The southernmost occurrence of *Ichthyosaurus* from the Sinemurian of Portugal

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Abstract. The ichthyosaur fossil record of Portugal is composed of specimens from the localities of São Pedro de Moel, Alhadas, Cadima, Murte de, Casal do Combo, Condeixa, Alvaízere and Tomar, within the confines of the Lusitanian Basin, ranging in age from the Sinemurian to the Aalenian. We reviewed the historical ichthyosaur finds in Portugal, and in this work we focus on the specimen IST-MDT 85, from the Sinemurian of Praia de Nossa Senhora da Vitória, central west coast of Portugal. The specimen was herein ascribed to *Ichthyosaurus cf. communis*, based on characters of the humerus in comparison with other specimens. This is the southernmost documented occurrence of *Ichthyosaurus*, widening the geographical range of the genus.

1 Introduction

1.1 Institutional abbreviations

MG, Museu Geológico de Lisboa, Portugal. IST-MDT, Instituto Superior Técnico de Lisboa, Museu Décio Thadeu, Portugal. NHMUK, Natural History Museum, London.

1.2 Ichthyosaurus

Ichthyosaurs are a group of Mesozoic reptiles, who stand out due to their extreme readaptation to a marine environment, being strictly marine organisms, incapable of venturing on land. The genus *Ichthyosaurus* was restricted to the Late Triassic and Early Jurassic, and geographically is not very widespread, being known mostly from European Early Jurassic formations, although this is considered to be due to lack of proper deposition conditions rather than limitations in species distribution (Sander, 2000). As of the latest research, the genus is comprised of the species *I. communis, I. breviceps, I. conybeari, I. anningae, I. larkini, and I. somersetensis* (Lomax and Massare, 2017).

1.3 Ichthyosaurs in Portuguese history

A majority of the documented ichthyosaur specimens in Portugal (Table 1) were found in Early Jurassic formations during stratigraphy fieldwork performed by the Serviços Geológicos de Portugal. The very first mention of Portuguese ichthyosaurs was made by Paul Choffat, in 1885–1886, mentioning the presence of flattened vertebrae in the Pliensbachian of Pintanheira (Pentelheira), Municipality of Alcobaça. In 1898, Henri Sauvage identified these, alongside a rostrum fragment found in the Aalenian of Alcobaça. In 1898, Henri Sauvage identified these, alongside a rostrum fragment found in the Aalenian of Alcobaça, as *Ichthyosaurus* sp. and compared them to the ichthyosaurs of the English Lias (Sauvage, 1898). Later, Zbyszewski and Moitinho de Almeida (1952) addressed the collections of the Serviços Geológicos de Portugal, reporting maxillary fragments, an anterior right limb, and vertebrae collected by Joaquim Pintassilgo and Ernest Fleury (1878–1958) from the Sinemurian of Praia de Nossa Senhora da Vitória, Municipality of Alcobaça, as the species *I. intermedius*, and maxillary and limb fragments and vertebrae from the Pliensbachian of Pintanheira as *Stenopterygius uniter* while leaving maxillary fragments from Alhadas (Aalenian) and Murte de (undetermined age – u.a), Municipality of Cantanhede, and vertebrae from Cadima (u.a), Municipality of Cantanhede, and Casal Comba (Casal do Combo), Municipality of Mealhada, as *Ichthyosaurus* indet. (Zbyszewski and Moitinho de Almeida, 1952). Later, Ferreira (1958) documented a jaw fragment and vertebra from the Pliensbachian of Praia de Nossa Senhora da Vitória and vertebrae from the Toarcian of Condeixa, Municipality of...
Condeixa-a-nova, and the Aalenian of Tomar, Municipality of Torres Novas, as *S. uniter* and vertebræ occurrences from the Sinemurian of Praia da Nossa Senhora da Victória, Águas Madeiras (Águas de Madeira), Municipality of Alcobaça, Casal Comba and the Pliensbachian of Alvaiaízere as *I. intermedius* (Ferreira, 1958). In 2007, Castanhinha and Mateus (2007) reviewed the marine reptiles of Portugal, revising and correcting previous classifications of the documented specimens. This work will focus on IST-MDT 85, the most complete documented ichthyosaur specimen in the Portuguese fossil record.

### 2 Methodology

IST-MDT 85 was determined to require further preparation in the laboratory, leading to the removal of the original plaster support and its substitution with an epoxy layer, as well as removal of sediment with an air scribe, and the cleaning of the specimen with formic acid at 2.5 % and the consequent deacidification process. Once this new preparation was deemed complete, a new description of the specimen was done, and its phylogenetic relations were explored, with IST-MDT 85 being observed, and the phylogenetic characters scored after Moon (2019), with reduced consensus trees being used to improve consensus resolution, and the wildcard taxa originally identified by Moon (2019), *Cymbospondylus piscoeus, Deearcmhara shawcrossi, Himalayasaurus tibetensis, Isfjordosaurus minor, Maiaspondylus lindoei, Malavania anachronus, Pervushovisaurus bannovkensis, Pervushovisaurus campylodon, Quasianosteosaurus vikinghoegda, Thaisaurus chonglakmanii* and *Tholodus schmidtii* being removed prior to the analysis. A 3D model was done with photogrammetry using Agisoft 1.2.0 (see Supplement).

The phylogenetic analysis, by maximum parsimony analysis, was performed using TnT version 1.5 (Goloboff and Catalano, 2016). The specimen here studied was added to the dataset of Moon (2019). The matrix, comprising 105 terminal taxa coded for 287 characters. Each dataset was analyzed using the new technology search in TNT, including sectorial search, ratchet, drift and tree fusing algorithms, with identical settings as those used by Moon (2019). Then an additional round of tree bisection reconnection using the trees in memory was performed, saving a maximum of 50 000 trees per analysis, due to hardware constraints. A pruning consensus algorithm, PCPrun, was then used with the intent of removing problematic taxa from the resulting tree. To optimize analytical time, this search and all the outputs of the analysis of specimen IST-MDT 85 were scripted (see Supplement).

### 3 Specimen – systematic paleontology

**Superorder Ichthyopterygia Owen, 1859**

**Order Ichthyosauria de Blainville, 1835**

**Family Ichthyosauridae Bonaparte, 1840**

**Genus *Ichthyosaurus* König, 1818**

*Ichthyosaurus cf. communis* De la Beche & Conybeare 1821

*Ichthyosaurus cf. communis*, IST-MDT 85

1952, *Ichthyosaurus intermedius* (cited in Zbyszewski and Moitinho de Almeida, 1952)
Table 1. Table of the distribution of Portuguese ichthyosaur specimens. MG: Museu Geológico de Lisboa, Portugal; IST-MDT: Instituto Superior Técnico de Lisboa, Museu Décio Thadeu, Portugal.

| Age/stage | Locality                  | Specimen number | Elements                     | Referenced by                      |
|-----------|---------------------------|-----------------|------------------------------|------------------------------------|
| Aalenian  | Alhadas                   | MG 36           | Jaw fragments and teeth      | Sauvage (1898)                     |
|           | Tomar                     | MG 4743         | Dorsal vertebra              | Ferreira (1958)                    |
|           |                           | MG 4753         | Caudal vertebra              |                                    |
| Toarcian  | Condeixa                  | MG 25182        | Set of 15 vertebra           |                                    |
|           |                           | MG 25183        | Set of 13 vertebra           |                                    |
| Pliensbachian | Alvaíázere                | MG 25184        | 1 vertebra                   |                                    |
|           | Praia de Nossa Senhora da Vitória | MG 4749    | 2 maxillary fragments, with 46 teeth | Zbyszewski and Moitinho de Almeida (1952) |
|           | Pintanheira               | MG 4751         | Jaw fragments and teeth      |                                    |
|           |                           | MG 4747         | Fin fragments                |                                    |
|           |                           | MG 4755         | 38 precaudal vertebra        |                                    |
| Sinemurian | Praia de Nossa Senhora da Vitória | IST-MDT 104 | Maxillary fragments with teeth |                                    |
|           |                           | IST-MDT 85      | Anterior right limb, with articulated radius and ulna |                                    |
|           |                           | IST-MDT 103     | Set of vertebra              |                                    |
|           | Águas de Madeiros         | MG 4748         | Set of 2 vertebra            | Ferreira (1958)                    |
|           | São Pedro de Moel         | MG 4745         | 1 vertebra                   | Undocumented                       |
| Uncertain age | (Sinemurian to Aalenian)  | Cadima          | Set of articulated vertebra  | Castanhinha and Mateus (2007)      |
|           | Murtede                   | MG 35           | Maxillary fragments with teeth |                                    |
|           | Unknown locality           | MG 25186        | Rib and vertebrae fragments  |                                    |
|           | Casal do Combo            | MG 4746         | Set of 2 caudal vertebra     | Ferreira (1958)                    |

Material

Forelimbs (IST-MDT 85; Figs. 2 and 3): almost complete left forelimb, in dorsal view, plus disarticulated phalanges from the right limb.

Locality

Praia de Nossa Senhora da Vitória. Cross-referencing the Sinemurian rocks with the original indications by Zbyszewski and Moitinho de Almeida (1952), the probable coordinates are around 39°42’25” N, 9°3’4” W, in Municipality of Alcobaça, Portugal.

Age and horizon

In the area, the Sinemurian is observable at Praia de Nossa Senhora da Vitória, in dolomite layers with Unicardium costae (Sharpe) (Zbyszewski and Assunção, 1965), which is the lower section of Coimbra Formation, considered lower Sinemurian (199.3–195.8 Ma).

3.1 Description

The more complete left fin is exposed dorsally, with the humerus slightly proximodistally longer than anteroposteriorly wide, and in dorsal view is equally as wide proximally and distally, lacking a differentiated proximal head. The anterior margin is markedly concave, while a proximally reduced anterior flange is present. The dorsal trochanter, a ridge-like structure across the length of the humerus, is observable,

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but a protruding deltopectoral crest and a plate-like dorsal ridge are absent. The distal facets are terminally placed, approximately equal in size, apparently continuous, and the ulnar facet does not deflect posterodistally. The anterodistal extremity shows no tuberosity and no anterior or posteriorly distal facets for the sesamoid. There is no contact between the humerus and the intermedium. The epipodial and metapodial elements are flattened and plate-like, with no notching on the anterior and posterior edges of the fin, and one postaxial accessory digit is observable. The radius and the ulna are equal in size, lacking an interosseous space between them, and the radius is wider than long. The ulna is severely damaged and difficult to discern, but it is apparently equally wide anteriorly and posteriorly, the posterior margin is convex, and as thick as the rest of the ulna. The manual pisiform is absent. The intermedium, damaged like the ulna, is smaller than the ulnare, located between the radius and the ulna, and apparently as wide as it is long, with a pointed proximal shape, an angular distal edge, and two directly supported digits. The ulnare sports one distal facet, supporting a single digit. There are six observable carpals, all of them are of comparable size and a postaxial row of phalanges identified as part of an accessory digit. There are four observable ossified elements in the metacarpal row, and a preaxial accessory digit is absent, with the smaller elements observable on the anterior edge of the fin identified as belonging to the more incomplete right fin, while a postaxial accessory digit is observable. The manual metacarpals ii–iv are polygonal with rounded edges. The 55 observable manual phalanges are tightly packed polygons proximally and growing rounded distally, and a digital bifurcation is observable on the anterior side of the second phalangeal row, apparently stemming from digit iii.
3.2 Phylogenetic analysis results

Specimen IST-MDT 85 had the following characters scored based on character list by Moon (2019): 198–252: 121 1010?1011? 00000101? 2121010001 0101002?1?0 001?1001211. The analysis yielded 50 000 MPTs (most-parsimonious trees), each with a length of 1694 steps.

The strict consensus is not well resolved, placing the specimen within the *Ichthyosaurus* genus (Fig. 4), as determined by the ulnare being larger than the intermedium (Char. 229: 1 → 0); the angular distal shape of the intermedium (Char. 233: 1 → 0); the subequal size of the distal facets of the intermedium (Char. 235: 1 → 0); and the four elements on the metacarpal row (Char. 241: 1 → 0). Within the genus, the specimen is placed into a polytomy, alongside *I. communis* and *I. anningae* and a subgroup of *I. breviceps*, *I. somersetensis* and *I. larkini* as determined by the humerus being of approximately equal width anteroposteriorly (Char. 206: 0 → 1) and the presence of digital bifurcation (Char. 252: 0 → 1).
Figure 3. *Ichthyosaurus* cf. *communis* (IST-MDT 85), humerus in dorsal (a) and ventral (b) view, from Praia de Nossa Senhora da Victória, São Pedro de Moel. ad – depression in the articular face; dt – dorsal trochanter. Bar marks 2 cm.

Figure 4. Reduced consensus tree of IST-MDT 85, *I. cf. communis*, after the matrix by Moon (2019).

4 Discussion

IST-MDT 85 was assigned by Zbyszewski and Moitinho de Almeida (1952) to the species *I. intermedius*, described by Conybeare in 1822, although its holotype location is unknown and what figures of it are available are not considered valid. The species was identified largely through tooth morphology, which nowadays is considered highly variable between individuals and thus not a valid character for species identification, and recent work posits that the species is a synonym to *I. communis*. Upon observation and comparison with other specimens, it is possible to see that the humerus of IST-MDT 85 shows diagnostic traits of the *Ichthyosaurus* genus that are observable in *I. communis*, such as the humerus being longer than wide, the presence of a depression in the articular surface, and the dorsal trochanter being large while extending less than halfway down the shaft (Massare and Lomax, 2018). The phylogenetic analysis further sup-

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ports the assignment of the specimen, to the *Ichthyosaurus* genus, as determined by the absence of notching in anterior elements of the forelimb (Char. 217), and the subequal size of the distal facets of the intermedium (Char. 235), and within this genus placed within a polytomy with *I. communis* and *I. anningae*, and a subgroup of *I. breviceps*, *I. somersetensis* and *I. larkini*, as determined by the approximately equal anteroposterior width of the humerus (Char. 206), and the presence of manual bifurcation (Char. 252). This last character, observable on the anterior side of the specimen, along with the observable presence of four elements in the distal carpal row, with the distal carpals 3 and 4 being in contact with the intermedium (Motani, 1999), and the humerus being equally as wide proximally and distally while the shaft is lightly constricted (Massare and Lomax, 2018), are identifying elements of *Ichthyosaurus*, which coupled with the analysis firmly places IST-MDT 85 as part of the genus. While a species identification for the specimen has proven difficult, a comparison to NHMUK PV R1162, the neotype for *I. communis* (Lomax and Massare, 2017), shows that, while the shaft of the humerus appears to be less constricted in IST-MDT, and identifying a species based on a single, damaged bone is a difficult endeavor, enough similarities are observable to allow us to consider the Portuguese specimen *I. cf. communis*. The *Ichthyosaurus* genus is very common in Europe, having occurrences in Belgium (Godefroit, 1996), Northern Ireland, Wales, several localities of England such as Dorset and Somerset (Massare and Lomax, 2018), and one documented occurrence outside of Europe in Alberta, Canada (McGowan, 1978). The *I. cf. communis* in Portugal is the southernmost occurrence of the genus (Fig. 5).

5 Conclusion

In summary, we conclude that IST-MDT 85, the ichthyosaur forelimb from the Sinemurian of Praia de Nossa Senhora da Victória, Municipality of Alcobaça, Portugal, located within the Lusitanian Basin, can be assigned to the *Ichthyosaurus* genus via phylogenetic analysis, and comparison of traits of the humerus with other specimens further lets us identify it as *I. cf. communis*. This makes IST-MDT 85 the southernmost occurrence of the genus, which expands its geographical range southwards.

Code and data availability. The source code for the matrix, which is based on the matrix by Moon (2019), was obtained from Lloyd (2021, https://graemelloyd.com). The relevant dataset for the purposes of the article is available in the Supplement.
Supplement. The supplement related to this article is available online at: https://doi.org/10.5194/fr-24-287-2021-supplement.

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