

On the Cretaceous ichthyosaur remains from the Northern Apennines (Italy)

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ABSTRACT – Several remains of Cretaceous ichthyosaurs are described from the “Chaotic Complex” Formation of the Northern Apennines, South of Modena and Bologna. Owing to the fragmentary preservation of the material, specific classification is impossible. However, the rostrum bone configuration of the Italian and of other Cretaceous species could indicate that, during Cretaceous time, at least two different lineages of ichthyosaurs were co-evolving.

In one lineage the maxilla extends more anteriorly than the nasal: it is represented by *Platypterygius birjukovi* (Ochev & Efimov, 1985) from the Russian lower Cretaceous and by *P. americanus* (Nace, 1939) from the Albian-Cenomanian of Wyoming.

In the second lineage the maxilla is shorter and extends anteriorly at about the same level as the nasal: it is represented by *Platypterygius bedengensis* (Efimov, 1997) from the Russian Hauterivian and by *P. longmani* (Wade, 1990) from the Australian Albian.

In the studied material, two of the fragments (Rostrum 1 and Rostrum 3) show a short maxilla and therefore probably are members of the second lineage.

RIASSUNTO – [Sugli ittiosauri del Cretaceo superiore dell'Appennino settentrionale] – Vengono presentati i risultati dello studio di alcuni resti isolati di ittiosauri cretacei rinvenuti nei sedimenti del “Complesso Caotico” affioranti nell'Appennino modenese e bolognese. La frammentarietà dei resti, pur non permettendo una attribuzione specifica, consente tuttavia di fare alcune notazioni sulla struttura e disposizione delle ossa costituenti lo splancnocranio negli ittiosauri cretacei.

Dal confronto con materiale già descritto si possono individuare, durante il Cretaceo, almeno due linee evolutive, distinte sulla base di un maggiore o minore sviluppo anteriore delle ossa mascellari.

La prima linea filetica è caratterizzata da mascellari estesi più anteriormente dei nasali. Essa è rappresentata da *Platypterygius birjukovi* (Ochev & Efimov, 1985), del Cretaceo inferiore russo, e da *P. americanus* (Nace, 1939), dell'Albiano-Cenomaniano del Wyoming (USA).

La seconda linea, con mascellari che si estendono anteriormente all'incirca quanto i nasali, è rappresentata da *Platypterygius bedengensis* (Efimov, 1997) del Cretaceo inferiore (Hauteriviano) russo e da *P. longmani* (Wade, 1990) dell'Albiano australiano.

Due dei frammenti da noi studiati (Rostrum 1 e Rostrum 3) appartengono al morfotipo che presenta mascellari poco estesi (linea *P. bedengensis* - *P. longmani*), per gli altri frammenti non è possibile questa notazione.

INTRODUCTION

The present knowledge of Cretaceous ichthyosaurs relies on few, mostly fragmentary remains found on different continents (Bardet, 1992). Some findings were also reported from Northern Italy, all from the Northern Apennines south of Modena and Bologna (Text-fig. 1). They were collected as scattered fragments from the so-called “Allochthonous Chaotic Complex”, a tectono-sedimentary complex that contains rocks of different ages, ranging from the Early/Late Cretaceous to the Oligocene (Bettelli *et al.*, 1989).

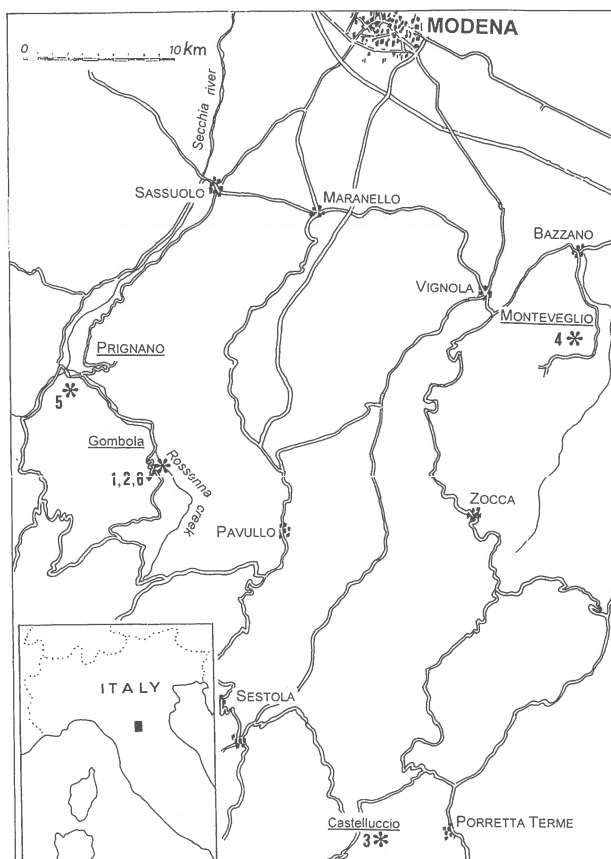
This paper deals with all known Italian Cretaceous ichthyosaur remains, including previously described material (Pantanelli, 1889; Capellini, 1889, 1890a, b; Simonelli, 1910; Rompianesi, 1975; Battista, 1993; Rompianesi & Sirotti, 1995), as well as some new findings.

The attempt to identify these fragmentary remains to the species level raises some problems

because of the incompleteness of the fossils: all the recognized Cretaceous ichthyosaur species are defined on different and often unrelated features, most of which cannot be observed in the Italian material. Consequently, it is not surprising that most of the Italian Cretaceous ichthyosaurs were not identified to the species level. Only Capellini (1889, 1890a, b) made an attempt in this direction by referring a fragmentary rostrum to *Ichthyosaurus campylodon* Carter, 1846.

The major aims of this study are:

- a) to give a complete overview of the Cretaceous ichthyosaur remains from the Northern Apennines;
- b) to contribute to the knowledge of the cranial osteology of the last representatives of the ichthyosaurs. The details of cranial anatomy are well known for some of the Jurassic (Sollas, 1916; McGowan, 1973, etc.) but not for the Cretaceous species.



Text-fig. 1 - Location-map of the ichthyosaur remains described in the text. 1) R1; 2) R2; 3) R3; 4) R4; 5) C; 6) H.

GEOLOGICAL SETTING

The material here described comes from at least four different localities of the Northern Apennines (Text-fig. 1). All these outcrops belong to the former "Argille scagliose Fm.", more recently labelled as "Allochthonous Chaotic Complex" (see Bettelli *et al.*, 1989). These names refer to a very complex set of different lithologies (mainly clays, sandstones and limestones) of different ages, whose stratigraphic relationships are still not clear. The Complex was originally deposited during a time span covering at least the early Cretaceous-Oligocene, as distinct lithological units in the Ligurian Sea. During the Apenninic orogenesis, these units were tectonically displaced to the east by processes of submarine debris flow or mud flow (Bettelli *et al.*, 1989). Therefore, it is difficult to recognise the originally continuous sequence.

All the Ichthyosaurian remains presumably originate from the lower units of the Complex, *i.e.* from the "Basal Units" (Bettelli *et al.*, 1989) whose age is approximately Aptian to Turonian. The studied material does not allow providing a precise age for the ichthyosaurs, owing to the lack of index fossils in the attached matrix.

PALAEONTOLOGICAL SECTION

The ichthyosaur fossils were found at different outcrops (Text-fig. 1), so they represent different individuals. Notwithstanding, all the specimens display some features that allow their attribution to Cretaceous representatives of the Ichthyosauria, so the relative age of all specimens should be quite similar. Every attempt of a specific classification failed, owing to the lack of species-diagnostic features. Below we provide detailed descriptions of the material.

R1) ROSTRUM 1 (Pl. 1; Text-fig. 2)

Material – Part of a rostrum anterior to the nares.

Locality – 1 Km WSW of Gombola (Modena) (Text-fig. 1), on the left side of the Rossenna creek (Pantanelli, 1889).

History – First reported by Pantanelli (1889) and later described by Capellini (1889, 1890a, b) who referred the specimen to *Ichthyosaurus campylodon*. He also provided interpretative line drawings of the bones shown in distal and proximal views.

Repository – Collection of the "Istituto di Paleontologia", University of Modena and Reggio Emilia (IPUM 30139).

Description – The fragment (length 16.6 cm) is well preserved, thus provides a considerable amount of information. During fossilisation, a significant lateral compression resulted in a dorsal displacement, with shifting upwards of the right side.

On the lateral surface, we recognise the nasals, the premaxilla, and the dentary.

Three longitudinal grooves are seen on the lateral surface: a dorsal one along the medial contact between the nasals and the premaxilla (*fossa naso-premaxillaris*), a deeper second one on the lateral side of the premaxilla (*fossa premaxillaris*), and a third one on the lateral side of the dentary (*fossa dentalis*).

Most of the teeth remain in an anatomically correct position. They are straight, robust cones with an

EXPLANATION OF PLATE 1

Figs. 1a-c - *Platypterygius* sp. Rostrum 1 (R1) from Gombola (Modena Province). IPUM 30139.
1a) Lateral (left) view. 1b) Lateral (right) view. 1c) Distal view.
Scale bar = 5 cm.



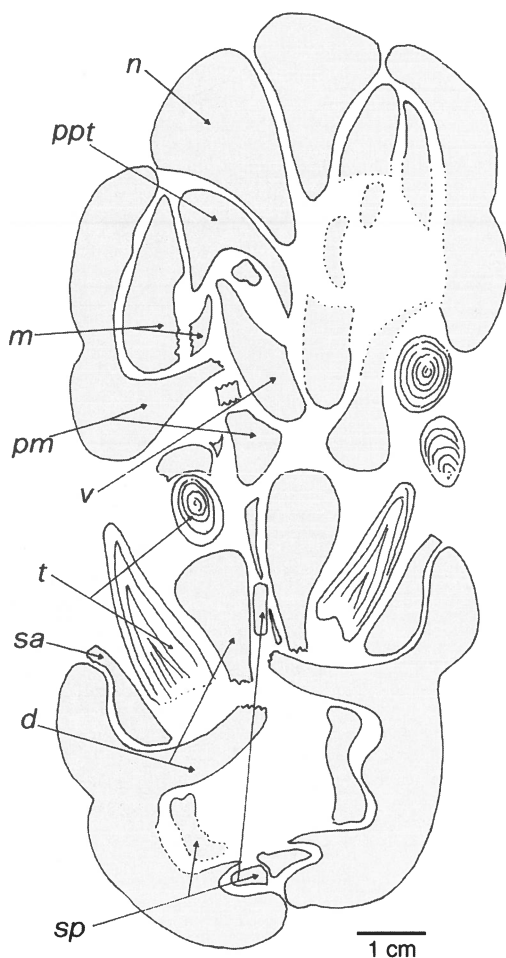
1a



1c



1b



Text-fig. 2 - Distal view of R1 (see Pl. 1, fig. 1c). d, dentary; m, maxilla; n, nasal; pm, premaxilla; ppt, processus palatinus pterygoidei; sa, surangular; sp, splenial; t, teeth; v, vomer.

acute and smooth tip. The maximum transversal diameter observed is 16 mm. The lower teeth are globally of larger size. The dorsal part of the root is transversely compressed. The ventral part of the root is roughly rectangular; as Bardet (1990) pointed out, this should be a distinctive feature of all the Cretaceous ichthyosaurs. The vertical ridges of the

enamel crown are all of similar length and closely approach the apex of the tooth. The part of the root emerging over the bone suggests an aulacodont type of dental implantation (Mazin, 1983).

To investigate the internal architecture and the relationships between the bones, Capellini (1889) provided a drawing of this specimen showing a reconstruction of the posterior (distal) side. After moderate polishing, we obtained a larger amount of information (Pl. 1, fig. 1c; Text-fig. 2). Of course, this chance section is not sufficient to gain a precise idea about the whole architecture of the skull. Anyway, it provides useful additional information on the cranial architecture in Cretaceous ichthyosaurs. Most of the bones observed in the medial part of the right side are fragmentary, probably due to the strong lateral compression. The left side (Text-fig. 2) is better preserved.

In the upper jaw, the lateral part of the section consists only of the nasal and of the premaxilla. The nasals have a heart-shaped cross-section and are quite massive; ventro-laterally they are covered by the anteriormost portion of the pterygoid (*processus palatinus pterygoidei*). A bone that may be interpreted as an anterior medial projection of the maxilla lines the premaxilla internally. The palatal roof is represented by the vomer and by the ventro-medial projection of the premaxilla. The dental groove of the premaxilla suffered distortions and breakage.

The lower jaw is laterally only formed by the dentary. Dorsally it bears a large dental groove that encloses the anterior process of the surangular. Ventrally, an antero-dorsal process of the splenial is visible, and a thin blade-like anterior process of the splenial spans the small gap between the two mandibular rami like a joint. Dorsally, between the dentary grooves, some small bone fragments might also be a part of the splenial.

Discussion – Apart from Capellini (1889), only Owen (1851), Kiprijanoff (1881) and Bardet (1989) described transversal sections of the cranial bones of Cretaceous ichthyosaurs. However, in all the specimens described the sections are located proximally in the rostrum and only show few elements. In particular the palatal bones were hitherto unknown.

In the present specimen, the posterior cross-section shows no lateral exposure of the maxilla, so that

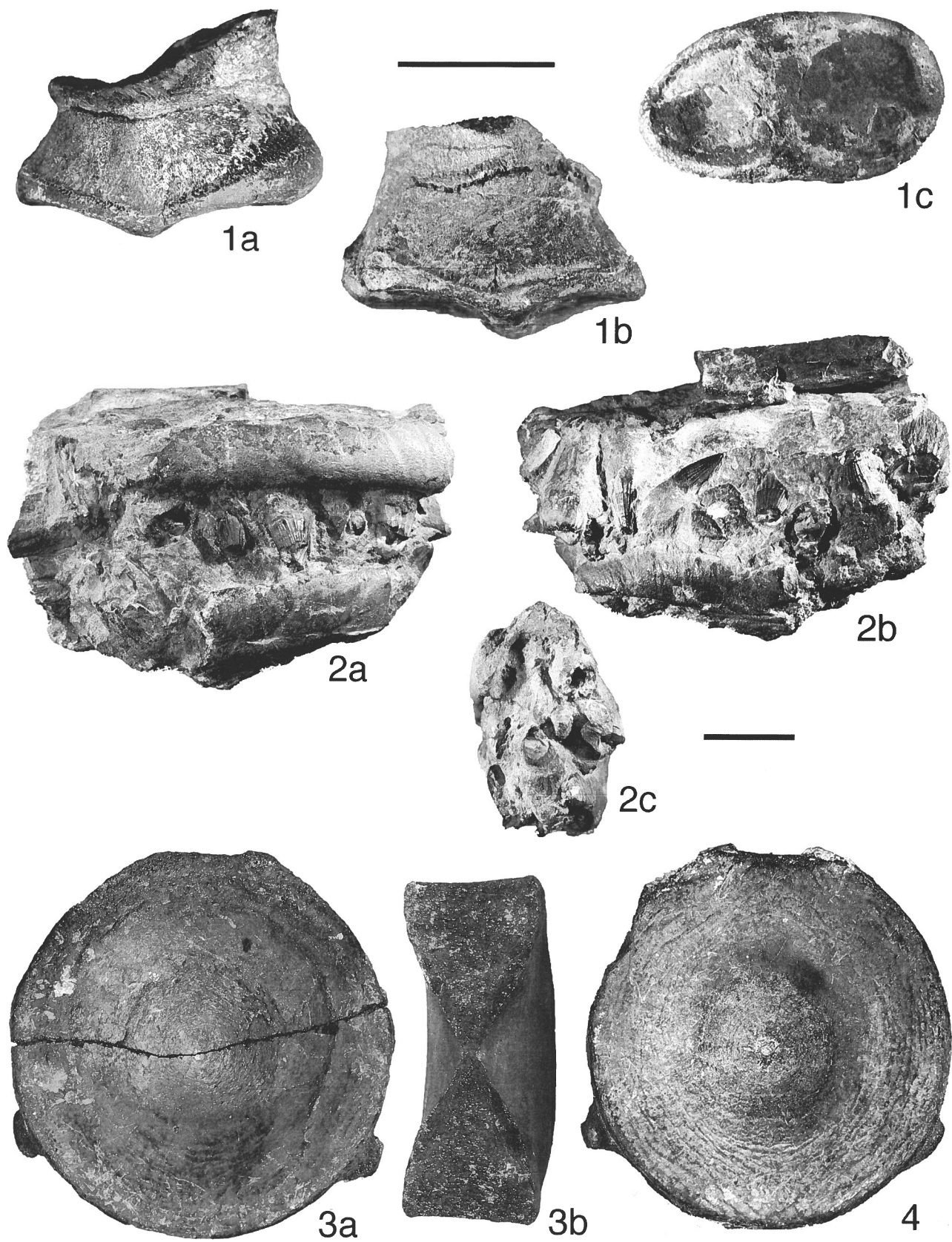
EXPLANATION OF PLATE 2

Figs. 1a-c - *Platypterygius* sp. Left humerus (H) from Gombola (Modena Province). IPUM 30141.
1a) Ventral view. 1b) Dorsal view. 1c) Distal view.

Figs. 2a-c - *Platypterygius* sp. Rostrum 2 (R2) from Gombola (Modena Province). IPUM 30140.
2a) Lateral (right) view. 2b) Lateral (left) view. 2c) Anterior (proximal) view.

Figs. 3a-b, 4 - *Platypterygius* sp. Caudal centra (C) from Prignano (Modena Province).

3a) Anterior articular surface of the centrum n. 1 (see Rompianesi & Sirotti, 1995). 3b) Transversal section of the centrum n. 1 (see Rompianesi & Sirotti, 1995). 4) Anterior articular surface of the centrum n. 2 (see Rompianesi & Sirotti, 1995).
Scale bar = 2 cm.



this fragment probably comes from an area of the rostrum located anteriorly to the external nares. Surprisingly, the occurrence of the vomer and pterygoid suggests a more distal position when compared to Sollas' (1916) sections of the Jurassic *I. communis* in which the pterygoid hardly anteriorly exceeds the internal nares.

Concerning the relationships between the external bones in the rostra of Cretaceous ichthyosaurs, good illustrations have been offered by Romer (1968), Wade (1984, 1990), Ochev & Efimov (1985) and Efimov (1997). In Romer's (1968) *P. americanus*, the maxilla extends far anteriorly in the rostrum, even farther than the nasals (Text-fig. 4a). In the Australian *P. longmani* (= *P. australis* Wade, 1984) the maxilla only extends posteriorly to the nasals (Text-fig. 4b).

The percentage of lateral exposure of the maxilla, between the nares and the tip of the snout is about 40% in *P. americanus* (after Romer, 1968, fig. 4) and only about 30% in *P. longmani* (after Wade, 1984, fig. 1). The same character can be observed in Hauterivian Russian taxa recently described: in *P. birjukovi* (Ochev & Efimov, 1985) the maxilla extends more anteriorly on the rostrum than the nasal, like in *P. americanus*, whereas in *P. bedengensis* (Efimov, 1997), the maxilla and nasal exhibit about the same anterior extension, similar to *P. longmani*.

Looking at the distal section of the Rostrum 1 (Text-fig. 2), the maxilla laid medially to the premaxilla (and so is not exposed in lateral view), whereas the nasal, vomer, and pterygoid are available. This indicates for Rostrum 1 a configuration close to that observed in both *P. longmani* and *P. bedengensis* (Text-fig. 4c). These two different rostrum bone configurations could indicate that more taxa than previously thought could be present during Cretaceous time. Pending for the discovery of more adequate material and for the analysis of the importance of this character in ichthyosaur phylogeny, the specimen herewith described is referred to as *Platypterygius* sp.

R2) ROSTRUM 2 (Pl. 2, figs. 2a-c)

Material – Anterior part of a rostrum, probably close to the tip.

Locality – 1 Km WSW of Gombola (Modena), on the left side of the Rossenna creek. Same locality as R1 (Text-fig. 1).

History – Collected by Mr. Enzo Grazioli, the specimen was described and illustrated by Rompianesi (1975).

Repository – Collection of the "Istituto di Paleontologia", University of Modena and Reggio Emilia (IPUM 30140), gift of Mr. P. Rompianesi.

Description – This small fragment has been found in 1974 near Gombola. It is the anterior part of a rostrum, 10 cm long and 7.2 cm high at maximum, with most of the teeth in original position. This fragment also suffered from lateral compression with a dorsal displacement of the right side, like R1.

Laterally, only the premaxilla, dentary and some teeth are visible. The visible portion of the upper jaw is wider than the lower one.

R3) ROSTRUM 3 (Pl. 3; Text-fig. 3)

Material – Part of a rostrum, in a very bad state of preservation, largely embedded in a dark rock, plus an isolated tooth-bearing fragment.

Locality – Castelluccio near Porretta Terme (Bologna) (Text-fig. 1).

History – The fragments have been illustrated by Simonelli (1910) and named *Ichthyosaurus* sp.

Repository – Museo Capellini, Bologna University, catalogue number 8845/1RE8.

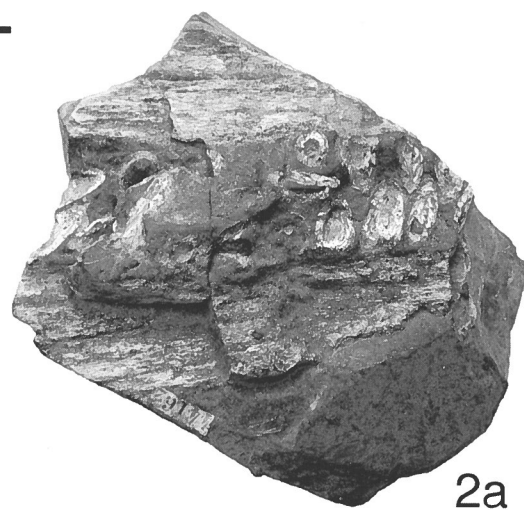
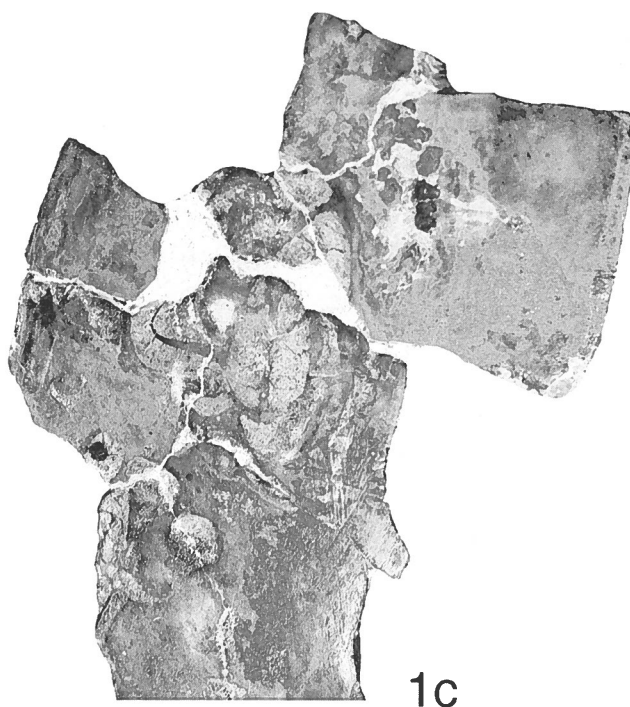
Description – The larger specimen illustrated by Simonelli (1910) laterally provides little information (Pl. 3, fig. 1b). Simonelli sectioned it at about half of its length (Simonelli, 1910, Pl. 1, fig. 2). The sections (Pl. 3, figs. 1a, c) provide some useful data: all the bones are less robust than in R1 and are largely disarticulated, so the interpretation of the architecture is partly conjectural (Text-fig. 3). In the upper jaw the heart-shaped nasal, the maxilla, now in lateral position, and possibly the lacrimal can be recognized; medially to the latter there is another element interpreted possibly as part of the premaxilla. The vomer, palatine and pterygoid, representing the palatal roof, are all well developed but not in anatomical connection. The post-mortem deformation displaced the right side of the jaw dorsally with respect to the left side.

EXPLANATION OF PLATE 3

Figs. 1a-c, 2a-b - *Platypterygius* sp. Rostrum 3 (R3) from Castelluccio near Porretta Terme (Bologna Province), catalogue number 8845/1RE8.

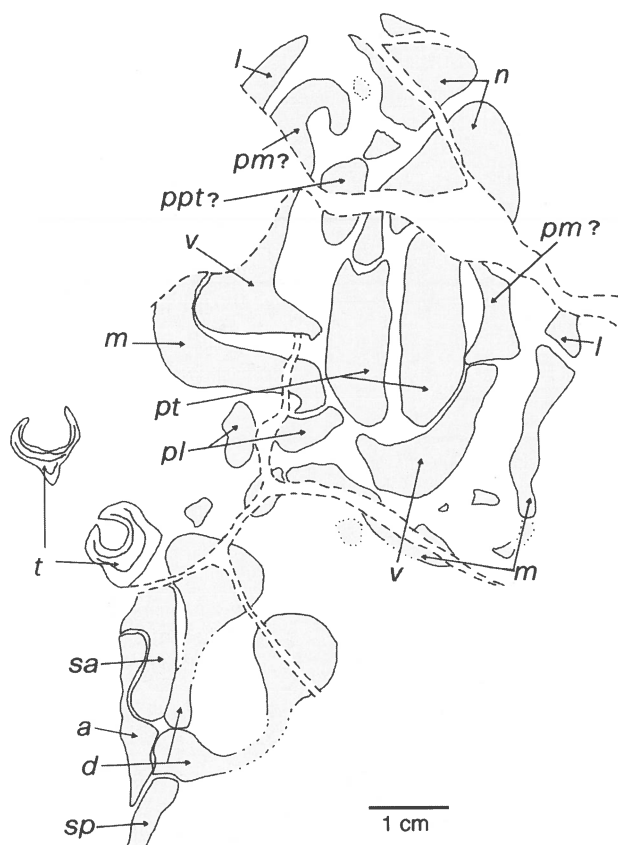
1a) Proximal view. 1b) Lateral (right) view of the proximal block. 1c) Distal view. 2a) Isolated block containing part of the rostrum with some teeth in lateral view. 2b) Detail of the teeth.

Scale bar = 5 cm, except for 2b (= 1 cm).



2b





Text-fig. 3 - Distal view of R3 (see Pl. 3, fig. 1c). Abbreviations as in Text-fig. 2, plus a, angular; l, lacrimal; pl, palatine; pt, pterygoid.

In the lower jaw, only the right side is preserved showing the dentary with the dorsal dental groove and, medially, the surangular. The angular and splenial are present ventromedial to the dentary, in the ventralmost part of the section (Text-fig. 3).

The isolated fragment (Pl. 3, figs. 2a, b) is about 11.5 cm long and approximately the same width. It was described and figured by Simonelli (1910, Pl. 1, fig. 3). Its relationships to the larger piece are not clear; probably it is part of the same specimen, but this is not sure. If so, it could be an anterior part of the rostrum. The teeth sections exposed show probably the dentine, being of white colour and with lamellar structure (Pl. 3, fig. 2b).

Discussion – Simonelli's (1910) interpretation of the inner architecture of this rostrum has to be revised because he mistook the lower part of the rostrum for the upper one. A possible interpretation of the bones visible on the section is shown in Text-fig. 3.

To gain an idea of the position of the section one has to consider the arrangement of the bones. In the lower jaw, the external surface is formed by the dentary (dorsally), and probably also by the surangular, angular and splenial (ventrally). In the upper jaw, the palatal roof is represented by several bones, among which the pterygoid is strongly developed. This means that the section is probably located in a position even closer to the external nares than the specimen R1. This is confirmed by the presence of the lacrimal dorsal to the maxilla, and of the palatine. The bone medially to the lacrimal may be the posteriormost part of the premaxilla.

It is important to note that here, like in the specimen R1, the maxilla is particularly strong posteriorly.

R4) ROSTRUM 4 (Pl. 4)

Material – Anterior, upper (?) part of a rostrum.

Locality – Monteveglio near Bazzano (Bologna) (Text-fig. 1).

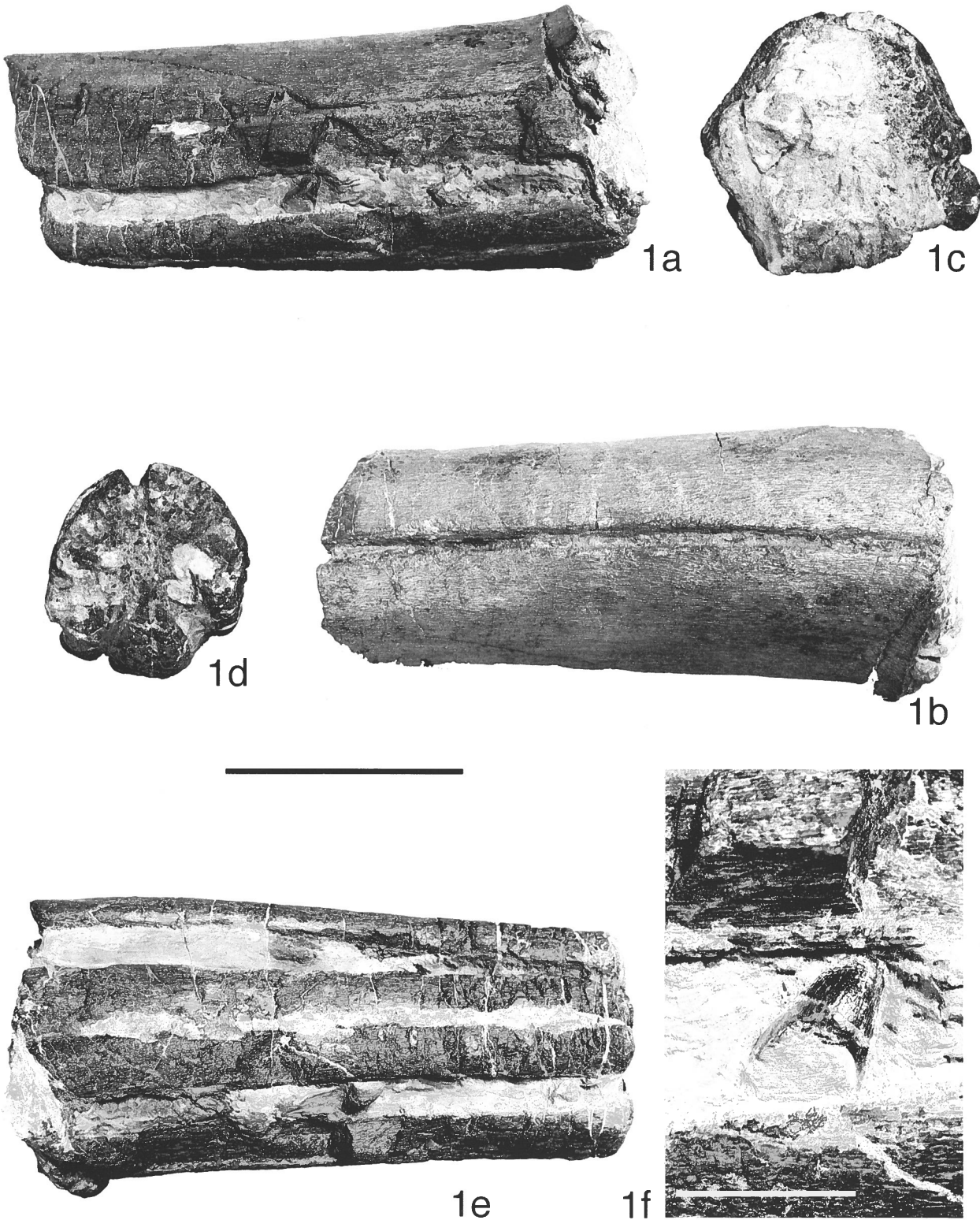
History – Collected by Mr. Renato Berselli, this specimen is described and illustrated here for the first time.

Repository – Stored in the Vignola Museum (Modena Province), without catalogue number.

Description – We interpret this fragment (with some doubt) as a partial upper jaw because it does not show any trace of the splenial medially; so, it should be formed only by the premaxilla. If so, it represents the anterior, dorsal part of a rostrum, probably quite close to the termination of the muzzle. It is 13.9 cm long, 5.8 (distal)-5.1 (proximal) cm high, and suffered from deformation which displaced the left side dorsally. On the lateral surface, it clearly shows the premaxillary groove (Pl. 4, fig. 1a). The dental grooves are well visible, 6 to 9 mm wide (Pl. 4, fig. 1e). Only one tooth is visible (Pl. 4, figs. 1a, e, f), but its tip is still covered by matrix. Two sections of possible teeth are visible on the proximal transverse section (Pl. 4, fig. 1d). The teeth seem smaller than the ones observed in the other material studied.

EXPLANATION OF PLATE 4

Figs. 1a-f - *Platypterygius* sp. Rostrum 4 (R4) from Monteveglio (Bologna Province).
1a) Lateral (left) view. 1b) Dorsal view. 1c) Distal view. 1d) Proximal view. 1e) Ventral view. 1f) Detail of the tooth.
Scale bar = 5 cm, except for 1f (= 1 cm).



Remarks – If this fragment is compared with R2, the smaller size of the teeth could indicate either:

- a) a taxonomic difference between R2 and R4;
- b) a more anterior position in the rostrum of R4 compared to R2;
- c) a juvenile ontogenetic growth stage of R4.

The fragment is too small to allow a reliable choice among these options.

C) CENTRA (Pl. 2, figs. 3a-b, 4)

Material – Two caudal centra.

Locality – Prignano (Modena), quarry on the left side of the Rossenna creek, close to its confluence with the Secchia river (Text-fig. 1).

History – Collected by Mr. Artemio Scurani, these bones have been described by Rompianesi & Sirotti (1995).

Repository – Stored in the Vignola Museum (Modena Province), without catalogue number.

Description – The centra are nearly circular in outline, with a height of 85.5 and 83.9 mm respectively, and a horizontal diameter of 84 and 80.5 mm. Their length along the dorsal margin is 33.8 and 33.5 mm while in the central part they are only 4.5–4.9 mm thick, being strongly amphicelous. On the dorsal surface, there are two prominent knobs, which marks the facets for the neural arch. The neural canal floor is 16–17 mm wide. The presence of a single well developed rib facet together with the large neural canal floor indicate that the centra are from the anterior part of the caudal region (Romer, 1956).

Remarks – These centra are clearly not specifically diagnostic. Nevertheless, comparison to the already published caudal centra allows recognising some differences. According to Broili (1907) *P. platydactylus* has a first caudal centrum that is more elongated, apparently less amphicelous and with rib facets that are more elliptical in outline. The same is the case in *P. hercynicus* (Kuhn, 1946).

A better correspondence is found to the centrum of “*Ichthyosaurus campylodon*” described by Owen (1851), particularly in the general outline and the rounded rib facet. However, this does not ensure that the centra represent the same species.

H) HUMERUS (Pl. 2, figs. 1a-c)

Material – Distal part of a left humerus.

Locality – Vicinity of Gombola (Modena), at about the same locality where R1 and R2 have been found (Text-fig. 1).

History – This specimen, collected by Mr. Pietro Rompianesi in 1975, was described by Battista (1993).

Repository – Collection of the “Istituto di Paleontologia”, University of Modena and Reggio Emilia (IPUM 30141), gift of Mr. P. Rompianesi.

Description – The preserved length is 27 mm, the distal width 40 mm, and the dorso-ventral maximum thickness at the distal end is 22 mm. Distally there are 3 articular facets for: a) the ulna, posterior, truncated elliptical, 17–13 mm wide; b) the radius, circular in outline, 17–18 mm in diameter, and c) in the anteriormost position a third one, articulated with the extra zeugopodial element (Motani, 1999) thin and crescentic in outline.

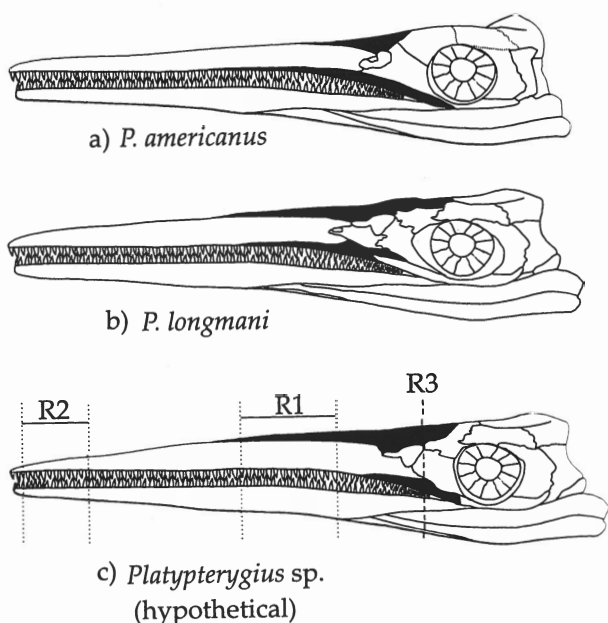
Remarks – When compared to *P. kiprijanoffi* (McGowan, 1972, fig. 6c, d), the studied humerus is more stoutly built, especially distally, and bears different articular facets. It looks more similar to the humerus of *P. platydactylus* (Broili, 1907, Pl. 13, figs 15, 16, 16a). Nevertheless, this fragment cannot be referred to the species *P. platydactylus* because the taxonomic usefulness of the morphology of the humerus is hitherto unknown in Cretaceous ichthyosaurs.

CONCLUDING REMARKS

The Italian material is not diagnostic at the specific level. However, it should be noted that this is a general condition for most of the Cretaceous ichthyosaur discoveries because the specific characters used as diagnostics are completely unrelated. Consequently, the various attempts to characterise the actually known “species”, even if striving for clarity, did not result in a natural classification. Moreover, McGowan’s (1979) phenetic methodology cannot be applied to the Cretaceous forms since the statistical approach to distinguish the species is prevented by the lack of material.

All the fragments here studied were referred to as *Platypterygius* sp., as all the known species of Cretaceous ichthyosaurs are included into the genus *Platypterygius* (Maisch & Matzke, 2000); the Russian usage to subdivide them into different genera (*Simbirskiasaurus* Ochev & Efimov, 1985; *Plutoniosaurus* Efimov, 1997) and subgenera (Arkhangelsky, 1998) are not sufficiently sustained by diagnostic characters.

In this paper, an attempt to distinguish Cretaceous ichthyosaurs on the anterior projection of the maxilla has been made. This is usually difficult to apply owing to the incompleteness of the material until now recovered. We propose to distinguish two morphotypes: a first where the maxilla extends posteriorly or at the same level than the nasal, and a second one where the maxilla extends more anteriorly than the nasals (Text-fig. 4).



Text-fig. 4 - Skull reconstructions of a) *Platypterygius americanus* (modified after Maisch & Matzke, 2000; b) *P. longmani* (modified after Maisch & Matzke, 2000), c) *Platypterygius* sp., partially inferred by the Apennine ichthyosaur remains; the cranial bones posterior to the nares were tentatively reconstructed as in *P. longmani*. The possible location of R1 and R2 is shown, as well as the position of the cross-section in R3; R4 (not shown) was probably close to R2. The nasal and the maxilla are in black.

This might indicate that at least two morphologically distinct lineages evolved during the Cretaceous. A first one, with short maxilla, is represented by *P. bedengensis* and by *P. longmani* (Text-fig. 4b) and our specimens R1 and R3 (Text-fig. 4c); a second one, with longer maxilla, is represented by *P. birjukovi* and by *P. americanus* (Text-fig. 4a).

The discovery of more material and the analysis of the importance of this character in ichthyosaur phylogeny is now necessary to confirm or infirm this hypothesis.

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