taxonomic features when compared with the material of the *Lourinhasaurus* lectotype. This raises doubt about their locality of origin.

The scarce record of the Arruda Sub-basin only allows the identification of an indeterminate neosauropod and a camarasaurid macronarian (*Lourinhasaurus alenquerensis*) preserved in sediments of the Abadia and the Sobral Formations, respectively (Figure 16.1-2).

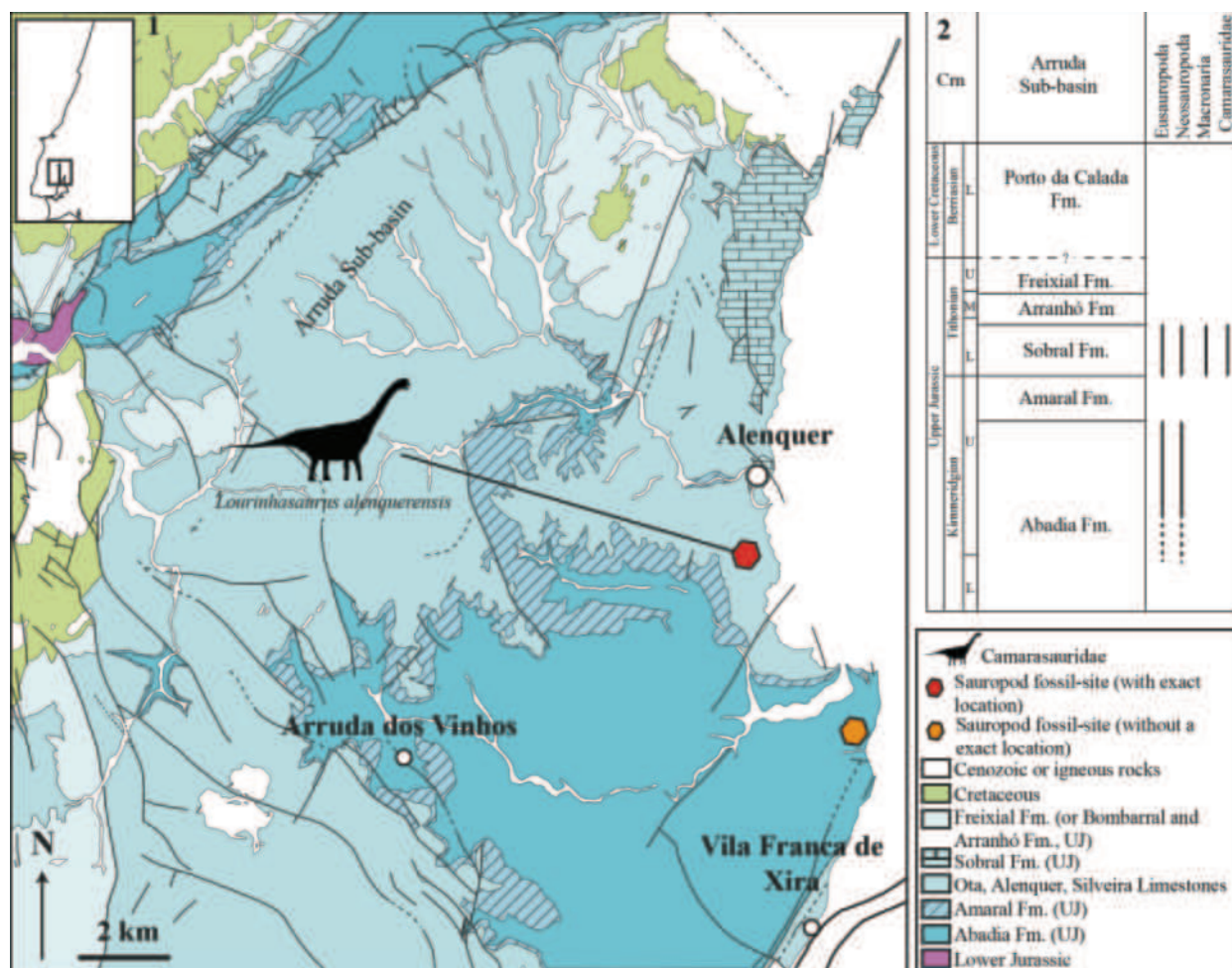


FIGURE 16. 1, Geological map of Arruda Sub-basin (modified Zbyszewski and Torre de Assunção, 1965; Zbyszewski et al., 1966) with the localities yielding fossil remains referred to Sauropoda. **2**, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for Arruda Sub-basin based on Kullberg et al. (2006) with the stratigraphic distribution of the main sauropod clades identified in this area. Cm – Chronostratigraphy.

Turcifal Sub-basin

The Turcifal Sub-basin is located west of the Arruda Sub-basin, in the SW part of the central sector, corresponding to distal palaeoenvironments, but showing abundant deltaic inputs from the west. The stratigraphy of both sub-basins is similar (Kullberg et al., 2006, 2013). Several authors provided recent updates on the stratigraphy of this area (e.g., Pereda-Suberbiola et al., 2005; Kullberg et al., 2006, 2013). Its Upper Jurassic outcrops are not as extensive as those of the Bombarral Sub-basin, but dinosaur fossil sites are particularly abundant in the coastal sector (Figures 18, 19). A diverse dinosaur fauna, composed of sauropods, theropods, thyreophorans, and ornithomorphs, has been identified. This sub-basin is bordered in the north by the Torres Vedras-Montejunto

Fault and in the east by the Runa Fault, which separates it from the Arruda Sub-basin (e.g., Wilson, 1988; Figure 2).

Theropods are represented by allosaurids, with an important specimen coming from Cambe-las (Malafaia et al., 2009b; Ortega et al., 2009). Thyreophoran dinosaurs are represented in this sub-basin by the holotype of the ankylosaur *Dracopelta zbyszewskii* (Galton, 1980; Pereda-Suberbiola et al., 2005), found in sediments of the Freixial Formation in Assenta (Torres Vedras). Another partial ankylosaur skeleton was found in the Porto Calada locality (Mafra), and tentatively identified as a 'polacanthid' nodosaurid (Mateus et al., 2013). Material referred to the stegosaur *Dacentrurus* was also described from the Moçafaneira locality (Escaso et al., 2007b).

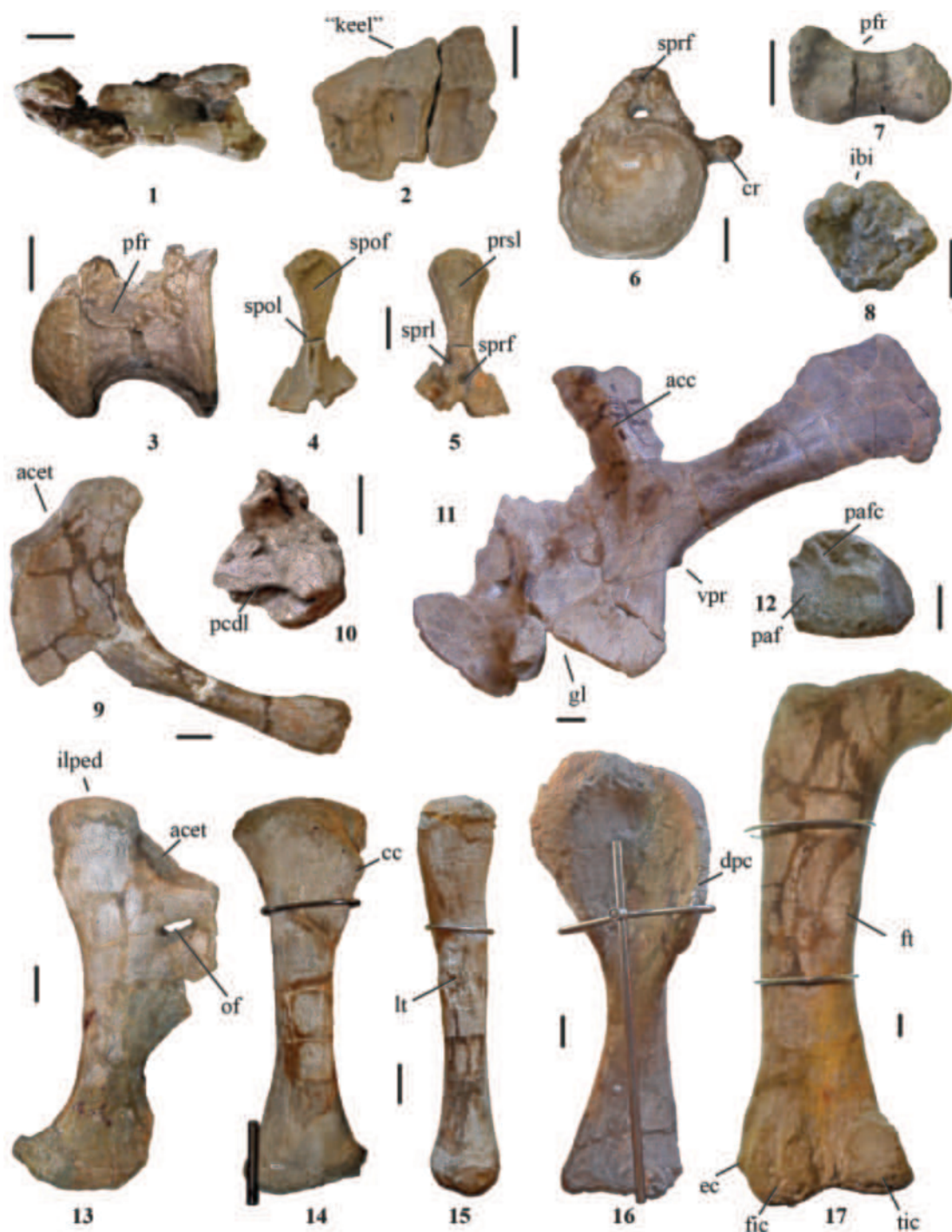


FIGURE 17. Postcranial sauropod remains from the Arruda Sub-basin: 1-6 and 8-17, lectotype material of *Lourinhasaurus alenquerensis* (Moinho do Carmo), middle-to-posterior cervical centrum (MG 30373) in left view (1), fused sacral neural spines (MG 30376) in left view (2), dorsal centrum (MG 4956) in left view (3), anterior caudal neural spine (MG 30374) in posterior (4) and anterior (5) views, anterior caudal centrum (MG 4956) in anterior view (6), middle dorsal neural spine (MG 30384) in posterior view (8), left ischium (MG 4957) in lateral view (9), posterior cervical neural spine (MG 30379) in right view (10), left scapula and coracoids (MG 5780) in lateral view (11), left astragalus (MG 30375) in proximal view (12), left pubis (MG 4970) in lateral view (13), left tibia (MG 4983) in anterior view (14), left fibula (MG 4984) in lateral view (15), left humerus (MG 2) in anterior view (16) and left femur (MG 4931) in posterior view (17); 7, Neosauropoda indet., partial dorsal centrum (MG 4799, Castanheira) in right view. Black scale bar: 10 cm. See Anatomical abbreviations for abbreviations.

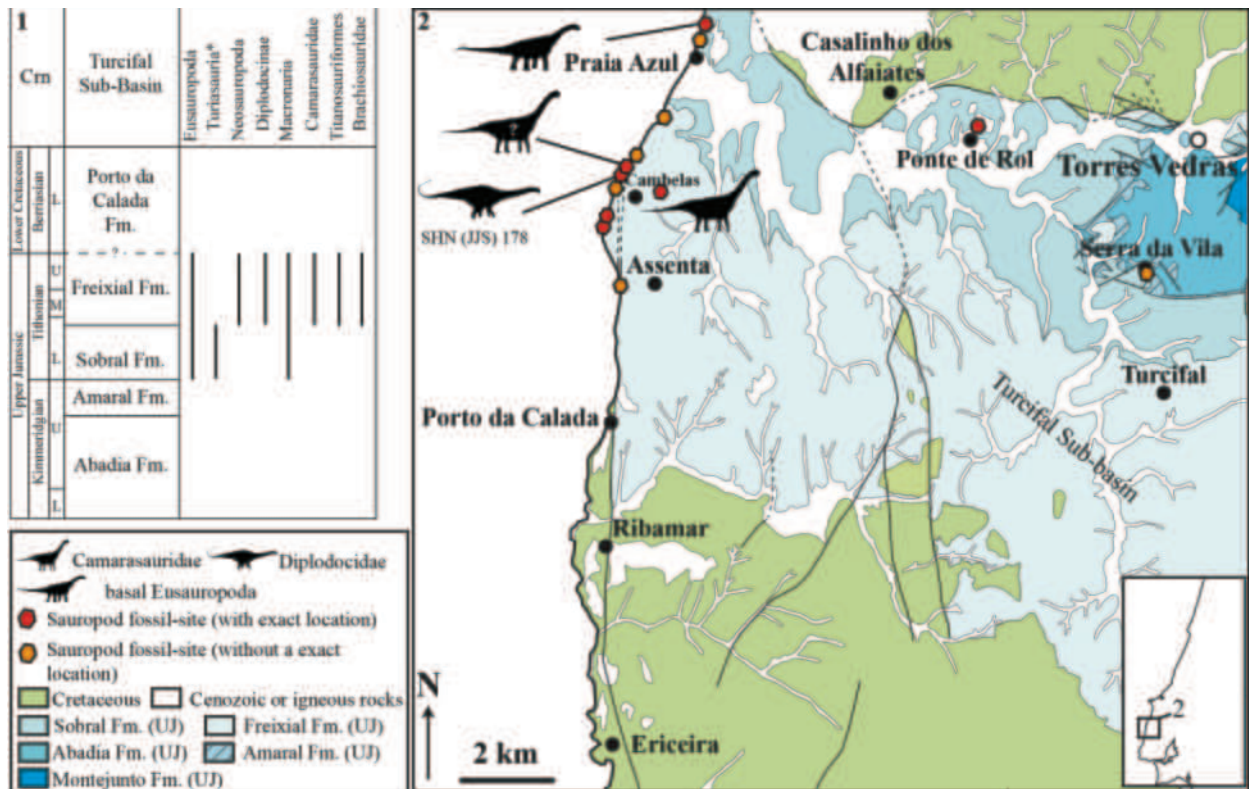


FIGURE 18. 1, Simplified stratigraphy of the Kimmeridgian-Tithonian sequence for Turcifal Sub-basin based on Pereda-Suberbiola et al. (2005), Kullberg et al. (2006) and Schneider et al. (2009) with the stratigraphic distribution of the main sauropod clades identified in this area. **2**, Geological map of Turcifal Sub-basin (modified from Zbyszewski et al., 1955) with the localities yielding fossil remains referred to Sauropoda. Crn – Chronostratigraphy; *the presence of Turtosauria is only supported by the presence of heart-shaped teeth.

Non-dinosaur vertebrates are also present in the sediments of this basin. Among them, the turtle record is very significant, including the type material of “*Plesiochelys*” *choffati* and *Hylaeochelys kappa* (Sauvage, 1897-98; Pérez-García et al., 2008; Pérez-García and Ortega, 2013; Pérez-García, 2015). The record of crocodyliforms is also abundant, represented not only by osteological elements, but also by a nest with eggs, found in the Cambelas area (Russo et al. 2014a, 2014b, 2017).

Sauropods are well-represented in the Turcifal Sub-basin. Most of the record of this clade is from recent findings, and so relatively little information is available yet, because most of these specimens are currently under study and/or in preparation. A short section of the Praia da Amoreira-Porto Novo Formation (fluvial environment) is found south of the Santa Cruz locality. A middle caudal vertebra (Figure 19.10, MG 4802) was collected in this area and was attributed to *Apatosaurus alenquerensis* (Lapparent and Zbyszewski, 1957). This vertebra is here considered to represent an indeterminate sauropod due to the absence of diagnostic charac-

ters that would allow a more detailed taxonomic assignment.

Most of the sauropod discoveries in the Turcifal Sub-basin come from the Sobral (coastal shallow marine to deltaic environment) and Freixial (coastal delta plain to fluvial environment) Formations (Hill, 1988; Manuppella et al., 1999). The Sobral Fm. crops out on the northern sector of this sub-basin. MG 8803 is an unpublished element from Serra da Vila (a locality reported by Lapparent and Zbyszewski, 1957, figure 1), identified herein as a fragment of the distal end of a tibia (Figure 19.11-12). In Ponte de Rol (Torres Vedras), yet unpublished sauropod remains were found (Figure 19.15-16), which include dorsal and caudal vertebrae, and several appendicular elements (scapula, femur, radius, etc.), probably belonging to a single individual (SHN 532). A detailed study of this specimen is in progress, in order to provide a more detailed systematic assessment.

Praia Azul (Torres Vedras) is a locality with several fossil sites. Several sauropod specimens have been collected here, including a single indi-



FIGURE 19. Cranial and postcranial sauropod remains from the Turcifal Sub-basin: **1-2**, ?Turiasauria, heart-shaped tooth (SHN (JJS) 140, Cambelas) in labial (**1**) and lingual (**2**) views; **3-4**, Macronaria indet., compressed cone-chisel-shaped tooth (SHN 580, Assenta) in lingual (**3**) and labial (**4**) views; **5**, ?Macronaria indet., spatulate tooth (SHN 519, South of Foz do Sizandro) in lingual view; **6**, Eusauropoda indet., middle cervical vertebra (SHN 528, Porto Barril) with camellae tissue bone (*sensu* Wedel, 2003); **7-8**, ?Camarasauridae indet., anterior caudal neural spine (SHN 529, Cambelas) in left (**7**) and anterior (**8**) views; **9**, Sauropoda indet., right tibia (SHN 527, Cambelas) in proximal view; **10**, Sauropoda indet., middle caudal vertebra (MG 4802, Santa Cruz) in right view; **11-12**, partial distal end of a ?left tibia (MG 8803, Serra da Vila) in anterior (**11**) and distal (**12**) views; **13**, humerus distal end (SHN 584, Assenta) in anterior view; **14**, cf. *Lusotitan atalaiensis*, middle caudal vertebra (MG 8804, Maceira) in right view; **15-16**, Sauropoda indet., partial skeleton (SHN, 532, Ponte de Rol), posterior caudal vertebra in left view (**15**) and distal end of a right femur in anterior (**16**) views; **17-19**, Diplodocidae indet., partial skeleton (SHN (JJS) 178, Cambelas), sacral neural spines in anterior (**17**) and left (**18**) views and right femur in anterior (**19**) view. Black scale bar: 10 cm; Grey scale bar: 1 cm. See Anatomical abbreviations for abbreviations.



FIGURE 20. Dorsal vertebrae in the field of a partial skeleton (SHN 531) collected in Casal da Costa (Cambelas) in 2003, and correspond to a member of *Camarasauridae* clade.

vidual comprising dorsal and sacral vertebrae and dorsal ribs (SHN 533), of appreciable size, and dorsal vertebrae with high neural spines and dorsolaterally projecting transverse processes. SHN 533 was extracted in 2014 by the SHN. Other vertebrate groups are also reported from this locality (e.g., Pérez-García, 2015). Several unpublished sauropod specimens are deposited in the palaeontological collections of the SHN, including a compressed cone-chisel-shaped tooth (SHN 549), and some unprepared partial skeletons and isolated bones. Some caudal vertebrae (MG 8804, MG 25254.2-4) were found close to Maceira (Torres Vedras). In particular, MG 8804 (Figure 19.14) was identified as *Lusotitan atalaiensis* by Lapparent and Zbyszewski (1957) and listed as cf. *Lusotitan atalaiensis* by Mateus (2005).

Three of the most important quarries with sauropod dinosaurs in the Turcifal Sub-basin are located near the Cambelas locality, where the Freixial Formation crops out. One is located in Casal da Costa, where sauropod appendicular and axial material were recovered (Figure 20, SHN 531), including dorsal vertebrae, and material from

other groups of dinosaurs (theropods and ornithischians), turtles, and crocodyliforms. The dorsal vertebrae show a similar morphology to those of *Camarasaurus supremus* (Mocho et al., 2013a, 2013b). Some of these specimens were recently recovered from the field and are now under preparation. Several finds were also reported on the Cambelas cliffs, including a site where several elements, probably from the same individual, were collected. This sauropod (SHN (JJS) 178) comprises axial and appendicular elements (Figure 19.17-19), including pelvic girdle and hindlimb remains (Mocho et al., 2014a). It was preliminarily referred to *Diplodocidae* based on the presence of a markedly expansion of the ischiatic distal end (Mocho et al., 2014a). The pronounced lateral bulge on the femur observed in this specimen is generally considered to be a synapomorphy of *Titanosauriformes* (e.g., Wilson, 2002) and also occurs in *Diplodocus* (e.g., Hatcher, 1901). A preliminary evaluation of SHN (JJS) 178 suggests a close relationship with an unpublished diplodocid recovered in Valmitão (SHN (JJS) 177), which shares affinities with the *Diplodocinae* (Mocho et

al., 2014a). Finally, a partial skeleton with axial and appendicular elements (Figure 19.7-8, SHN 529) was found in a distinct fossil site from the Cambelas locality, and includes an anterior caudal neural spine with a delta-shaped distal end, a feature common in camarasaurids (Ikejiri, 2004; Mocho et al., 2014b). Several sauropod finds have been identified in the Freixial Fm. in the section of the Cambelas, Gentias, and Assenta cliffs, including several teeth, axial, and appendicular elements (Figure 19.1-5, 19.9, 19.13). The collected teeth include heart-shaped (Figure 19.1-2; see also Mocho et al., 2012, 2016b) and spatulate teeth (Figure 19.5, see also Mocho et al., 2011), and one compressed cone-chisel-shaped tooth (Figure 19.3-4). In Porto Barril (Mafra), an unpublished possible middle cervical vertebra (Figure 19.6, SHN 528) was found, with a well-developed camellate internal bone tissue similar to the condition present in basal titanosauriforms and mamenchisaurids (following Wedel, 2003).

In conclusion, the Turcifal Sub-basin presents a relatively continuous Upper Jurassic sequence, with a rich sauropod record. The sauropod fauna identified in the Turcifal Sub-basin is composed of non-neosauropod eusauropods (probably turiasaurs), diplodocids (with probable diplodocine affinities), and macronarians, including camarasaurids and members within Titanosauriformes + *Europasaurus*.

SAUROPOD PALAEOBIODIVERSITY AND LITHOSTRATIGRAPHIC DISTRIBUTION FOR THE LUSITANIAN BASIN

The Upper Jurassic record of the Lusitanian Basin is rich in dinosaur occurrences and, in particular, in fossil sites with sauropod remains. The Portuguese Late Jurassic sauropods have been the focus of several recent papers, including the description of new material (Yaguë et al., 2006; Mocho et al., 2011; Mannion et al., 2012; Mocho et al., 2012, 2013a, 2013b; Mateus et al., 2014; Mocho et al., 2014a, 2016a, 2016b, 2017), as well as the systematic revision of previously established taxa (Mannion et al., 2012, 2013; Mocho et al., 2014b, 2016c). A geographical and lithostratigraphic context for the sauropod record reported in the Lusitanian Basin is proposed here for the first time. We also report several new finds that highlight the potential of the Portuguese record for the understanding of the palaeobiodiversity and the evolutionary history of the Late Jurassic sauropod fauna from the Iberian Peninsula. The stratigraphic distribution of this fossil record suggests that the

major clades (i.e., non-neosauropod eusauropods, diplodocoids, and macronarians) are present throughout the continental and transitional sedimentary sequence dated from the early Kimmeridgian to the late Tithonian. The only exceptions, which might reflect sampling bias, are: i) Camarasauridae (specimens attributed to *Macronaria* indet. might pertain to Camarasauridae), which were only identified with confidence in the Sobral and Freixial Formations, at the most meridional sub-basins of Arruda and Turcifal; ii) Diplodocinae remains unreported in the Sobral Fm., the most marine-influenced Tithonian unit in these sub-basins; and iii) Brachiosauridae, only present with confidence in the Sobral Fm. accepting *Lusotitan* as a member of this clade (Mannion et al., 2013; Mocho et al., 2016c).

Turiasauria is a non-neosauropod eusauropod clade, and its presence in the Upper Jurassic of the Lusitanian Basin was first recognised by Royo-Torres et al. (2006). The heart-shaped tooth morphology has been proposed as exclusive of turiasaurs (Royo-Torres et al., 2006, 2009; Mocho et al., 2012; Royo-Torres and Upchurch, 2012; Royo-Torres et al., 2014a). Nevertheless, the wide stratigraphic (Middle Jurassic to Lower Cretaceous) and palaeogeographic (Europe and Africa) range for this shape suggests that this morphology of teeth could be a feature of a more inclusive group or a convergent feature in other sauropod clades (Mocho et al., 2016b). Heart-shaped teeth have a wide stratigraphic distribution throughout the Upper Jurassic levels of the Lusitanian Basin, being present in the Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Bombarral and Freixial Formations. *Zby atlanticus*, found in Praia da Amoreira-Porto Novo Formation, is the only specimen that can be confidently assigned to Turiasauria (Mateus, 2005; Mateus et al., 2014). Nevertheless, other specimens found in the Portuguese Upper Jurassic record have been preliminarily identified as non-neosauropod eusauropods, and they could represent turiasaurians (non-neosauropod eusauropods outside Turiasauria have not been identified from the Iberian Upper Jurassic record so far). Non-neosauropod eusauropods have a wide stratigraphic range in the Upper Jurassic levels of Portugal (Figure 3). Non-neosauropod eusauropod remains have been recovered from the coastal marine to lagoonal and fluvio-deltaic Alcobaça Fm., the fluvial Praia da Amoreira-Porto Novo Fm. (e.g., ML 368, SHN 530), the marine to deltaic Sobral Fm. (e.g., SHN 533), the fluvial to deltaic Freixial Fm. and the fluvial-lacustrine Bombarral Fm.

Diplodocoidea is a clade recorded from the upper Kimmeridgian up to probably the upper Tithonian of the Portuguese Upper Jurassic record (Figure 3). This clade is represented by one described diplodocine, *Dinheirosaurus lourinhanensis*, and material considered as belonging to indeterminate diplodocines (Mannion et al., 2012; Mocho et al., 2014a; Tschopp et al., 2015; Mocho et al., 2016a, 2017). Based on the material from Moita dos Ferreiros (ML 418), Mannion et al. (2012) suggested the presence of at least two diplodocids in the Portuguese Upper Jurassic levels. The specimen from Moita dos Ferreiros was subsequently considered as an indeterminate diplodocine by Tschopp et al. (2015). Diplodocines have been recorded from the Praia da Amoreira-Porto Novo, Bombarral, and Freixial Formations. The presence of this clade in the Alcobaça (coastal marine to lagoonal and fluvio-deltaic environments) or Sobral (deltaic environments) Formations is so far unreported. Apatosaurines are apparently absent in the Upper Jurassic of the Iberian Peninsula. Apatosaurinae is considered an endemic group from the Late Jurassic of the North America (Foster and Peterson, 2015).

Macronarians are a diverse group in the Iberian territory, represented by the Portuguese *Lourinhasaurus* and *Lusotitan*, and the Spanish *Aragosaurus* and *Galveosaurus* (e.g., Barco, 2009; Mannion et al., 2013; Mocho et al., 2014b; Royo-Torres et al., 2014b), and a putative new form from Portugal (SHN 181). Several indeterminate specimens assigned to Macronaria have been found in the Upper Jurassic record of the Lusitanian Basin, present in the Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Freixial, and Bombarral Formations. A stratigraphic range from the lower Kimmeridgian to the probably upper Tithonian is therefore recognised (Figure 3). Camarasaurids are clearly identified in the Sobral Fm. (*Lourinhasaurus alenquerensis*) and Freixial Fm. (SHN 531), but the systematic affinities of several other specimens needs to be evaluated (e.g., SHN 002, from the Praia da Amoreira-Porto Novo Fm., found in Porto Novo, Torres Vedras; and SHN 529, from the Freixial Fm., found in Cambelas, Torres Vedras), in order to understand the true stratigraphic range of this group. At the moment, Camarasauridae is recorded from the upper Kimmeridgian-basal Tithonian to probably upper Tithonian (Figure 3). If the Porto Novo specimens belong to Camarasauridae, the stratigraphic range of the clade would be upper Kimmeridgian to probably upper Tithonian, and SHN 002 would be the first occurrence of a cama-

rasaurid from the Praia da Amoreira-Porto Novo Fm.

Titanosauriforms are present in the Praia da Amoreira-Porto Novo, Sobral, and Bombarral Formations. *Lusotitan atalaiensis* is a possible brachiosaurid (Mannion et al., 2013; Mocho et al., 2016c) from the Sobral Fm. Apart from the presence of several specimens with titanosauriform affinities, *Lusotitan* might be the strongest evidence for the presence of this clade during the Upper Jurassic of the Lusitanian Basin. Several compressed cone-chisel teeth were found in the Upper Jurassic sedimentary sequence of the Lusitanian Basin (Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Freixial, and Bombarral Formations). This tooth morphology was traditionally considered as synapomorphic of Titanosauriformes (e.g., Upchurch et al., 2004; D'Emic, 2012), but this morphology was also found in the possible basal macronarian *Europasaurus* (Carballido and Sander, 2014), which was also considered to be a member of Titanosauriformes by D'Emic (2012) and Mannion et al. (2013). If we accept the phylogenetic position proposed for *Europasaurus* by Carballido and Sander (2014), this tooth morphology should be present in a more inclusive group than Titanosauriformes. In this case, the compressed cone-chisel teeth found in the Lusitanian Basin should be referred to Macronaria indet. New discoveries are necessary to improve our knowledge about the Iberian titanosauriforms, especially about brachiosaurids, which is mainly based on incomplete specimens.

Several new sauropod specimens, belonging to different clades, are herein reported. Nevertheless, the collections of the ML and SHN still house many specimens that need to be prepared, catalogued, and studied (see Mateus, 2005; Mocho et al., 2013a, 2013b, 2014a; pers. observ., PM). New relevant specimens have also recently been discovered and collected by the Museu Nacional de História Natural e da Ciência, SHN and ML. Herein, we report some of the most important sauropod finds, including informative partial skeletons, such as the specimens from Praia Vermelha (SHN (JJS) 179, Peniche), Porto das Barcas (ML 351, Lourinhã; see Antunes and Mateus, 2003; Mateus, 2005), Porto Novo (SHN 002, Torres Vedras), Praia da Corva (SHN 530, Torres Vedras), Santa Rita (SHN 534, Torres Vedras), Praia Azul (SHN 533, Torres Vedras), and Cambelas (SHN 529, Torres Vedras). The systematic study of all these finds will significantly improve our knowledge of Portuguese Late Jurassic sauropod fauna. The study of

other, so far unpublished, specimens will also be informative, such as those including axial and appendicular elements, in particular the basal macronarians recovered in Casal da Costa (SHN 531, Torres Vedras) and Valmitão (SHN 181, Lourinhã) and the diplodocids from Valmitão (SHN (JJS) 177, related to Diplodocinae), and Cambelas (SHN (JJS) 178, Torres Vedras). These specimens will allow a better understanding of the palaeobiodiversity of Diplodocinae and Camarasauridae in the Upper Jurassic record of the Lusitanian Basin. SHN 181, from Valmitão (Praia da Amoreira-Porto Novo Formation, late Kimmeridgian-basal Tithonian in age) is a specimen that is currently being described, and might represent a new basal macronarian, increasing the palaeobiodiversity of the Portuguese Late Jurassic sauropod fauna, which seems to be comprised of at least six taxa: one turiasaur (*Zby*), two different diplodocines (*Dinheirosaurus* and one indeterminate diplodocine); and at least three macronarians: one camarasaurid (*Lourinhasaurus*), one brachiosaurid (*Lusotitan*), and one non-camarasaurid basal macronarian (SHN 181).

CONCLUSIONS

The Upper Jurassic sequence of the central sector of the Lusitanian Basin has yielded a rich sauropod dinosaur fossil record, particularly abundant in the Bombarral and Turcifal Sub-basins. A geographic and stratigraphic context for the known sauropod record in the Lusitanian Basin is proposed, and several new specimens are herein reported for the first time. Sauropods are present throughout the continental to transitional deposits of the Lusitanian Basin, recorded in the Alcobaça, Praia da Amoreira-Porto Novo, Sobral, Freixial, and Bombarral Formations. Some areas of the Bombarral Sub-basin and Arruda Sub-basin are still poorly understood, due to scarce and incomplete material. The identified sauropod fauna are mainly comprised of non-neosauropod eusauropods (turiasaurs and indeterminate forms), diplodocids (diplodocines and indeterminate forms), basal macronarians (non-camarasaurids and camarasaurids), and titanosauriforms (some specimens with brachiosaurid affinities). No particular stratigraphic pattern was identified within the Upper Jurassic sequence, and the major clades are present throughout the lower Kimmeridgian to upper Tithonian levels. However, the detailed relationships between the different palaeoenvironments and sauropod fauna will require a

systematic analysis of the geological context (formation, facies, environment) of the listed findings, which is not always easy to assure, given the uncertain provenance of some specimens. Such analysis may eventually shed some light on the spatio-temporal distribution of the fauna and its control by stratigraphic and/or palaeoenvironmental factors.

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APPENDIX 1.

List of the sauropod material from the Lusitanian Basin Upper Jurassic.

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
MG 30483	Eusauropoda	Eusauropoda indet.	?	?	?	Anterior caudal vertebra	?
MG 30484	Sauropoda	Sauropoda indet.	?	Alenquer?	?	Humeral distal end	?
MG 8799	Sauropoda	Sauropoda indet.	Praia das Almoinhas?	Caldas da Rainha or Torres Vedras?	?	Posterior caudal vertebra	Bombarral (Csb) or Turcifal Sub-basin
MG 8802	Sauropoda	Sauropoda indet.	?	?	?	Middle caudal vertebra	?
SHN (JJS) 148	? Turiasauria	? Turiasauria indet.	?	?	?	Tooth	?
SHN (JJS) 149	? Turiasauria	? Turiasauria indet.	?	?	?	Tooth	?
SHN 511	? Turiasauria	? Turiasauria indet.	?	?	?	Tooth	?
SHN 563	Sauropoda	Sauropoda indet.	?	?	?	Tooth	?
unlabeled	Diplodocidae	Diplodocidae indet.	?	?	?	Anterior caudal vertebra	?
MG 4799	Neosauropoda	Neosauropoda indet.	Castanheira	Vila Franca de Xira	Abadia Fm.	Middle/posterior dorsal vertebra	Arruda Sub-basin
MG 27891	Macronaria	Macronaria indet.	Guimarota	Leiria	Alcobaça Fm.	Tooth	Bombarral Sub-basin
MG 27892	Macronaria	Macronaria indet.	Guimarota	Leiria	Alcobaça Fm.	Tooth	Bombarral Sub-basin
MG 27894	Macronaria	Macronaria indet.	Guimarota	Leiria	Alcobaça Fm.	Tooth	Bombarral Sub-basin
MG 27895	Macronaria	Macronaria indet.	Guimarota	Leiria	Alcobaça Fm.	Tooth	Bombarral Sub-basin
MG 4832	? Turiasauria	? Turiasauria indet.	São Martinho do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
MG 4974	Sauropoda	Sauropoda indet.	Abadia (northern of Batalha)	Leiria	Alcobaça Fm.	Partial dorsal vertebra and a partial caudal series	Bombarral Sub-basin
MMPM.P/307	Sauropoda	Sauropoda indet.	Golfeiros	Batalha	Alcobaça Fm.	Femoral proximal end	Bombarral Sub-basin
MMPM.P/551	Eusauropoda	Eusauropoda indet.	São Martinho do Porto	Alcobaça	Alcobaça Fm.	Middle caudal vertebra and a chevron distal end	Bombarral Sub-basin (Csb)
MMPM.P/554	Sauropoda	Sauropoda indet.	Fonte do Oleiro	Porto de Mós	Alcobaça Fm.	Posterior caudal vertebra	Bombarral Sub-basin
MMPM.P/587	Sauropoda	Sauropoda indet.	São Martinho do Porto	Alcobaça	Alcobaça Fm.	Appendicular bone	Bombarral Sub-basin (Csb)
SHN (JJS) 146	? Turiasauria	? Turiasauria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 147	? Turiasauria	? Turiasauria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 151	? Turiasauria	? Turiasauria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 154	? Turiasauria	? Turiasauria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 501	? Turiasauria	? Turiasauria indet.	Praia da Gralha	Alcobaça	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 504	? Turiasauria	? Turiasauria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 537	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Caudal vertebrae, pelvic fragments and 1 pedal element (+ indeterminate fragments)	Bombarral Sub-basin (Csb)
SHN 553	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN 559	Macronaria	Macronaria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 562	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 564	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 567	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 570	Sauropoda	Sauropoda indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 581	Macronaria	Macronaria indet.	Salir do Porto	Caldas da Rainha	Alcobaça Fm.	Tooth	Bombarral Sub-basin (Csb)
unlabeled	Sauropoda	Sauropoda indet.	Chiqueda de Cima	Alcobaça	Alcobaça Fm.	Posterior caudal vertebra	Bombarral Sub-basin (B-Asb)
unlabeled	Sauropoda	Sauropoda indet.	São Mamede	Bombarral	Alcobaça Fm.	Humerus	Bombarral Sub-basin (B-Asb)
MG 277	?Turiasauria	?Turiasauria indet.	Fervença	Alcobaça	Alcobaça Fm.?	Tooth	Bombarral Sub-basin
MG 16	?Turiasauria	?Turiasauria indet.	Ourém	Ourém	Alcobaça Fm.?	Tooth	Bombarral Sub-basin
MG 8779	Macronaria	Macronaria indet.	Ourém	Vila Nova de Ourém	Alcobaça Fm.?	Tooth	Bombarral Sub-basin
unlabeled	Macronaria	Macronaria indet.	Ourém	Ourém	Alcobaça Fm.?	Tooth	Bombarral Sub-basin
MG 30389	Sauropoda, Diplodocidae	Sauropoda indet. and Diplodocinae indet.	Batalha	Batalha	Alcobaça or Bombarral Fm.	Axial and appendicular elements	Bombarral Sub-basin (Csb)
?	?	?	Vale de Frades	Lourinhã	Bombarral Fm.	Femur	Bombarral Sub-basin (Csb)
GeoFCUL(AB)	? Eusauropoda	? Eusauropoda indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Nine middle caudal vertebrae and chevrons	Bombarral Sub-basin (Csb)
MG 4804	Eusauropoda	Eusauropoda indet.	Casal de Lã, Salir de Matos	Caldas da Rainha	Bombarral Fm.	Middle caudal vertebra	Bombarral Sub-basin (Csb)
MG 4811	Sauropoda	Sauropoda indet.	Albergaria dos Doze	Pombal	Bombarral Fm.	Middle/posterior caudal vertebra	Bombarral Sub-basin
MG 4819, 4821, 4826	Diplodocinae	Diplodocinae indet.	São Gregório da Fanadia	Caldas da Rainha	Bombarral Fm.	Three partial middle/posterior caudal vertebra	Bombarral Sub-basin (B-Asb)
MG 4915, 4916, 4917, 4919	Neosauropoda	Neosauropoda indet.	Pedras Muias	Peniche	Bombarral Fm.	Cervical vertebrae remains	Bombarral Sub-basin (Csb)
MG 4920	Eusauropoda	Eusauropoda indet.	Monte da Cruz do Facho, Foz do Arelho	Monte da Cruz do Facho, Foz do Arelho	Monte da Cruz do Facho, Foz do Arelho	Anterior dorsal neural spine	Bombarral Sub-basin (Csb)
MG 4986	Titanosauriformes	Neosauropoda indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Left femur	Bombarral Sub-basin (Csb)
MG 8772	Macronaria	Macronaria indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Teeth fragments	Bombarral Sub-basin (Csb)
ML 418	Diplodocidae	Diplodocidae indet.	Moita dos Ferreiros	Lourinhã	Bombarral Fm.	Cervical and dorsal vertebrae	Bombarral Sub-basin (B-Asb)
MMPM.P/72	Sauropoda	Sauropoda indet.	Malásia	Caldas da Rainha	Bombarral Fm.	Appendicular bone	Bombarral Sub-basin (B-Asb)
MMPM.P/75	Eusauropoda	Eusauropoda indet.	Imaginário	Caldas da Rainha	Bombarral Fm.	Left astragalus	Bombarral Sub-basin (B-Asb)
MNHNUL.P.AN D302	Diplodocoidea	Diplodocoidea indet.	Andrés	Pombal	Bombarral Fm.	Tooth	Bombarral Sub-basin
MNHNUL.P.AN D303	Diplodocoidea	Diplodocoidea indet.	Andrés	Pombal	Bombarral Fm.	Tooth	Bombarral Sub-basin
MNHNUL.P.AN D304	Diplodocoidea	Diplodocoidea indet.	Andrés	Pombal	Bombarral Fm.	Tooth	Bombarral Sub-basin

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN (JJS) 179	Diplodocidae	Diplodocidae indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 006	Diplodocidae	Diplodocidae indet.	Mexilhoeira	Torres Vedras	Bombarral Fm.	Axial elements	Bombarral Sub-basin (Csb)
SHN 150	? Turiasauria	? Turiasauria indet.	Serra do Bouro	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 152	? Turiasauria	? Turiasauria indet.	Serra do Bouro	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 502	? Turiasauria	? Turiasauria indet.	Foz do Arelho	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 503	? Turiasauria	? Turiasauria indet.	Foz do Arelho	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 508	? Turiasauria	? Turiasauria indet.	Serra do Bouro	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 512	? Turiasauria	? Turiasauria indet.	Foz de Arelho	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 514	? Macronaria	? Macronaria indet.	Serra do Bouro	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 517	? Macronaria	? Macronaria indet.	Foz do Arelho	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 526	Macronaria	Macronaria indet.	Baleal-Almagreira	Peniche	Bombarral Fm.	Right pubis	Bombarral Sub-basin (Csb)
SHN 535	Eusauropoda	Eusauropoda indet.	Praia do Seixo	Torres Vedras	Bombarral Fm.	?Cervical vertebra	Bombarral Sub-basin (Csb)
SHN 538	Sauropoda	Sauropoda indet.	Almagreira	Peniche	Bombarral Fm.	Sacral ribs and indeterminate fragments	Bombarral Sub-basin (Csb)
SHN 554	Macronaria	Macronaria indet.	Almagreira	Peniche	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 556	Macronaria	Macronaria indet.	Almagreira	Peniche	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 571	Sauropoda	Sauropoda indet.	Serra do Bouro	Caldas da Rainha	Bombarral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 585	Sauropoda	Sauropoda indet.	Almagreira	Peniche	Bombarral Fm.	Cervical vertebrae remains	Bombarral Sub-basin (Csb)
SHN 590	Eusauropoda	Eusauropoda indet.	Mexilhoeira	Torres Vedras	Bombarral Fm.	Two presacral vertebrae	Bombarral Sub-basin (Csb)
unlabeled	? Turiasauria, Diplodocoidea, Macronaria	Indeterminate taxa	Andrés	Pombal	Bombarral Fm.	Teeth and postcranial material	Bombarral Sub-basin (Csb)
MNHNUL.P.R2 7	Eusauropoda	Eusauropoda indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
unlabeled	Sauropoda	Sauropoda indet.	Praia da Areia Branca	Lourinhã	Bombarral Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
unlabeled	Eusauropoda	Eusauropoda indet.	Vermoil	Pombal	Bombarral Fm.	Middle-to-posterior dorsal neural arch	Bombarral Sub-basin
MMPM.P/73	Eusauropoda	Eusauropoda indet.	Paimogo	Lourinhã	Bombarral Fm. or Sobral Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
MMPM.P/587	Sauropoda	Sauropoda indet.	Albergaria	Porto de Mós	Bombarral or Alcobaça Fm.	Posterior caudal vertebra	Bombarral Sub-basin
MG 25254.2-4	Sauropoda	Sauropoda indet.	Between Foz Velha da Maceira and Cambelas	Torres Vedras	Freixial Fm.	Partial caudal vertebra and indeterminate fragments	Turcifal Sub-basin
MG 8804	Titanosauriformes	cf. <i>Lusotitan atalaiensis</i>	Maceira	Torres Vedras	Freixial Fm.	Middle caudal vertebra	Turcifal Sub-basin
SHN (JJS) 121	? Macronaria	? Macronaria indet.	Cambelas	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin
SHN (JJS) 140	? Turiasauria	? Turiasauria indet.	Cambelas	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN (JJS) 178	Diplodocidae	Diplodocidae indet.	Cambelas	Torres Vedras	Freixial Fm.	Partial skeleton	Turcifal Sub-basin
SHN 519	? Macronaria	? Macronaria indet.	Sul da Foz do Rio Sizandro	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin
SHN 522	Sauropoda	Sauropoda indet.	Cambelas	Torres Vedras	Freixial Fm.	Left pubis	Turcifal Sub-basin
SHN 527	Sauropoda	Sauropoda indet.	Cambelas	Torres Vedras	Freixial Fm.	Right tibia	Turcifal Sub-basin
SHN 528	Eusauropoda	Eusauropoda indet.	Porto Barril	Mafra	Freixial Fm.	Middle cervical vertebrae	Turcifal Sub-basin
SHN 529	Camarasauridae	Camarasauridae indet.	Cambelas	Torres Vedras	Freixial Fm.	Partial skeleton (one or more individuals)	Turcifal Sub-basin
SHN 531	Camarasauridae	Camarasauridae indet.	Cambelas	Torres Vedras	Freixial Fm.	Partial skeleton	Turcifal Sub-basin
SHN 541	? Macronaria	? Macronaria indet.	South of Pedra da Ursa	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin
SHN 560	Sauropoda	Sauropoda indet.	Cambelas	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin
SHN 580	Macronaria	Macronaria indet.	Assenta	Torres Vedras	Freixial Fm.	Tooth	Turcifal Sub-basin
SHN 584	Sauropoda	Sauropoda indet.	Assenta	Torres Vedras	Freixial Fm.	Humerus distal end	Turcifal Sub-basin
SHN 586	Sauropoda	Sauropoda indet.	Gentias	Torres Vedras	Freixial Fm.	Partial femur	Turcifal Sub-basin
MG 25197.1-6	Diplodocinae	Diplodocinae indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Caudal, ribs and an indeterminate fragment	Bombarral Sub-basin (Csb)
MG 30480	Sauropoda	Sauropoda indet.	Outeiro do Seixo, Ribamar	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Dorsal rib fragments	Bombarral Sub-basin (Csb)
MG 4800	Sauropoda	Sauropoda indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
MG 4802	Sauropoda	Sauropoda indet.	Alto da Vela, Santa Cruz	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Middle caudal vertebra	Turcifal Sub-basin
MG 4976	Eusauropoda	cf. <i>Duriantitan humerocristatus</i>	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Right humerus	Bombarral Sub-basin (Csb)
MG 4978	Eusauropoda	Eusauropoda indet.	São Bernardino	Peniche	Praia da Amoreira-Porto Novo Fm.	16 anterior to middle caudal vertebrae	Bombarral Sub-basin (Csb)
MG 8783	? Macronaria	? Macronaria indet.	Baleal	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
ML 368	Turiasauria	<i>Zby atlanticus</i>	Vale de Pombas	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN (JJS) 127	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 128	? Turiasauria	? Turiasauria indet.	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 129	? Turiasauria	? Turiasauria indet.	Praia de Pedrogãos	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 130	? Turiasauria	? Turiasauria indet.	Praia de Pedrogãos	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 131	? Turiasauria	? Turiasauria indet.	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 132	? Turiasauria	? Turiasauria indet.	São Bernardino	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 133	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 135	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 139	? Turiasauria	? Turiasauria indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN (JJS) 141	? Turiasauria	? Turiasauria indet.	Baleal	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 142	? Turiasauria	? Turiasauria indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN (JJS) 177	Diplodocinae	Diplodocinae indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 002	? Macronaria	? Macronaria indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 134	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 137	? Turiasauria	? Turiasauria indet.	São Bernardino	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 138	? Turiasauria	? Turiasauria indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 143	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 145	? Turiasauria	? Turiasauria indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 180	Eusauropoda	Eusauropoda indet.	Baleal	Peniche	Praia da Amoreira-Porto Novo Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
SHN 181	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 505	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 506	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 507	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 509	? Turiasauria	? Turiasauria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 510	? Turiasauria	? Turiasauria indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 513	? Macronaria	? Macronaria indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 516	? Macronaria	? Macronaria indet.	Praia dos Frades-São Bernardino	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 520	Sauropoda	Sauropoda indet.	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Left femur	Bombarral Sub-basin (Csb)
SHN 521	Diplodocinae	Diplodocinae indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Middle caudal vertebra	Bombarral Sub-basin (Csb)
SHN 523	Titanosauriformes	Titanosauriformes indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Caudal vertebrae	Bombarral Sub-basin (Csb)
SHN 524	Sauropoda	Sauropoda indet.	Praia de Pedrogãos	Peniche	Praia da Amoreira-Porto Novo Fm.	Ungueal I	Bombarral Sub-basin (Csb)
SHN 525	Sauropoda	Sauropoda indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Axial elements	Bombarral Sub-basin (Csb)
SHN 530	Eusauropoda	Eusauropoda indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Partial skeleton (one or more individuals)	Bombarral Sub-basin (Csb)
SHN 534	Sauropoda	Sauropoda indet.	Santa Rita	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 536	Sauropoda	Sauropoda indet.	Pedras Muitas	Peniche	Praia da Amoreira-Porto Novo Fm.	Partial right ilium	Bombarral Sub-basin (Csb)
SHN 540	? Macronaria	? Macronaria indet.	São Bernardino	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 543	Macronaria	Macronaria indet.	Baleal	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 546	Macronaria	Macronaria indet.	Praia Vermelha	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN 547	Macronaria	Macronaria indet.	Pedras Muitas	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 548	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 555	Sauropoda	Sauropoda indet.	Porto Novo	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 557	Sauropoda	Sauropoda indet.	Praia de Pedrogãos	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 558	Sauropoda	Sauropoda indet.	Praia de Pedrogãos	Peniche	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 561	Sauropoda	Sauropoda indet.	Praia das Amoeiras	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 565	Sauropoda	Sauropoda indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 566	Sauropoda	Sauropoda indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 568	Sauropoda	Sauropoda indet.	Valmitão Sul	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 573	Macronaria	Macronaria indet.	Vale de Pombas	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 574	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 575	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 577	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 578	Macronaria	Macronaria indet.	Valmitão	Lourinhã	Praia da Amoreira-Porto Novo Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 582	? Turiasauria	? Turiasauria indet.	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Maxilla fargment	Bombarral Sub-basin (Csb)
SHN 583	Turiasauria	cf. Turiasauria	Praia dos Frades	Peniche	Praia da Amoreira-Porto Novo Fm.	Metacarpal I	Bombarral Sub-basin (Csb)
SHN 587	Eusauropoda	Eusauropoda indet.	Praia da Corva	Torres Vedras	Praia da Amoreira-Porto Novo Fm.	Distal chevron	Bombarral Sub-basin (Csb)
SHN 589	Diplodocinae	Diplodocinae indet.	Baleal	Peniche	Praia da Amoreira-Porto Novo Fm.	Posterior caudal vertebra	Bombarral Sub-basin (Csb)
ML 414	Diplodocinae	Dinheirosaurus lourinhanensis	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
SHN 144	? Turiasauria	? Turiasauria indet.	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 153	? Turiasauria	? Turiasauria indet.	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 542	Macronaria	Macronaria indet.	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 572	Macronaria	Macronaria indet.	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 588	Diplodocinae	Diplodocinae indet.	Porto Dinheiro	Lourinhã	Praia da Amoreira-Porto Novo Fm./ Sobral Fm.	Posterior caudal vertebra	Bombarral Sub-basin (Csb)
MG 30486	Eusauropoda	Eusauropoda indet.	Atougua da Baleia?	Lourinhã?	Praia da Amoreira-Porto Novo Fm.?	Right fibula	Bombarral Sub-basin (Csb)
MG 30390	Eusauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Four anterior and middle caudal vertebrae plus indeterminate fragments	Bombarral Sub-basin (Csb)

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
MG 3794, 4798, 4801, 4805-10, 4838, 4944, 4950, 4952, 4958, 4964, 4965, 4966, 4981, 4982, 4803, 4985-1, 4985 2-20, 5795, 8793, 8794, 8807 and unlabeled sacral neural spine and chevron	Brachiosauridae	<i>Lusotitan atalaiensis</i>	Peralta	Lourinhã	Sobral Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
MG 4956, 30373, 30377, 30379, 4956, 30378, 30384, 30370, 4956, 30380, 30376, 4956, 30374, 30388, 30387, 5780, 30371, 5780, 30372, 30383, 30382, 2, 30381, 4979, 4979, 30385, 5781, 4975, 4970, 4957, 4931, 4983, 4984, 30375, 30386 and unlabelled fragmentary elements	Camarasauridae	<i>Lourinhasaurus alenquerensis</i>	Moinho do Carmo	Alenquer	Sobral Fm.	Partial skeleton	Arruda Sub-basin
MG 8771	Sauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Two teeth fragments associated with " <i>Omasaurus lenieri</i> " material	Bombarral Sub-basin (Csb)
MG 8792	Sauropoda	Sauropoda indet.	Atalaia	Lourinhã	Sobral Fm.	Two dorsal rib fragments	Bombarral Sub-basin (Csb)
MG 8800	Eusauropoda	Eusauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Middle caudal vertebra	Bombarral Sub-basin (Csb)
MG 8803	Sauropoda	Sauropoda indet.	Serra da Vila	Torres Vedras	Sobral Fm.	Partial tibial distal end	Bombarral Sub-basin (Csb)
MG 8805	Sauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Middle caudal vertebra	Bombarral Sub-basin (Csb)
MG 8809	Sauropoda	Sauropoda indet.	Atalaia	Lourinhã	Sobral Fm.	Three neural arch fragments	Bombarral Sub-basin (Csb)
ML 351	Eusauropoda	Eusauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Partial skeleton	Bombarral Sub-basin (Csb)
ML 684	Sauropoda	Sauropoda indet.	Lage Fria	Lourinhã	Sobral Fm.	Sternal plate	Bombarral Sub-basin (Csb)
SHN (JJS) 136	? Turiasauria	? Turiasauria indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 122	? Macronaria	? Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 515	? Macronaria	? Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 518	? Macronaria	? Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 532	Eusauropoda	Eusauropoda indet.	Ponte de Rol	Torres Vedras	Sobral Fm.	Partial skeleton	Turcifal Sub-basin
SHN 533	Eusauropoda	Eusauropoda indet.	Praia Azul	Torres Vedras	Sobral Fm.	Partial skeleton	Turcifal Sub-basin

Number	Taxonomy		Locality	Municipal	Horizon	Anatomy	Sub-basin
SHN 539	Sauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Axial and appendicular elements	Bombarral Sub-basin (Csb)
SHN 544	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 545	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 549	Macronaria	Macronaria indet.	Praia Azul	Torres Vedras	Sobral Fm.	Tooth	Turcifal Sub-basin
SHN 550	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 551	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 552	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 576	Macronaria	Macronaria indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
SHN 579	Macronaria	Macronaria indet.	Peralta	Lourinhã	Sobral Fm.	Tooth	Bombarral Sub-basin (Csb)
unlabeled	Sauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
unlabeled	Sauropoda	Sauropoda indet.	Porto das Barcas	Lourinhã	Sobral Fm.	Anterior caudal vertebra	Bombarral Sub-basin (Csb)
MG 30481	Neosauropoda	Neosauropoda indet.	Atalaia?	Lourinhã?	Sobral Fm.?	Partial dorsal centrum	Bombarral Sub-basin (Csb)
MG 30482	Sauropoda	Sauropoda indet.	Atalaia?	Lourinhã?	Sobral Fm.?	Caudal neural spine	Bombarral Sub-basin (Csb)
MG 30485	Titanosauriformes	Titanosauriformes indet.	Moinho do Carmo?	Alenquer?	Sobral Fm.?	Pubic peduncle of an ilium	Arruda Sub-basin
*More unpublished material is referred in a list provided by Mateus (2005)							
SHN	Sociedade de História Natural, Torres Vedras, Portugal (plus (JJS) for the José Joaquim dos Santos collection deposited in the Sociedade de História Natural)						
MNHNUL	Museu Nacional de História Natural e da Ciência, Universidade de Lisboa, Lisboa, Portugal						
ML	Museu da Lourinhã, Lourinhã, Portugal						
MG	Museu Geológico, Lisboa, Portugal						
MMB.PALEO	Museu Municipal do Bombarral, Bombarral, Portugal (plus PALEO for the paleontological collection)						
MMLT	Museu Municipal de Leonel Trindade, Torres Vedras, Portugal						
MMPM	Museu Municipal de Porto de Mós, Porto de Mós, Portugal						
GeoFCUL(AB)	Departamento de Geologia da Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal (plus AB for Areia Branca)						
Csb	Consolação Sub-basin (following Taylor et al., 2014)						
B-Asb	Bombarral-Alcobaça Sub-basin (following Taylor et al., 2014)						