Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Geobios 39 (2006) 346–354
GEOBIOS
http://france.elsevier.com/direct/GEOBIO/

Marine reptiles (Thalattosuchia) from the Early Jurassic of Lombardy (northern Italy)

Rettili marini (Thalattosuchia) del Giurassico inferiore della Lombardia (Italia settentrionale)

Reptiles marins (Thalattosuchia) du Jurassique inférieur de la Lombardie (Italie du nord)

Massimo Delfino [a,*], Cristiano Dal Sasso [b]

[a] *Dipartimento di Scienze della Terra, Università di Firenze, Via G. La Pira 4, 50121 Firenze, Italy*
[b] *Museo Civico di Storia Naturale, Corso Venezia 55, 20121 Milano, Italy*

Received 24 May 2004; accepted 3 January 2005
Available online 28 February 2006

Abstract

The fossil remains of two small reptiles recently discovered in the Sogno Formation (Lower Toarcian) near Cesana Brianza (Lecco Province), represent the first mesoeucrocodylians reported for Lombardy and some of the few Jurassic reptiles from Italy. Due to the absence of diagnostic skeletal elements (the skulls are lacking), it is not possible to refer the new specimens at genus level with confidence. Although the well developed dermal armour would characterise Toarcian thalattosuchians of the genera *Steneosaurus* (Teleosauridae) and *Pelagosaurus* (Metriorhynchidae), the peculiar morphology of the osteoderms allow to tentatively refer the remains to the latter taxon (cf. *Pelagosaurus* sp.). The small size, along with the opening of the neurocentral vertebral sutures and, possibly, the non sutured caudal pleurapophyses, indicate that the specimens were morphologically immature at death. These "marine crocodiles" confirm the affinities between the fauna of the Calcare di Sogno Formation and coeval outcrops of central Europe that also share the presence of similar fishes and crustaceans.

Riassunto

I resti fossili di due piccoli rettili recentemente rinvenuti nella formazione di Sogno (Toarciano inferiore) presso Cesana Brianza (Provincia di Lecco) rappresentano i primi Mesoeucrocodylia provenienti dalla Lombardia e incrementano lo scarso registro dei rettili giurassici in Italia. A causa dell'assenza di elementi scheletrici diagnostici (quali gli elementi cranici), non è possibile identificare con certezza i nuovi esemplari a livello di genere. Sebbene la presenza di osteodermi ben sviluppati caratterizzi sia il genere *Steneosaurus* (Teleosauridae) sia il genere *Pelagosaurus* (Metriorhynchidae), la peculiare morfologia degli osteodermi stessi rende più probabile l'appartenenza dei resti al secondo taxon (cf. *Pelagosaurus* sp.). Le piccole dimensioni, unite alla presenza di suture neurocentrali aperte e di pleurapofisi caudali non suturate, suggeriscono che si tratti di individui morfologicamente immaturi. Il rinvenimento di "coccodrilli marini" nella Formazione dei Calcari di Sogno conferma le sue affinità faunistiche con le formazioni coeve dell'Europa centrale, che condividono anche la presenza di alcuni pesci e crostacei.

* Corresponding author. Tel.: +39 055 275 7525.
E-mail address: massimo-delfino@unifi.it (M. Delfino).

0016-6995/$ - see front matter © 2006 Elsevier SAS. All rights reserved.
doi:10.1016/j.geobios.2005.01.001

Résumé

Les restes fossiles de deux petits reptiles récemment trouvés dans la Formation de Sogno (Toarcien inférieur), près de Cesana Brianza (Province de Lecco), représentent les premiers Mesoeucrocodylia provenant de la Lombardie qui enrichissent les rares données fossiles concernant les reptiles jurassiques d'Italie. Compte tenu de l'absence d'éléments squelettiques servant à une diagnose précise, même au niveau du genre (tels que les éléments crâniens), il n'est pas possible de déterminer avec certitude ces exemplaires. Bien que l'existence d'ostéodermes bien développés soit caractéristique tant du genre *Pelagosaurus* (Pelagosauridae) que du genre *Steneosaurus* (Teleosauridae), la morphologie particulière des ostéodermes eux-mêmes rend plus probable l'appartenance des restes au dernier taxon (cf. *Pelagosaurus* sp.). Les petites dimensions des restes, tout comme la présence sur les vertèbres de sutures neurocentrales ouvertes et, probablement, de pleurapophyses caudales non fusionnées, suggèrent qu'il s'agit d'éléments appartenant à des individus immatures. La découverte de « crocodiles marins » dans la Formation de Sogno, confirme les affinités de cette faune avec celles des formations contemporaines de l'Europe centrale, avec lesquelles elle partage aussi des poissons et des crustacés similaires.

Keywords: Pelagosaurus; Mesoeucrocodylia; Thalattosuchia; Toarcian; Italy

Parole chiave: Pelagosaurus; Mesoeucrocodylia; Thalattosuchia; Toarciano; Italia

Mots clés : Pelagosaurus ; Mesoeucrocodylia ; Thalattosuchia ; Toarcien ; Italie

1. Introduction

The Mesozoic Formations outcropping in Lombardy have so far yielded an extraordinarily rich reptilian fauna dated almost exclusively to the Middle and Late Triassic and represented by world-wide renowned localities such as Besano (Varese Province), Cene and Endenna (Bergamo Province). The record of Cretaceous reptiles is limited to a single humerus, referred to a plesiosaur, coming from the Campanian-Santonian of Zavattarello (Pavia Province) (Renesto, 1993). The presence of fossil reptiles in the Early Jurassic locality of Saltrio (Varese Province) is known since more than one century. To the putative ichthyosaur ("*Ichthyosaurus platyodon*") and pterosaur ("*Pterodactylus longirostris*") remains quoted by Lioy (1896; specimens that apparently have never been described or figured and whose present repository is unknown), we can now add the theropod dinosaur that has been preliminarily described by Dal Sasso (2001, 2003).

In the spring of 2001, three slabs bearing evident tetrapod remains have been discovered and brought to the Museo di Storia Naturale di Milano (MSNM) by the amateur palaeontologists Silvio Mariani and Angelo Zanella. The specimens, now housed in the Fossil Vertebrates Collection of the same Museum under the numbers MSNM V4012, V4013a and V4013b, were originally difficult to interpret but after careful preparation are now available for study.

2. Geological setting

The fossils come from the southern flank of Monte Cornizzolo, which faces the small town of Cesana Brianza (Lecco Province, about 40 km NE of Milano). Six hundred and fifty meters above sea level, extensive quarrying activities expose a thin, dark-grey marlstone layer of the Lower Toarcian Calcare di Sogno Formation, that is included between the Morbio Formation and the Rosso Ammonitico Lombardo Formation. The Sogno Formation crops out, without continuity, in several localities in northern Lombardy (northern Italy), with an overall extension not exceeding 10 km^2. On a biostratigraphical basis, it is possible to assume that its age ranges from latest Early Jurassic (Toarcian) to Middle Jurassic (Lower Bajocian; Gaetani and Poliani, 1978; Gaetani and Erba, 1990; Delfrati, 1998).

According to stratigraphical correlations made on the latter formations on the basis of ammonites and calcareous nannofossils (Landra, 2003, pers. com.), the absolute age of the Sogno Fm. at Cesana can be well estimated as ranging from 189.6 to 186.8 ± 4.3 mya (Gradstein et al., 1995). Up to now, within the Sogno Formation, macrofossils have been found only in the lowermost portion of the Lithozone 1 (sensu Gaetani and Poliani, 1978). Besides the new reptiles, vertebrates are limited to the teleostean fishes *Leptolepis*, *Pachycormus* and *Pholidophorus* (Tintori, 1977); crustaceans are represented by the decapod *Proeryon* (Garassino, pers. com. 2003).

3. Systematic palaeontology

REPTILIA Laurenti, 1768.
CROCODYLIFORMES Benton and Clark, 1988.
MESOEUCROCODYLIA Whetstone and Whybrow, 1983.
THALATTOSUCHIA Fraas, 1902.
METRIORHYNCHIDAE Fitzinger, 1843.
Pelagosaurus Bronn, 1841.

The material consists of the remnants of two specimens, one of which preserved as part and counterpart, fossilised on slabs. Most of the available skeletal elements are in anatomical connection, well preserved in three dimensions, not showing any sign of erosion or damage due to post-mortem transport; however, some of the limb bones are partly crushed. Some of the elements, or parts of them, are represented by imprints in the matrix that, being fine-grained, allows to identify the original bone shape in detail and, sometimes, its surface morphology, too. In one of the two specimens (MSNM V4013) there are possible integumentary remains, represented by a blackish halo surrounding the caudal vertebrae and covering the distal elements of the hind limbs.

MSNM V4012. The specimen MSNM V4012 (Fig. 1) represents the posterior trunk and anterior caudal region of the body of a single individual exposed almost entirely on its left lateral side. The total length of the preserved vertebral column is about 155 mm. Several vertebrae, ribs, osteoderms, and part of the hind limbs are preserved.

The vertebral column is represented by a row of six elements (I–VI; the last one is partial) followed by two imprints (VII–VIII) and then by eight more vertebrae (IX–XVI; the first one is partial); close to the last element of the row there is one more displaced vertebra (XVII). Posterior trunk, sacral and anterior caudal vertebrae are present but it is not easy to identify them since the pelvic girdle and associated vertebral structures are poorly preserved. The vertebrae are partly embedded in the matrix showing regularly their left side except those in the last few positions that show their ventral (XIV) or their

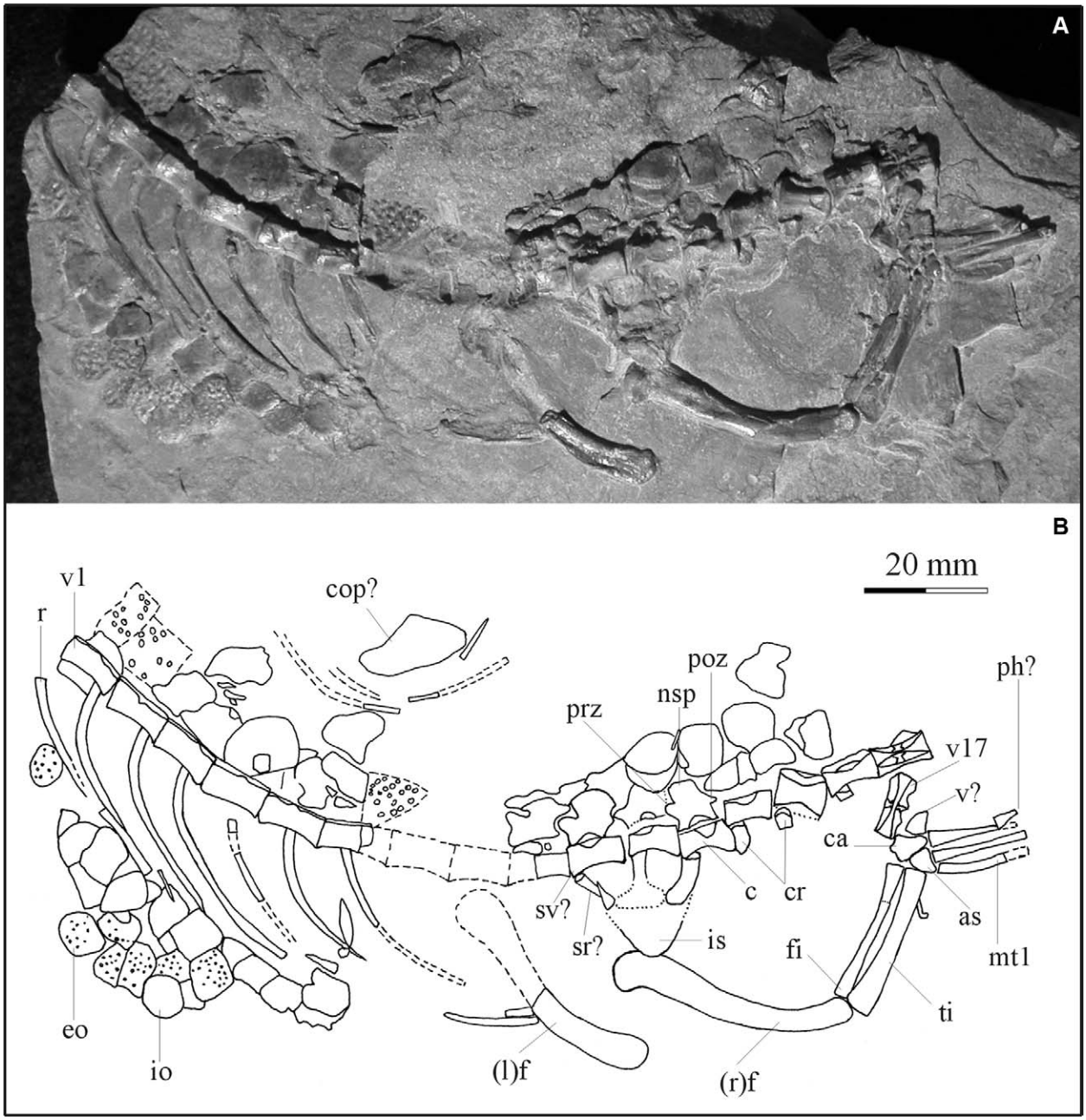

Fig. 1. cf. *Pelagosaurus* sp. MSNM V4012. Photo of the specimen (**A**) and sketch of its skeleton (**B**). Abbreviations: as, astragalus; c, centrum; ca, calcaneum; co, caudal osteoderm; chv, chevron bone; cop, coprolite; cr, caudal rib; eo, external osteoderm (surface); f, femur; fi, fibula; g, gastralia; io, internal osteoderm (surface); is, ischium; mt, metatarsal; na, neural arch; nsp, neural spine; ph, phalanx; poz, postzygapophysis; prz, prezygapophysis; pu, pubis; r, rib; sr, sacral rib; sv, sacral vertebra; tp, transverse process; ta, tarsal; ti, tibia; uph, ungueal phalanx; v, vertebra; (r), right; (l), left.

Fig. 1. cf. *Pelagosaurus* sp. MSNM V4012. Fotografia del reperto (**A**) e suo disegno schematico (**B**). Abbreviazioni: as, astragalo; c, centro; ca, calcagno; co, osteoderma caudale; chv, chevron; cop, coprolite; cr, costa caudale; eo, esterno osteoderma (superficie); f, femore; fi, fibula; g, gastralia; io, interno osteoderma (superficie); is, ischio; mt, metatarsale; na, arco neurale; nsp, spina neurale; ph, falange; poz, postzigapofisi; prz, prezigapofisi; pu, pube; r, costa; sr, costa sacrale; sv, vertebra sacrale; tp, processo trasverso; ta, tarsale; ti, tibia; uph, falange ungueale; v, vertebra; (r), destro; (l), sinistro.

dorsal surface (XVI–XVII). The lateral surfaces of the first (more cranial) vertebral bodies are moderately concave, whereas those of the last ones show a pair of longitudinal grooves which delimit the ventralmost area of the centrum (this is particularly evident on vertebra XIV). The centra are 9–12 mm long, show an amphicoelous condition, roundish articular surfaces, and are usually devoid of neural arches because of the non closure of the neurocentral sutures; typically, their dorsal (sutural) surface shows two rugose lateral areas delimiting a smooth hourglass shaped depression at the centre, which corresponds to the neural canal (Fig. 2). The only preserved neural arches are those of the vertebrae from IX to XII; they are a little shifted from their original position and partly broken or covered by osteoderms. In some cases, pre- and postzygapophyses are visible.

Para-diapophyses and hypapophyses are not present. The neural suture rim of the vertebrae posterior to X shows marked foldings, about 3 mm long, that extend also to the corresponding neural arches (when present) and delimit altogether an elliptical concavity. Such small concavities could represent the sutural areas of the sacral ribs and/or caudal pleurapophyses that, in immature modern crocodilians, are still separated from the vertebrae (Hoffstetter and Gasc, 1969).

Seven narrow and elongated presacral ribs are preserved in anatomical connection (a little shifted from their original position); because of the overlapping vertebral centra, it is not possible to point out any detail about the morphology of their articular heads. A few isolated and displaced fragments are visible on both sides of the vertebral column.

Osteoderms are quite numerous (about 40), relatively thin (around 1 mm), of variable size (sides between 12 and 6 mm) and shape (often approximately square). Some of them are juxtaposed, others lay partly overlapping. The few ones that do not show the internal (smooth) surface, exhibit an external surface with dense, roundish depressions that fill it completely; wide smooth overlap surfaces, longitudinal keels or anterior peg-like structures are not present. Some other osteoderms only left their prints on the matrix.

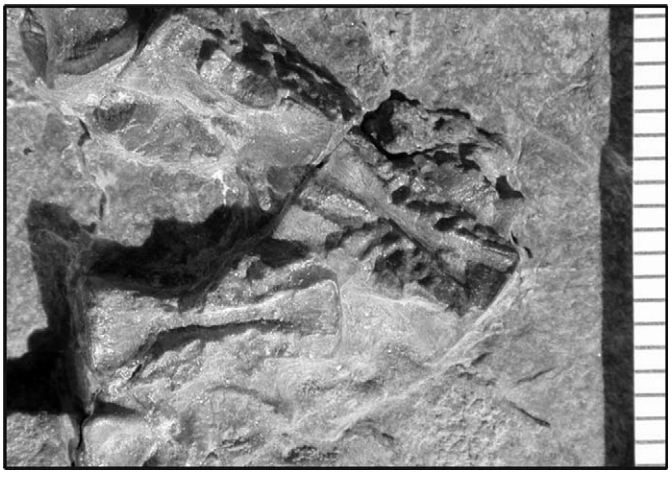

Fig. 2. Close-up of MSNM V4012, showing the open neurocentral suture of vertebrae XVI–XVII (proximal caudal centra). The scale is in mm.
Fig. 2. Dettaglio di MSNM V4012, che mostra l'apertura della sutura neurocentrale delle vertebre XVI–XVII (vertebre caudali prossimali). La scala è in millimetri.

The pelvic girdle seems to be present between the vertebral column and the right femur but it is poorly preserved. At the level of vertebrae X–XII, some elongated and partly crushed elements are visible: the biggest one could represent the pubis but the others are more likely displaced ribs. Vertebra X could be the first sacral vertebra.

Hind limbs are represented by a partial left femur (whose general shape can be inferred by the imprint of the missing part) and by a nearly complete right limb that shows femur, tibia, fibula, tarsal elements and at least three incomplete metatarsals. The length of the femur is 39.8 mm.

Dorsally to the vertebral column, a relatively big (nearly 20 mm) and homogenous mass may be interpreted as a coprolite.

MSNM V4013. This fossil consists of a slab-counterslab pair containing the almost homologous remains of a second specimen (Figs. 3 and 4). The preserved part of the skeleton (total length about 160 mm), corresponding to a tract of at least 19 vertebrae, extends a little more caudally than that of the specimen V4012. Along with the vertebral column and several osteoderms, the right and part of the left hind limbs are preserved.

The bulk of the spinal elements is preserved as bones on V4013b and therefore as imprints on V4013a. The only well exposed presacral vertebra has a centrum, 8.41 mm long, similar in shape and proportions to that of the homologous vertebrae described for V4012. At least two following centra show the neural canal and its surrounding rugose surfaces indicating the non closure of the neurocentral suture. The caudal vertebrae show their right lateral surface on V4013b; the centra are characterised by a longitudinal concavity marked by a well developed ventral keel. These vertebrae possess non displaced neural arches (apparently, but not necessarily, sutured) showing a thin neural crest, small transverse processes and, in some cases, pre- and postzygapophyses. Chevron bones are located in their original position. The anterior most vertebrae (I–VIII) are visible in dorsal view and show, in some cases, part of the neural arch, in others (when the dorsal arches have been lost due to the non closure of the neurocentral suture) the median hourglass shaped surfaces on the dorsal surface of centra.

The osteoderms are smaller than those described for V4012 (sides of 6 mm) but morphologically similar. Some imprints of their external surface are visible cranially. At high magnification, the blackish organic halo above the limb bones appears as a thin, smooth encrusting material, devoid of any peculiar microstructure. Close to the vertebrae, the halo extends quite intact in the matrix for at least 53 mm, and shows fine striations parallel to the vertebral column. Although no dermal framework can be seen in the tail region of MSNM V4013, these striations might be related to very small and keeled osteoderms that actually are present over, or near, the last caudal vertebrae.

Remains of the pelvic girdle (pubis and ischium fragments) are partly preserved on one slab and partly on the other. The

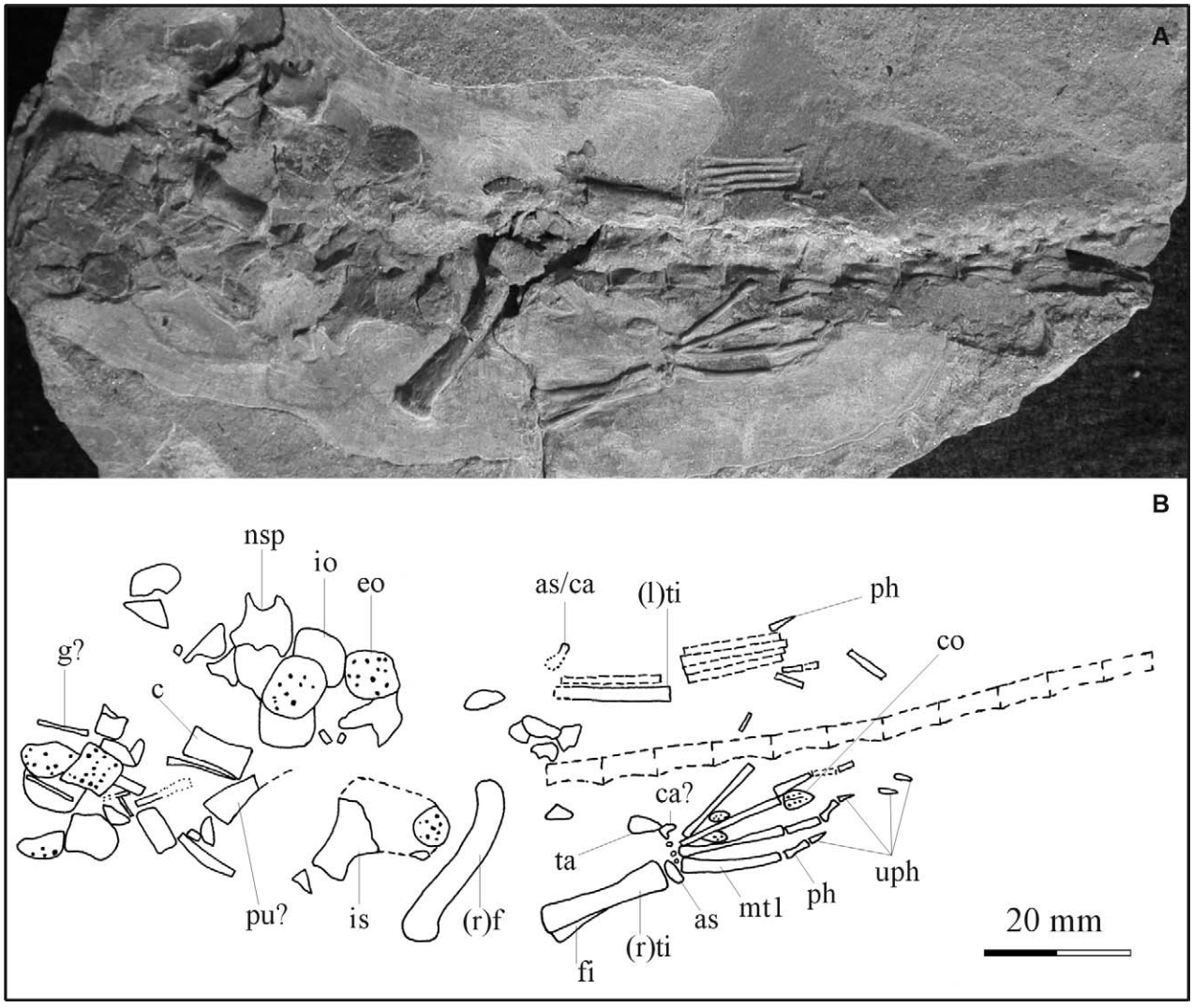

Fig. 3. cf. *Pelagosaurus* sp. MSNM V4013a. Photo of the specimen (**A**) and sketch of its skeleton (**B**). Possible integumentary remains are represented by the blackish halo surrounding the caudal vertebrae. Abbreviations as in Fig. 1.
Fig. 3. cf. *Pelagosaurus* sp. MSNM V4013a. Fotografia del reperto (**A**) e suo disegno schematico (**B**). L'alone nerastro che circonda le vertebre caudali potrebbe rappresentare una traccia dei tessuti epidermici. Abbreviazioni come in Fig. 1.

limb elements are relatively well preserved, as in V4012: the left hind limb is partially preserved on slab V4013b, where femur and tibia fragments as well as the fibula and four metatarsals are visible. The position of the femur hinders any detailed anatomical description. On V4013a, bone fragments of the same limb and all elements of the right hind limb, better preserved and articulated (especially in the pes), are present.

4. Discussion

The specimens here described belong to a limbed and tailed vertebrate characterised by having amphicoelous vertebrae and a relatively well developed armour of osteoderms. Despite the absence of the skulls, anterior trunk vertebrae and front limbs, the available anatomical characters fit well with those of a crocodyliform belonging to the mesoeucrocodylian group of the Thalattosuchia.

A precise allocation within the Thalattosuchia is hampered by the absence of cranial elements, but taking into consideration the age of the Sogno Formation, some remarks can be further developed. The Toarcian members of Teleosauroidea are the genera *Platysuchus* Westphal, 1961, and *Steneosaurus* Geoffroy, 1825. The presence of the former can be excluded since it is characterised by "ostéodermes […] très larges, le rapport largeur/longueur est voisin de 1.5 à 1.7" (Vignaud, 1995). The presence of dermal armour does not allow to exclude a priori the superfamily Metriorhynchoidea that, along with members devoid of osteoderms, as *Metriorhynchus*, also hosts a member with an armour reduced but still present, as *Pelagosaurus* that inhabited central and northern Europe during the Toarcian (Vignaud, 1995; the allocation of *Pelagosaurus* to Metriorhynchidae follows here the traditional arrangement of Thalattosuchia—for *Pelagosaurus* see Buffetaut, 1980—although Vignaud, 1995, proposed to place it in the newly created taxon Pelagosauridae). Vertebral char-

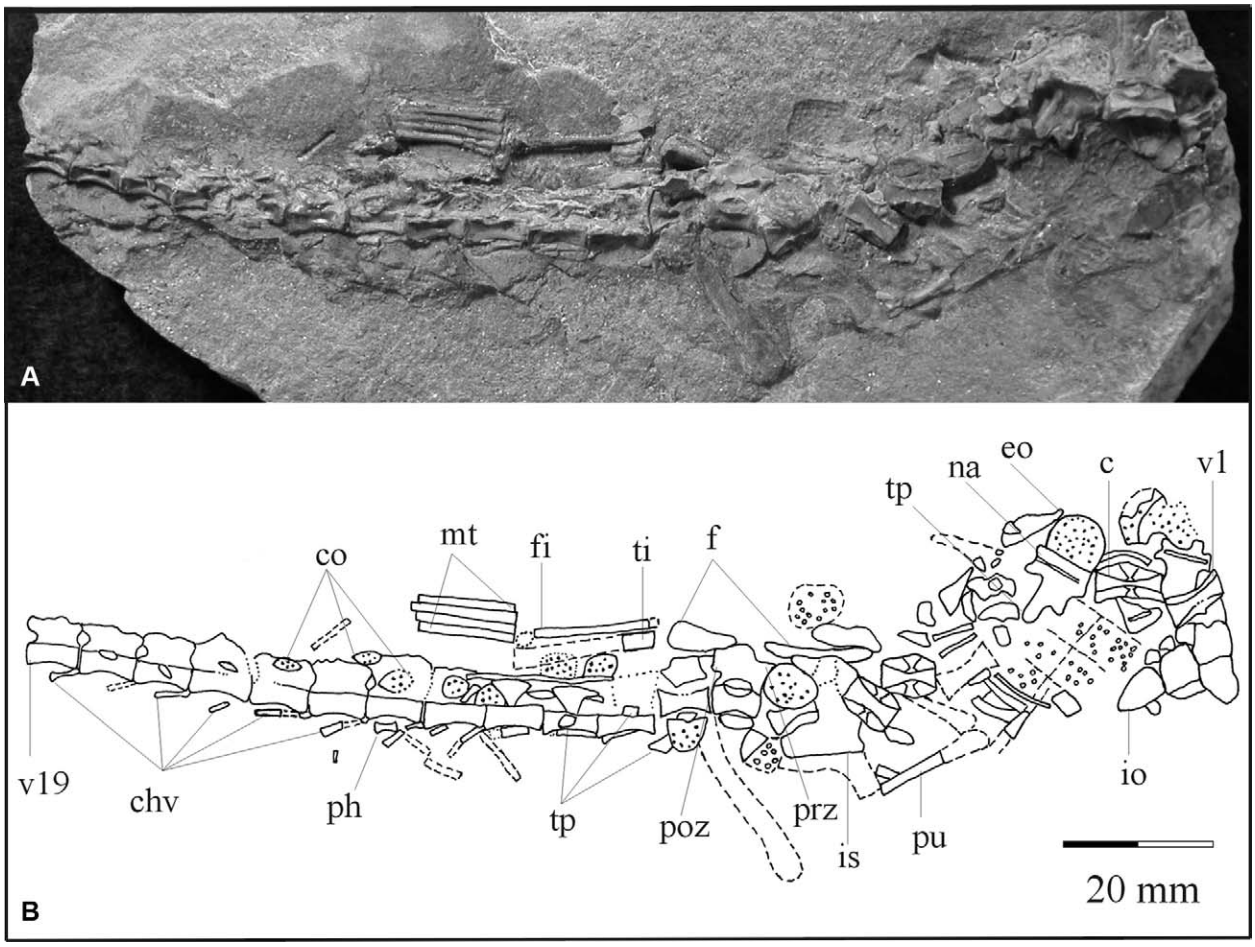

Fig. 4. cf. *Pelagosaurus* sp. MSNM V4013b. Photo of the specimen (**A**) and sketch of its skeleton (**B**). Abbreviations as in Fig. 1.
Fig. 4. cf. *Pelagosaurus* sp. MSNM V4013b. Fotografia del reperto (**A**) e suo disegno schematico (**B**). Abbreviazioni come in Fig. 1.

acters concerning the discrimination between *Steneosaurus* and *Pelagosaurus*, as discussed by Westphal (1962), are here considered unsuitable for such small specimens. However, the osteoderms of the Cesana specimens lack characters that are invariably present in *Steneosaurus*: they do not show any trace of longitudinal keels and anterior pegs (a median keel is present only in the tiny caudal osteoderms); such a morphology matches with that of *Pelagosaurus typus* Bronn, 1841 (cf. Eudes-Deslongchamps, 1864, for *Pelagosaurus* and Andrews, 1913, for *Steneosaurus*) and therefore the remains are here tentatively referred to cf. *Pelagosaurus* sp. A direct comparison with and adult specimen of *P. typus* (Muséum National d'Histoire Naturelle, Paris, collection number 1883-14) revealed some differences in terms of osteoderm general shape and proportions (i.e. pits are proportionally much more marked in the adult) but a basic congruence in terms of diagnostic features. Nevertheless, the taxonomic particle "cf." has been introduced because of the young age of the specimens (see below) and the fact that ontogeny could influence the expression of such features.

A juvenile specimen belonging to this genus has been already described by Duffin (1979) but since it only preserves the skull, no comparisons with the Cesana remains are possible.

5. Faunal comparison and palaeogeographic implications

Although the record of a couple of specimens might appear of rather local interest, these finds are interesting because they reveal further similarity between the Toarcian fauna of northern Italy and that from the worldwide famous localities north of the Alps, such as Holzmaden.

A faunal comparison is briefly reported below.

Reptiles – The thalattosuchian *Pelagosaurus* is present at Holzmaden and well known since the 19th century (Bronn, 1841; Westphal, 1962) but is not exclusive of southern Germany, as fossil remains referred to the same genus were also described from the Toarcian of France, United Kingdom and Luxembourg (Buffetaut, 1980; Vignaud, 1995).

Fishes – While the genera *Leptolepis* and *Pholidophorus* are known to have had a relatively wide distribution, which includes France and Britain, the range of *Pachycormus*, previous to its finding in the Sogno Fm. (Tintori, 1977), was thought to be limited to central Europe.

Crustaceans – The crustacean remains show similarities even at specific level. A very recent work demonstrated that in the Sogno Fm. of Cesana, within the same levels of the thalattosuchians, the eryonid decapod *Proeryon hartmanni* (Garassino and Gironi, in press) is present. This taxon, pre-

viously named *Coleia banzensis* (Garassino and Teruzzi, 2001), is known only from Holzmaden (Kuhn, 1952). Interestingly, in the Sogno Fm. a second crustacean, so far reported uniquely from the Toarcian of Holzmaden and referred to the genus *Uncina*, was found (Garassino and Teruzzi, 2001; Schweigert et al., 2003).

The so called *Posidonienschiefer*, outcropping in southern Germany between Holzmaden and Dotternhausen, is therefore the locality that preserves a coeval biota with the closest similarity to the black shales of the Sogno Fm. in Lombardy.

During the Early Toarcian, black shales deposited in many sectors of Tethys, constituting the "Oceanic Anoxic Event" (Jenkyns, 1988). According to Dercourt et al. (1993) and Hesselbo et al. (2000), the geographic position of the Lombardian Basin in the Toarcian is consistent with the existence of a W–NW connection with the Central European Basins, the closest of which appears to be the South-German Basin.

From a palaeoenvironmental standpoint, the Sogno Fm. originated in the central area of the Lombardian Basin in basinal conditions that, in a limited period of time, gave origin to a *Posidonienschiefer*-like facies. As in Holzmaden (Kauffman, 1978; Schmid-Röhl et al., 2002), the Sogno Fm. represents a pelagic succession of bathyal environment, that deposited at a rate of about 8–11 m/my, within a subsident depression between morphologically more elevated areas (Gaetani and Poliani, 1978). The finely laminated, blackish shales of the Lithozone 1, as revealed by the completeness of the fossils and by the absence of bioturbations, accumulated under anoxic conditions in the deepest portion of the basin.

6. The Italian fossil record of the Thalattosuchia

The origin of Italian palaeoherpetology goes back to the second half of the XVIIIth century and is connected with the first findings of crocodyliforms (Delfino, 2001). One of the most renowned findings in Italy was a skull discovered in 1787 in the Rosso Ammonitico Formation (possibly Tithonian) of the surroundings of Roana (Vicenza Province, Veneto) (Barettoni, 1794a, 1794b; Arduino, 1794), but identified as *Steneosaurus barettoni* only one century later (De Zigno, 1883). Although well known and quoted by many contemporary authors (among others, Georges Cuvier), this material has never been revised with a modern approach and Bizzarini (1996) casts some doubts about its proper taxonomic allocation. The detailed analysis of the thalattosuchian fossil record recently carried out by Vignaud (1995) does not take this taxon into consideration but quotes, as a sporadic finding (the only one from Italy in his review), the "Portomaggiore crocodile". This specimen was described by Leonardi (1956) and referred to *Metriorhynchus* sp., with doubts, by Kotsakis and Nicosia (1980). The origin of the fossil is unknown, but most likely it comes from the Rosso Ammonitico Formation of Sant'Ambrogio di Valpolicella (Verona Province, Veneto) and could be Oxfordian in age (Bizzarini, 1996; "S. Ambrogio Veronese", locality name given in his paper). From the same Formation, again in Veneto, Bizzarini (1996) recently described two other specimens discovered at Ponte Serra (Belluno Province) and Sasso di Asiago (Vicenza Province). The first one probably belongs to the genus *Steneosaurus* and is Upper Oxfordian–Tithonian in age; the second one has been dubiously referred to the family Metriorhynchidae and is Bathonian in age.

Few other Jurassic "crocodiles" from Italy have been reported in the literature: Avanzini (1998) quotes the presence of fragmentary and poorly preserved remains of "Teleosauridae?" in the Early Jurassic of Monte Pasubio (Trento Province, Trentino), while Sirna et al. (1994) list "Mesosuchians undetermined" from the Middle Jurassic of Sant'Ambrogio di Valpolicella (Verona Province, Veneto) and the Late Jurassic of Tolmezzo (Udine Province, Friuli). These "Mesosuchians" most likely represent thalattosuchian remains since they come from marine deposits.

The only non Jurassic marine "crocodile" from Italy was, for a while, a fragmentary skull coming from the Early Cretaceous of Rio Marangone, near San Valentino (Castellaro, Reggio Emilia Province, Emilia Romagna) (Uzielli, 1887). Once identified as a new metriorhynchid, *Capelliniosuchus mutinensis* Simonelli, 1896, it was then considered by Sirotti (1989) to belong to *Mosasaurus hoffmanni* Mantell, 1828.

The isolated tooth on which the taxon *Rhytisodon tuberculatus* Costa, 1853 was erected, does not belong to a Neocomian teleosaurid but to a Miocene odontocete (Steel, 1973; Delfino, 2002).

7. Conclusions

Jurassic reptiles are rather rare in Italy but the discovery of thalattosuchian remains in at least six Jurassic localities, distributed on a relatively wide area of northern Italy extending across Lombardy, Trentino, Veneto and possibly Friuli, allows to consider the presence of these "marine crocodiles" as far from being sporadical (Fig. 5). Although poor preparation and absence of well preserved cranial material hinder a proper taxonomic allocation of the Italian finds, both the families Teleosauridae (genus *Steneosaurus*) and Metriorhynchidae (genus *Metriorhynchus* and now *Pelagosaurus*) have been mentioned. The remains referred to *S. barettoni* (present repository: Palaeontological Department of Padua University), as well those of the "Portomaggiore crocodile" (present repositories: Earth Sciences Department of Bologna University and Museum of Palaeontology and Prehistory, of Ferrara University), should be revised under a modern taxonomic approach in order to confirm their actual status.

The Cesana thalattosuchians here described are among the oldest crocodyliforms ever found in Italy and represent the first evidence of genus *Pelagosaurus* for this area. They are rather peculiar because their very small size contrasts with that of the Italian specimens referred to "putative" *Steneosaurus*. According to Brochu (1996), the hatchlings of the Crocodylia show fully closed neurocentral suture in the caudal vertebrae only, and closure follows a caudal to cranial sequence during ontogeny. The condition shown by the Cesana thalattosuchians (open sutures in the dorsal vertebrae and apparently closed su-

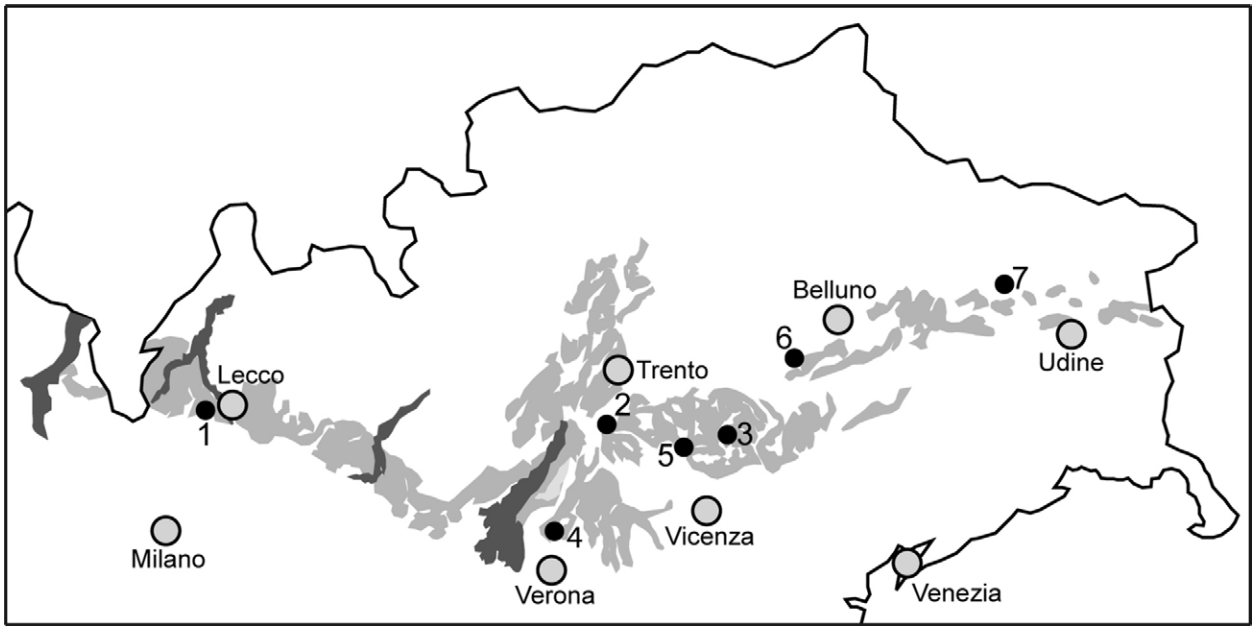

Fig. 5. Italian localities that yielded Jurassic "crocodiles": **1**. cf. *Pelagosaurus* sp., Early Jurassic, Cesana Brianza (Lecco), Lombardy; **2**. ?Teleosauridae, Early Jurassic, Malga Gulva, Monte Pasubio (Trento), Trentino; **3**. ?Metriorhynchidae, Middle Jurassic, Valbella, Sasso di Asiago (Vicenza), Veneto; **4**. Mesosuchia and ? *Metriorhynchus* sp., Middle-Late Jurassic, Sant'Ambrogio di Valpolicella (Verona), Veneto; **5**. *S. barettoni*, Late Jurassic, Zovetto, Treschè Conca, Roana (Vicenza), Veneto; **6**. *Steneosaurus* sp., Late Jurassic, Ponte Serra, Vette Feltrine, Feltre (Belluno), Veneto; **7**. Mesosuchia, Late Jurassic, Monte Verzegnis, Tolmezzo (Udine), Friuli-Venezia Giulia. Map of NE Italy: major lakes in dark grey, Jurassic outcrops in light grey.

Fig. 5. Località italiane da cui provengono resti di "coccodrilli" giurassici: **1**. cf. *Pelagosaurus* sp., Giurassico inf., Cesana Brianza (Lecco), Lombardia; **2**. ? Teleosauridae, Giurassico inf., Malga Gulva, Monte Pasubio (Trento), Trentino; **3**. ?Metriorhynchidae, Giurassico medio, Valbella, Sasso di Asiago (Vicenza), Veneto; **4**. Mesosuchia e ?*Metriorhynchus* sp., Giurassico medio-sup., Sant'Ambrogio di Valpolicella (Verona), Veneto; **5**. *S. barettoni*, Giurassico sup., Zovetto, Treschè Conca, Roana (Vicenza), Veneto; **6**. *Steneosaurus* sp., Giurassico sup., Ponte Serra, Vette Feltrine, Feltre (Belluno), Veneto; **7**. Mesosuchia, Giurassico sup., Monte Verzegnis, Tolmezzo (Udine), Friuli-Venezia Giulia. Laghi principali in grigio scuro; affioramenti giurassici in grigio chiaro.

tures in distal caudal ones) matches such a pattern, providing a size-independent criterion to assess the immature condition of the specimens, and suggests that the usefulness of this criterion can also be extended to mesoeucrocodylians.

The presence of cf. *Pelagosaurus* sp. in the Sogno Formation confirms its faunal affinities with the Toarcian deposits of northern and central Europe already underlined by Tintori (1977) and Garassino and Teruzzi (2001) on the basis of fishes and crustaceans.

Acknowledgements

The fossil reptiles have been discovered by Silvio Mariani and Angelo Zanella who kindly donated them to the Museo di Storia Naturale di Milano. Alberto Lualdi and Giovanni Landra provided useful geological data. Bernard Battail kindly assisted during the examination of comparative material at MNHN (Paris). Pascal Godefroit, and the reviewers Donald Brinkman and Eric Buffetaut critically commented the manuscript; the latter considerably contributed to the identification of the specimens. Salvador Bailon translated the French abstract. Marco Ferretti, Wann Langston Jr., Paolo Piras, Inken Mueller-Töwe and Ron Tykoski helped in the literature retrieval. Fossil preparation by Lorenzo Magnoni, photos by Luciano Spezia and graphics by Franco Nodo.

References

Andrews, C.W., 1913. A descriptive catalogue of the marine reptiles of the Oxford Clay. Part 2. British Museum Natural History, London.

Arduino, G., 1794. Lettera al Sig. Girolamo Barettoni. Nuovo Giornale d'Italia 6, 105–108.

Avanzini, M., 1998. Resti di vertebrati dal Giurassico inferiore della piattaforma di Trento (Italia settentrionale). Nota prelimiare. Studi Trentini di Scienze Naturali. Acta Geologica 73 (1996), 75–80.

Barettoni, G., 1794a. Lettera al Sig. Giovanni Arduino. Nuovo Giornale d'Italia 6, 103–104.

Barettoni, G., 1995b. Lettera al Sig. Giovanni Arduino. Nuovo Giornale d'Italia 6, 108–109.

Bizzarini, F., 1996. Sui resti di coccodrillo del Rosso Ammonitico veronese di Sasso di Asiago (Altopiano dei Sette Comuni, Prealpi Venete). Annali del Museo Civico di Rovereto 11 (1995), 339–348.

Brochu, C.A., 1996. Closure of neurocentral sutures during crocodilian ontogeny: implications for maturity assessment in fossil archosaurs. Journal of Vertebrate Paleontology 16, 49–62.

Bronn, H.G., 1841. Handbuch einer Geschichte der Natur. Stuttgart.

Buffetaut, E., 1980. Position systématique et phylogénétique du genre *Pelagosaurus* Bronn, 1841 (Crocodylia, Mesosuchia) du Toarcien d'Europe. Geobios 13, 783–786.

Dal Sasso, C., 2001. Dinosauri italiani. Marsilio, Venezia.

Dal Sasso, C., 2003. Dinosaurs of Italy. Comptes Rendus Palevol 2, 46–66.

Delfino, M., 2001. Coccodrilli italiani. Pianura 13, 47–49.

Delfino, M., 2002. Erpetofaune italiane del Neogene e del Quaternario. Ph.D. thesis, Modena and Reggio Emilia University, Modena.

Delfrati, L., 1998. Formazione di Sogno. Worksheet No. 1009. Carta Geologica d'Italia, Catalogo delle Formazioni, 178–184.

Dercourt, J., Ricou, L.E., Vrielynck, B., 1993. Atlas Tethys Paleoenvironmental Maps. Gauthier-Villars, Paris.

De Zigno, A., 1883. Sui vertebrati fossili dei terreni Mesozoici delle Alpi Venete. Nuovi Saggi della Regia Accademia di Scienze Lettere e Arti di Padova 9, 2–14.

Duffin, C., 1979. *Pelagosaurus* (Mesosuchia, Crocodylia) from English Toarcian (Lower Jurassic). Neues Jahrbuch für Geologie und Paläontologie Monatshefte 8, 475–485.

Eudes-Deslongchamps, J.A., 1864. Mémoires sur les Téléosauriens de l'époque jurassique du Département du Calvados. Premier mémoire. Mémoires de la Société linnéenne de Normandie 12, 1–138.

Gaetani, M., Erba, E., 1990. Il Bacino Lombardo: un sistema paleo alto/fossa in un margine continentale passivo durante il Giurassico. In: Jadoul, F., Massiotta, P. (Eds.), La geologia italiana degli anni '90. Guida alle escursioni pre-congresso. 75° Congresso Nazionale Della Societa Geologica Italiana, Escursione A3. p. 23.

Gaetani, M., Poliani, G., 1978. Il Toarciano ed il Giurassico medio in Albenza (Bergamo). Rivista Italiana di Paleontologia e Stratigrafia 84, 349–382.

Garassino, A., Teruzzi, G. I crostacei decapodi del Toarciano (Giurassico inferiore) di Sogno (Bergamo, N Italia). Atti della Società italiana di Scienze naturali e Museo civico di Storia naturale di Milano 141 (2000), (187–197).

Gradstein, F.M., Agterberg, F.P., Ogg, J.G., Hardenbol, J., van Veen, P., Thierry, J., Huang, Z., 1995. A Triassic, Jurassic, and Cretaceous time scale. In: Berggren, W.A., Kent, D.V., Aubry, M.-P., Hardenbol, J. (Eds.), Geochronology, Time Scales and Global Stratigraphic Correlation. Special Publication 54, SEPM, pp. 95–126.

Hesselbo, S.P., Gröcke, D.R., Jenkyns, H.C., Bjerrum, C.J., Farrimond, P., Morgans Bell, H.S., Green, O.R., 2000. Massive dissociation of gas hydrate during a Jurassic oceanic anoxic event. Nature 406, 392–395.

Hoffstetter, R., Gasc, J.P., 1969. Vertebrae and ribs of modern Reptiles. In: Gans, C. (Ed.), Biology of the Reptilia, Vol. 1. Morphology A. Academic Press, London and New York, pp. 201–310.

Jenkyns, H.C., 1988. The early Toarcian (Jurassic) anoxic event: stratigraphic, sedimentary and geochemical evidence. American Journal of Science 288, 101–151.

Kauffman, E.G., 1978. Benthic environments and paleoecology of the Posidonienschiefer (Toarcian). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 157, 18–36.

Kotsakis, T., Nicosia, U., 1980. Il "coccodrillo di Portomaggiore" (Ferrara) (Ed.), In: I vertebrati fossili italian. Catalogo delle Mostra, Verona, pp. 103–104.

Kuhn, O., 1952. Neue crustacea decapoda und insecta aus dem untersten lias epsilon von Nordfranken. Palaeontographica 101, 153–166.

Leonardi, P., 1956. Notizie preliminari sul "Coccodrillo di Portomaggiore". Bollettino della Società Geologica Italiana 75, 88–92.

Lioy, P., 1896. I coccodrilli fossili del Veneto. Atti del Regio Istituto Veneto di Scienze Lettere e Arti (7) 7, 753–783.

Renesto, S., 1993. A Cretaceous Plesiosaur remains (Reptilia, Sauropterygia) from the Argille Varicolori of Varzi (Pavia, Lombardy, Northern Italy). Rivista Italiana di Paleontologia e Stratigrafia 99, 101–106.

Schmid-Röhl, A., Röhl, H., Oschmann, W., Frimmel, A., Schwark, L., 2002. Palaeoenvironmental reconstruction of Lower Toarcian epicontinental black shales (Posidonia Shale, SW Germany): global versus regional control. Geobios 35, 13–20.

Schweigert, G., Garassino, A., Hall, R.L., Hauff, R.B., Karasawa, H., 2003. The Lower Jurassic Lobster Uncina Quenstedt, 1821 (Crustacea: Decapoda: Astacidea: Uncinidae). Stuttgart Beiträge zur Naturkunde B 332, 1–20.

Sirna, G., Dalla Vecchia, F.M., Muscio, G., Piccoli, G., 1994. Catalogue of Paleozoic and Mesozoic vertebrates and vertebrate localities of the Tre Venezie area (North Eastern Italy). Memorie di Scienze Geologiche 46, 255–281.

Sirotti, A., 1989. *Mosasaurus hoffmanni* Mantell, 1828 (Reptilia) nelle "Argille Scagliose" di S. Valentino. Atti della Società dei Naturalisti di Modena 120, 135–146.

Steel, R., 1973. Crocodylia. Encyclopedia of Paleoherpetology, part 16. Gustav Fischer Verlag, Stuttgart, New York.

Tintori, A., 1977. Toarcian fishes from the Lombardian basin. Bollettino della Società Paleontologica Italiana 16, 143–152.

Uzielli, G., 1887. Sopra un cranio di coccodrillo trovato nel Modenese. Bollettino della Società Geologica Italiana 5, 355–365.

Vignaud, P., 1995. Les Thalattosuchia, crocodiles marins du Mésozoïque : systématique phylogénétique, paléoécologie, biochronologie et implications paléogéographiques. Ph.D. thesis, Poitiers University, Poitiers (unpublished).

Westphal, F., 1962. Die Krokodilier des deutschen und englischen oberen Lias. Palaeontographica A 118, 23–118.