

# A new chondrichthyan fauna from the Late Jurassic of the Swiss Jura (Kimmeridgian) dominated by hybodonts, chimaeroids and guitarfishes

Leuzinger L., Cuny G., Popov E., Billon-Bruyat J.  
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

---

## Abstract

© 2017 The Authors. Palaeontology published by John Wiley & Sons Ltd on behalf of The Palaeontological Association. The fossil record of chondrichthyans (sharks, rays and chimaeroids) principally consists of isolated teeth, spines and dermal denticles, their cartilaginous skeleton being rarely preserved. Several Late Jurassic chondrichthyan assemblages have been studied in Europe based on large bulk samples, mainly in England, France, Germany and Spain. The first study of this kind in Switzerland is based on controlled excavations in Kimmeridgian deposits related to the construction of the A16 motorway in the Swiss Jura (Porrentruy, NW Switzerland). This study is based on more than 2000 isolated chondrichthyan remains (teeth, dental plates, spines and dermal denticles) and adds to our knowledge of the chondrichthyan distribution at a regional scale in Europe. We describe and identify this new fauna, define a new species of hybodont with crushing-type dentition (*Asteracanthus udulfensis* sp. nov.) and report for the first time the carcharhiniform *Corysodon cirinensis* in Switzerland. By the Late Jurassic, modern neoselachian sharks had overtaken hybodonts in European marine realms, the latter being gradually confined to brackish or freshwater environments. However, while the associated fauna of the Porrentruy platform indicates marine conditions, neoselachian sharks are surprisingly rare. The chondrichthyan assemblage is largely dominated by hybodonts, guitarfishes (rays) and chimaeroids that are all known to be euryhaline. This unexpected chondrichthyan faunal composition questions the presence of fresh to brackish water in the vicinity of the platform, and the occurrence of salinity fluctuations within a general context marine. This could explain the scarcity of neoselachian sharks and the extended success of hybodonts in the Porrentruy area as late as the Late Jurassic.

<http://dx.doi.org/10.1002/spp2.1085>

---

## Keywords

*Asteracanthus*, chondrichthyan, hybodont, Kimmeridgian, Swiss Jura, water salinity

## References

- [1] Agassiz, L. 1833-1844. Recherches sur les poissons fossiles, 5 vols. Imprimerie de Petitpierre, Neuchâtel, 1420 pp.

- [2] Anquetin, J., Püntener, C. and Billon-Bruyat, J.-P. 2014. A taxonomic review of the Late Jurassic eucryptodiran turtles from the Jura Mountains (Switzerland and France). *PeerJ*, 2, e369.
- [3] Anquetin, J., Püntener, C. and Billon-Bruyat, J.-P. 2015. *Portlandemys gracilis* n. sp., a new coastal marine turtle from the Late Jurassic of Porrentruy (Switzerland) and a reconsideration of plesiochelyid cranial anatomy. *PloS One*, 10, e0129193.
- [4] Berg, L. S. 1940. Classification of fishes, both recent and fossil. *Transactions of the Institute of Zoology Academy of Sciences USSR*, 5.
- [5] Bermúdez-Rochas, D. D. 2009. New hybodont shark assemblage from the Early Cretaceous of the Basque-Cantabrian Basin. *Geobios*, 42, 675–686.
- [6] Bernhauser, A. 1953. Über Mycelites ossifragus ROUX, Auftreten und Formen im Tertiär des Wiener Beckens. *Sitzungsberichte der Akademie der Wissenschaften mathematisch-naturwissenschaftliche*, 162, 119–127.
- [7] Bloch, M. E. and Schneider, J. G. 1801. *Systema ichthyologiae*. Berlin, 584 pp. <https://doi.org/10.5962/bhl.title.5750>
- [8] Blainville, H. M. D. de 1816. Prodrome d'une distribution systématique du règne animal. *Bulletin de la Société Philomathique de Paris*, 8, 105–124.
- [9] Bonaparte, C. L. 1832–1831. Iconografia della fauna Italica per le quattro classi degli animali vertebrati, vol. 3. Rome. <https://doi.org/10.5962/bhl.title.70395>
- [10] Bonaparte, C. L. 1838. Selachorum tabula analytica. *Nuovi Annali delle Scienze Naturali*, Bologna, 2, 195–214.
- [11] Bone, Q. and Moore, R. H. 2008. Biology of fishes. Taylor & Francis, 478 pp.
- [12] Buckland, W. 1835. A notice on the fossil beaks of four extinct species of fishes, referable to the genus Chimaera, which occur in the Oolitic and Cretaceous formations of England. *Proceedings of the Geological Society of London*, 2, 205–206.
- [13] Buen, F. de 1926. Catálogo ictiológico del Mediterraneo Español y de Marruecos, recopilando lo publicado sobre peces de las costas mediterráneas y próximas del Atlántico (Mar de España). Resultados de las Campañas realizadas por acuerdos internacionales, Instituto español, vol. 2, 1–221.
- [14] Candoni, L. 1993. Découverte de *Parasymbolus octevillensis* gen. et sp. nov. (Scyliorhinidae – Elasmobranchii) dans le Kimméridgien de Normandie, France. *Belgian Geological Survey*, 264, 147–156.
- [15] Cappetta, H. 1980. Les sélaciens du Crétacé supérieur du Liban. II Batoïdes. Abteilung A. *Palaeontographica*, 168, 149–229.
- [16] Cappetta, H. 1987. Chondrichthyes II – Mesozoic and Cenozoic Elasmobranchii. *Handbook of Paleoichthyology*, 3B, Friedrich Pfeil, 193 pp.
- [17] Cappetta, H. 2012. Chondrichthyes – Mesozoic and Cenozoic Elasmobranchii: teeth. *Handbook of Paleoichthyology*, 3E, Friedrich Pfeil, 512 pp.
- [18] Carrier, J., Musick, J. and Heithaus, M. 2010. Sharks and their relatives. II Biodiversity, adaptive physiology, and conservation. CRC Press, 711 pp.
- [19] deCarvalho, M. R., Kriwet, J. and Thies, D. 2008. A systematic and anatomical revision of Late Jurassic angelsharks (Chondrichthyes: Squatinidae). 469–502. In Arratia, G., Schultze, H.-P. and Wilson, M. V. H. (eds). *Mesozoic fishes 4: Homology and phylogeny*. Friedrich Pfeil.
- [20] Casier, E. 1959. Contributions à l'étude des Poissons fossiles de la Belgique. XII. Sélaciens et Holocephales sinémuriens de la province de Luxembourg. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique*, 35, 1–27.
- [21] Cavin, L., Cappetta, H. and Séret, B. 1995. Révision de *Belemnobatis morinicus* (SAUVAGE, 1873) du Portlandien du Boulonnais (Pas-dé Calais, France). Comparaison avec quelques rhinobatidés jurassiques. *Geologica et Palaeontologica*, 29, 245–267.
- [22] Collins, A. B., Heupel, M. R., Hueter, R. E. and Motta, P. J. 2007. Hard prey specialists or opportunistic generalists? An examination of the diet of the cownose ray, *Rhinoptera bonasus*. *Marine & Freshwater Research*, 58, 135–144.
- [23] Comment, G. 2012. Ammonites découvertes par la Paléontologie A16 dans le cadre de la construction de l'autoroute A16 (Transjurane). Office de la Culture du Canton du Jura, section d'Archéologie et de Paléontologie, 113 pp.
- [24] Comment, G., Ayer, J. and Becker, D. 2011. Deux nouveaux membres lithostratigraphiques de la Formation de Reuchenette (Kimméridgien, Ajoie, Jura suisse) – Nouvelles données géologiques et paléontologiques acquises dans le cadre de la construction de l'autoroute A16 (Transjurane). *Swiss Bulletin für angewandte Geologie*, 16, 3–24.
- [25] Comment, G., Lefort, A., Koppka, J. and Hantzpergue, P. 2015. Le Kimméridgien d'Ajoie (Jura, Suisse): lithostratigraphie et biotratigraphie de la Formation de Reuchenette. *Revue de Paléobiologie*, 34, 161–194.
- [26] Compagno, L. J. V. 1973. Interrelationship of living elasmobranchs. In Greenwood, P. H., Patterson, C. and Miles, R. (eds). *Interrelationships of fishes*. Academic Press, 15–61.
- [27] Compagno, L. J. V. 1977. Phyletic relationships of living sharks and rays. *American Zoologist*, 17, 303–322.

- [28] Compagno, L. J. V. 1999. Checklist of living elasmobranchs. In Hamlett, W. C. (ed.) Sharks, skates, and rays: the biology of elasmobranch fishes. The Johns Hopkins University Press, 471–498.
- [29] Cuny, G. 2002. Les requins sont-ils des fossiles vivants? EDP Sciences, 208 pp.
- [30] Cuny, G. 2012. Freshwater hybodont sharks in Early Cretaceous ecosystems: a review. In Godefroit, P. (ed.) Dinosaurs and Early Cretaceous terrestrial ecosystems, 518–530.
- [31] Cuny, G. and Benton, M. J. 1999. Early radiation of the neoselachian sharks in western Europe. *Geobios*, 32, 193–204.
- [32] Cuny, G., Suteethorn, V., Kamha, S., Buffetaut, E. and Philippe, M. 2006. A new hybodont shark assemblage from the Lower Cretaceous of Thailand. *Historical Biology*, 18, 21–31.
- [33] Cupello, C. D., Bermúdez-Rochas, D. D., Martill, D. M. and Brito, P. M. 2012. The Hybodontiformes (Chondrichthyes: Elasmobranchii) from the Missão Velha Formation (?Lower Cretaceous) of the Araripe Basin, North-East Brazil. *Comptes Rendus Palevol*, 11, 41–47.
- [34] Duffin, C. J. 1993. New records of Late Jurassic sharks teeth from Southern Germany. *Stuttgarter Beiträge zur Naturkunde – Serie B (Geologie und Paläontologie)*, 193, 1–13.
- [35] Duffin, C. J. and Thies, D. 1997. Hybodont shark teeth from the Kimmeridgian (Late Jurassic) of northwest Germany. *Geologica et Palaeontologica*, 31, 235–256.
- [36] Duméril, A. M. C. 1806. Zoologie analytique ou méthode naturelle de classification des animaux. Allais, Paris, 344 pp.
- [37] Egerton, P. G. 1843. On some new species of fossil chimaeroid fishes, with remarks on their general affinities. *Proceedings of the Geological Society of London*, 4(94), 153–157.
- [38] Egerton, P. G. 1854. XXXIX.—On some new genera and species of fossil fishes. *Annals & Magazine of Natural History*, Series 2, 13, 433–436.
- [39] Fischer, J., Voigt, S., Schneider, J. W., Buchwitz, M. and Voigt, S. 2011. A selachian freshwater fauna from the Triassic of Kyrgyzstan and its implication for Mesozoic shark nurseries. *Journal of Vertebrate Paleontology*, 31, 937–953.
- [40] Fowler, H. W. 1941. New taxonomic names of fish-like vertebrates. *Notulae Naturae*, 187, 16 pp.
- [41] Fraas, O. 1854. Squatina acanthoderma. Der Meerengel von Nusplingen. *Zeitschrift Der Deutschen Geologischen Gesellschaft*, 6, 782–799.
- [42] Furic, M. 2016. Les chondrichthyens de la série callovo-oxfordienne (Jurassique moyen-supérieur) de Normandie. Unpublished Master's thesis, Université de Rennes 1, 23 pp.
- [43] Garman, S. 1901. Genera and families of the chimeroids. *Proceedings of the New England Zoological Club*, 2, 75–77.
- [44] Gill, T. 1862. Analytical analysis of the order of Squali and revision and nomenclature of genera. *Annals of the Society of Natural History of New York*, 7, 367–408.
- [45] Gray, J. E. 1851. List of specimens of fish in the collection of th British Museum. Part 1. British Museum (Natural History), London, 160 pp.
- [46] Gretz, M., Ayer, J. and Comment, G. 2010. Analyse microscopique de la formation de Reuchenette (Kimmeridgien) – Nouvelles données acquises dans le cadre de la construction de l'autoroute A16. Office de la Culture du Canton du Jura, section d'Archéologie et de Paléontologie, 105 pp.
- [47] Guinot, G., Underwood, C. J., Cappetta, H. and Ward, D. J. 2012. Squatiniformes (Chondrichthyes, Neoselachii) from the Late Cretaceous of southern England and northern France with redescription of the holotype of *Squatina cranei* Woodward, 1888. *Palaeontology*, 55, 529–551.
- [48] Guinot, G., Cappetta, H. and Adnet, S. 2014. A rare elasmobranch assemblage from the Valanginian (Lower Cretaceous) of southern France. *Cretaceous Research*, 48, 54–84.
- [49] Hay, O. P. 1902. Bibliography and catalogue of the fossil vertebrata of North America. *Bulletin of the United States Geological Survey*, 179, 1–868.
- [50] Hoganson, J. W. and Erickson, J. M. 2005. A new species of *Ischyodus* (Chondrichthyes: Holocephali: Callorhynchidae) from Upper Maastrichtian shallow marine facies of the Fox Hills and Hell Creek Formations, Williston Basin, North Dakota, USA. *Palaeontology*, 48, 709–721.
- [51] Huxley, T. H. 1880. On the application of the laws of evolution to the arrangement of the Vertebrata and more particularly of the Mammalia. *Proceedings of the Zoological Society of London*, 43, 649–662.
- [52] Jaekel, O. 1898. Über die verschiedenen Rochentypen. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin*, 135–146.
- [53] Jank, M., Wetzel, A. and Meyer, C. A. 2006. A calibrated composite section for the Late Jurassic Reuchenette Formation in northwestern Switzerland (?Oxfordian, Kimmeridgian sensu gallico, Ajoie-Region). *Eclogae Geologicae Helvetiae*, 99, 175–191.
- [54] Klug, S. and Kriwet, J. 2013a. An offshore fish assemblage (Elasmobranchii, Actinopterygii) from the Late Jurassic of NE Spain. *Paläontologische Zeitschrift*, 87, 235–257.

- [55] Klug, S. and Kriwet, J. 2013b. Node age estimations and the origin of angel sharks, Squatiniformes (Neoselachii, Squalomorphii). *Journal of Systematic Palaeontology*, 11, 91-110.
- [56] Klug, S., Tütken, T., Wings, O., Pfretzschner, H. and Martin, T. 2010. A Late Jurassic freshwater shark assemblage (Chondrichthyes, Hybodontiformes) from the southern Junggar Basin, Xinjiang, Northwest China. *Palaeobiodiversity & Palaeoenvironments*, 90, 241-257.
- [57] Koken, E. 1911. Pisces. In Broili, F., Koken, E. and Schlosser, M. (eds). *Grundzüge der Paläontologie (Paläozoologie) von Karl A. von Zittel. II Vertebrata*. R. Oldenbourg, München & Berlin, 598 pp. <https://doi.org/10.5962/bhl.title.50145>
- [58] Koppka, J. 2015. Revision of the bivalvia from the Upper Jurassic Reuchenette Formation, Northwest Switzerland—Ostreidea. *Zootaxa*, 3927, 1-117.
- [59] Kozuch, L. and Fitzgerald, C. 1989. A guide to identifying shark centra from southeastern archaeological sites. *Southeastern Archaeology*, 8, 146-157.
- [60] Kriwet, J. 2003. Neoselachian remains (Chondrichthyes, Elasmobranchii) from the Middle Jurassic of SW Germany and NW Poland. *Acta Palaeontologica Polonica*, 48, 583-594.
- [61] Kriwet, J. 2004. Late Jurassic selachians (Chondrichthyes: Hybodontiformes, Neoselachii) from central Portugal. *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, 4, 233-256.
- [62] Kriwet, J. 2008. A new species of extinct bullhead sharks, *Paracestracion viohli* sp. nov. (Neoselachii, Heterodontiformes), from the Upper Jurassic of South Germany. *Acta Geologica Polonica*, 58, 235-241.
- [63] Kriwet, J. and Klug, S. 2004. Late Jurassic selachians (Chondrichthyes, Elasmobranchii) from southern Germany: re-evaluation on taxonomy and diversity. *Zitteliana*, A 44, 67-95.
- [64] Kriwet, J. and Klug, S. 2008. Diversity and biogeography patterns of Late Jurassic neoselachians (Chondrichthyes: Elasmobranchii). *Geological Society, London, Special Publications*, 295, 55-70.
- [65] Kriwet, J. and Kussius, K. 1996. Palaeoecological implications of sharks from the lower Barremian of Galve and Alcaine, Province of Teruel, Spain. *Journal of Vertebrate Paleontology*, 16, 35-46.
- [66] Kriwet, J., Nunn, E. V. and Klug, S. 2009. Neoselachians (Chondrichthyes, Elasmobranchii) from the Lower and lower Upper Cretaceous of north-eastern Spain. *Zoological Journal of the Linnean Society*, 155, 316-347.
- [67] Last, P. R. and Stevens, J. D. 2009. Sharks and rays of Australia. CSIRO Publishing, 656 pp.
- [68] Last, P. R., Séret, B. and Naylor, G. J. P. 2016. A new species of guitarfish, *Rhinobatos borneensis* sp. nov. with a redefinition of the family-level classification in the order Rhinopristiformes (Chondrichthyes: Batoidea). *Zootaxa*, 4117, 451-475.
- [69] Lécuyer, C., Picard, S., Garcia, J.-P., Sheppard, S. M. F., Grandjean, P. and Dromart, G. 2003. Thermal evolution of Tethyan surface waters during the Middle-Late Jurassic: Evidence from δO values of marine fish teeth. *Paleoceanography*, 18 (3), 1076, 1-16.
- [70] Leuzinger, L., Kocsis, L., Billon-Bruyat, J.-P., Spezzaferri, S. and Vennemann, T. W. 2015. Stable isotope study of a new chondrichthyan fauna (Kimmeridgian, Porrentruy, Swiss Jura): an unusual freshwater-influenced isotopic composition for the hybodont shark *Asteracanthus*. *Biogeosciences*, 12, 6945-6954.
- [71] Maisey, J. G. 1976. The Jurassic selachian fish *Protospinax* Woodward. *Palaeontology*, 19, 733-747.
- [72] Maisey, J. G. 1978. Growth and form of finspines in hybodont sharks. *Palaeontology*, 21, 657-666.
- [73] Maisey, J. G. 1979. Fin spine morphogenesis in squalid and heterodontid sharks. *Zoological Journal of the Linnean Society*, 66, 161-183.
- [74] Maisey, J. G. 1982a. The Anatomy and Interrelationships of Mesozoic Hybodont Sharks. *American Museum Novitates*, 2724, 1-48.
- [75] Maisey, J. G. 1982b. Fossil hornshark finspines (Elasmobranchii; Heterodontidae) with notes on a new species (*Heterodontus tuberculatus*). *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*, 164, 393-413.
- [76] Maisey, J. G. 1989. *Hamiltonichthys mapesi*, g. & sp. nov. (Chondrichthyes; Elasmobranchii), from the Upper Pennsylvanian of Kansas. *American Museum Novitates*, 2931, 1-42.
- [77] Maisey, J. G., Naylor, G. J. P. and Ward, D. J. 2004. Mesozoic elasmobranchs, neoselachian phylogeny and the rise of modern elasmobranch diversity. 17-56. In Arratia, G. and Tintori, A. (eds). *Mesozoic fishes 3: Systematics, paleoenvironments and biodiversity*. Friedrich Pfeil.
- [78] Marck, W. von der 1863. Fische der Oberen Kreide Westfalens. *Palaeontographica*, Cassel, 11, 233-269.
- [79] Marty, D. 2008. Sedimentology, taphonomy, and ichnology of Late Jurassic dinosaur tracks from the Jura carbonate platform (Chevenez-Combe Ronde tracksite, NW Switzerland): insights into the tidal-flat palaeoenvironment and dinosaur diversity, locomotion, and palaeoecology. *GeoFocus*, 21, 278 pp.
- [80] Marty, D. and Billon-Bruyat, J.-P. 2009. Field-trip to the excavations in the Late Jurassic along the future Transjurane highway near Porrentruy (Canton Jura, NW Switzerland): dinosaur tracks, marine vertebrates and invertebrates. 94-129. In Billon-Bruyat, J.-P., Marty, D., Costeur, L., Meyer, C. A. and Thüring, B. (eds). *Abstracts and field Guides: 5th International Symposium on Lithographic Limestone & Plattenkalk*. Société jurassienne d'émulation, Porrentruy, Switzerland.

- [81] Marty, D., Ayer, J., Becker, D., Berger, J.-P., Billon-Bruyat, J.-P., Braillard, L., Hug, W. A. and Meyer, C. A. 2007. Late Jurassic dinosaur tracksites of the Transjurane highway (Canton Jura, NW Switzerland): overview and measures for their protection and valorisation. *Bulletin für Angewandte Geologie*, 12, 75–89.
- [82] Mudroch, A. 2001. Fischzähne aus dem Oberjura Nordwesteuropas – Systematik, Biogeochemie und Palökologie. Unpublished Master's thesis, Universität Hannover, 189 pp.
- [83] Müller, M. K. 2011. The fish fauna of the Late Jurassic Solothurn Turtle Limestone (NW Switzerland). *Swiss Journal of Geosciences*, 104, 133–146.
- [84] Münster, G. v. 1842. Beschreibung einiger neuer Fische aus den lithographischen Schiefern von Bayern. *Beiträge zur Petrefactenkunde*, 5, 55–64.
- [85] Nelson, J. S. 2006. Fishes of the world. Wiley, 601 pp.
- [86] Nessov, L. A. 1997. Cretaceous non-marine vertebrates of Northern Eurasia. In Golovneva, L. B. and Averianov, A. O. (eds). University of St Petersburg, Institute of Earth Crust, 218 pp. [in Russian]
- [87] Nessov, L. A. and Averianov, A. O. 1996. Ancient chimaeriform fishes of Russia, Ukraine, Kazakhstan and Middle Asia. I. Some ecological characteristics of chimaeroids and a summary of their occurrences. *Bulletin of Saint-Petersburg University*, 7, 11–19 [in Russian, English summary]
- [88] Obruchev, D. V. 1953. Studies on edestids and the works of A.P. Karpinski, vol. 45. *Transactions of the Palaeontological Institute, U.S.S.R. Academy of Sciences*, 1–86 pp.
- [89] Owen, R. 1845. Odontology, or a treatise of the comparative anatomy of the teeth. Hippolyte Baillière, London, 655 p.
- [90] Owen, R. 1846. 1. Fishes. Lectures on the comparative anatomy and physiology of the vertebrate animals, delivered at the Royal College of Surgeons of England in 1844 and 1846. Longman, London, 308 pp.
- [91] Owen, R. 1869. I. Description of a great part of a jaw with the teeth of *Strophodus medius*, Ow., from the Oolite of Caen in Normandy. *Geological Magazine*, 6, 193 pp.
- [92] Patterson, C. 1965. The phylogeny of the chimaeroids. *Philosophical Transactions of the Royal Society of London*, B249, 101–219.
- [93] Patterson, C. 1966. British Wealden Sharks. *Bulletin of the British Museum (Natural History)*, 11, 283–350.
- [94] Patterson, C. 1992. Interpretation of the toothplates of chimaeroid fishes. *Zoological Journal of the Linnean Society*, 106, 33–61.
- [95] Peyer, B. 1946. Die schweizerischen Funde von *Asteracanthus* (*Strophodus*). *Schweizerische Palaeontologische Abhandlungen*, 64, 1–103.
- [96] Pfeil, F. H. 2011. Ein neues *Asteracanthus*-Gebiss aus den Kieselplattenkalken (Oberjura, Tithonium, Malm Zeta 3, Mörnsheim-Formation) des Besuchersteinbruchs in Mühlheim. *Jahresbericht 2010 und Mitteilungen der Freunde der Bayerischen Staatssammlung für Paläontologie und historische Geologie München e. V.*, 39, 36–60.
- [97] Philippe, M., Billon-Bruyat, J.-P., Garcia-Ramos, J. C., Bocat, L., Gomez, B. and Piñuela, L. 2010. New occurrences of the wood *Protocupressinoxylon purbeckensis* Francis: implications for terrestrial biomes in southwestern Europe at the Jurassic/Cretaceous boundary. *Palaeontology*, 53, 201–214.
- [98] Pinheiro, F. L., de Figueiredo, A. E. Q., Dentzien-Dias, P. C., Fortier, D. C., Schultz, C. L., Somália, M. and Viana, S. 2013. *Planohybodus marki* sp. nov., a new fresh-water hybodontid shark from the Early Cretaceous of northeastern Brazil. *Cretaceous Research*, 41, 210–216.
- [99] Plieninger, T. 1847. Die Wirbeltierreste im Korallenkalk von Schnaitheim. *Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg*, 3, 226–227.
- [100] Popov, E. V. and Beznosov, P. 2006. Remains of chimaeroid fishes (Holocephali: Chimaeroidei) from the Upper Jurassic deposits of Komi Republic, Russia. In Rozanov, A. Y., Lopatin, A. V. and Parkhaev, P. Y. (eds). *Modern Russian paleontology: classic and newest methods – 2006*. Russian Academy of Sciences, Paleontological Institute, Moscow, 55–64 [in Russian, English summary]
- [101] Popov, E. V. and Machalski, M. 2014. Late Albian chimaeroid fishes (Holocephali, Chimaeroidei) from Annopol, Poland. *Cretaceous Research*, 47, 1–18.
- [102] Popov, E. V. and Shapovalov, K. M. 2007. New finds of chimaeroid fishes (Holocephali, Chimaeroidei) from the Jurassic of European Russia. In Rozanov, A., Yu., Lopatin, A. V. and Parkhaev, P. Yu. (eds). et al. (eds). *Modern Russian paleontology: classic and newest methods*. Russian Academy of Sciences, Paleontological Institute, Moscow, 25–47 pp. [in Russian, English summary]
- [103] Popov, E. V., Ward, D. and Lepage, G. 2009. The diversity and nomenclatural revision of the Holocephalian fishes (Chimaeriformes) from the Kimmeridgian (Late Jurassic) of Western Europe. *Journal of Vertebrate Paleontology*, 29, 166A.
- [104] Popov, E. V., Duffin, C. J., Tischlinger, H. and Atuchin, A. 2013. Reconstructions of the German Plattenkalk (Late Jurassic) chimaeroid fishes (Holocephali, Chimaeroidei). 56. In Schwarz, C. and Kriwet, J. (eds). *6th International Meeting on Mesozoic Fishes: Diversification and Diversity Patterns. Abstracts*. Friedrich Pfeil.

- [105] Püntener, C., Anquetin, J. and Billon-Bruyat, J.-P. 2015. *Thalassemys bruntrutana* n. sp., a new coastal marine turtle from the Late Jurassic of Porrentruy (Switzerland), and the paleobiogeography of the Thalassemydidae. *PeerJ*, 3, e1282.
- [106] Rees, J. 2005. Neoselachian shark and ray teeth from the Valanginian, Lower Cretaceous, of Wawał, central Poland. *Palaeontology*, 48, 209–221.
- [107] Rees, J. 2008. Interrelationships of Mesozoic hybodont sharks as indicated by dental morphology – preliminary results. *Acta Geologica Polonica*, 58, 217–221.
- [108] Rees, J. 2012. Palaeoecological implications of neoselachian shark teeth from the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland. *Acta Geologica Polonica*, 62, 397–402.
- [109] Rees, J. and Underwood, C. J. 2006. Hybodont sharks from the Middle Jurassic of the Inner Hebrides, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 96, 351–363.
- [110] Rees, J. and Underwood, C. J. 2008. Hybodont sharks of the English Bathonian and Callovian (Middle Jurassic). *Palaeontology*, 51, 117–147.
- [111] Rees, J., Cuny, G., Pouech, J. and Mazin, J.-M. 2013. Non-marine selachians from the basal Cretaceous of Charente, SW France. *Cretaceous Research*, 44, 122–131.
- [112] Rigal, S. and Cuny, G. 2016. On the rarity of anterior teeth of *Asteracanthus magnus* (Euselachii: Hybodontiformes). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 279 (1), 1–7.
- [113] Roux, W. 1887. Über eine im Knochen lebende Gruppe von Fadenpilzen (*Mycelites ossifragus*). *Zeitschrift für wissenschaftliche Zoologie*, 16.
- [114] Saint-Seine, P. de 1949. Les poissons des calcaires lithographiques de Cerin (Ain). *Nouvelles Archives du Muséum d'Histoire Naturelle de Lyon*, 2, 1–357.
- [115] Sauvage, H. E. 1873. Notice sur un spathobate du terrain portlandien de Boulogne-sur-Mer. *Bulletin de la Société Académique de Boulogne-sur-Mer*, 2, 94–103.
- [116] Schaefer, K. 2012. Variabilité de la morphologie dentaire des crocodiliens marins (Thalattosuchia) du Kimméridgien d'Ajoie (Jura, Suisse). Unpublished Master's thesis, University of Fribourg, 111 pp.
- [117] Schlotheim, E. F. von 1820. Die Petrefactenkunde auf ihrem jetztigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt. Becker, Gotha, 437 pp.
- [118] Schudack, U., Schudack, M., Marty, D. and Comment, G. 2013. Kimmeridgian (Late Jurassic) ostracods from Highway A16 (NW Switzerland): taxonomy, stratigraphy, ecology, and biogeography. *Swiss Journal of Geosciences*, 106, 371–395.
- [119] Schweizer, R. 1961. Über die Zähne von *Heterodontus semirugosus* (Plieninger). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 113, 95–109.
- [120] Stahl, B. J. 1999. Chondrichthyes III – Holocephali. *Handbook of Paleoichthyology*, 4, Friedrich Pfeil, 164 pp.
- [121] Sweetman, S. C. and Underwood, C. J. 2006. A Neoselachian shark from the non-marine Wessex Formation (Wealden Group: Early Cretaceous, Barremian) of the Isle of Wight, southern England. *Palaeontology*, 49, 457–465.
- [122] Thies, D. 1983. Jurazeitliche Neoselachier aus Deutschland und S-England. *Courier Forschungsinstitut Senckenberg*, 58, 1–117.
- [123] Thies, D. 1995. Placoid scales (Chondrichthyes: Elasmobranchii) from the Late Jurassic (Kimmeridgian) of northern Germany. *Journal of Vertebrate Paleontology*, 15, 463–481.
- [124] Thies, D. and Candoni, L. 1998. *Corysodon* SAINT-SEINE 1949 – a valid genus of Mesozoic neoselachian sharks. *Geologica et Palaeontologica*, 32, 221–233.
- [125] Thies, D. and Leidner, A. 2011. Sharks and guitarfishes (Elasmobranchii) from the Late Jurassic of Europe. *Palaeodiversity*, 4, 63–184.
- [126] Thiolière, V. 1852. Troisième notice sur les gisements à poissons fossiles situés dans le Jura du département de l'Ain. *Annales des Sciences Physiques et Naturelles, d'Agriculture et d'Industrie*, 2, 353–446.
- [127] Underwood, C. J. 2002. Sharks, rays and a chimaeroid from the Kimmeridgian (Late Jurassic) of Ringstead. *Palaeontology*, 45, 297–325.
- [128] Underwood, C. J. 2004. Environmental controls on the distribution of neoselachian sharks and rays within the British Bathonian (Middle Jurassic). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 203, 107–126.
- [129] Underwood, C. J. 2006. Diversification of the Neoselachii (Chondrichthyes) during the Jurassic and Cretaceous. *Paleobiology*, 32, 215–235.
- [130] Underwood, C. J. and Cumbaa, S. L. 2010. Chondrichthyans from a Cenomanian (Late Cretaceous) bonebed, Saskatchewan, Canada. *Palaeontology*, 53, 903–944.
- [131] Underwood, C. J. and Rees, J. 2002. Selachian faunas from the Earliest Cretaceous Purbeck Groups of Dorset, Southern England. *Special Papers in Palaeontology*, 68, 83–101.

- [132] Underwood, C. J. and Ward, D. J. 2004a. Neoselachian sharks and rays from the British Bathonian (Middle Jurassic). *Palaeontology*, 47, 447–501.
- [133] Underwood, C. J. and Ward, D. J. 2004b. Environmental distribution of Bathonian (Middle Jurassic) neoselachians in southern England. 111–122. In Tintori, A. and Arratia, G. (eds). *Mesozoic fishes 3: Systematics, palaeoenvironments and biodiversity*. Friedrich Pfeil.
- [134] Underwood, C. J., Mitchell, S. F. and Veltkamp, C. J. 1999. Microborings in mid-Cretaceous fish teeth. *Proceedings of the Yorkshire Geological Society*, 52, 269–274.
- [135] Underwood, C. J., Ward, D. and Guinot, G. 2016. Development of understanding of the Mesozoic and Cenozoic chondrichthyan fossil record. *Geological Society, London, Special Publications*, 430, 155–164.
- [136] Vullo, R. 2011. Direct evidence of hybodont shark predation on Late Jurassic ammonites. *Naturwissenschaften*, 98, 545–549.
- [137] Wagner, J. A. 1857. Charakteristik neuer Arten von Knorpelfischen aus den lithographischen Schiefern der Umgegend von Solnhofen. *Gelehrte Anzeiger Bayer Akademie Wissenschaft*, 44, 288–293.
- [138] Waite, R., Marty, D., Strasser, A. and Wetzel, A. 2013. The lost paleosols: masked evidence for emergence and soil formation on the Kimmeridgian Jura platform (NW Switzerland). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 376, 73–90.
- [139] Weis, R. and Bei, R. 2015. Le Jurassique au Luxembourg (1) – Vertébrés, échinodermes et céphalopodes du Bajocien. *Musée national d'Histoire naturelle, Luxembourg*, 112 pp.
- [140] Wenz, S., Bernier, P., Barale, G., Bourseau, J. P., Buffetaut, É. and Gaillard, C. 1993. L'ichthyofaune des calcaires lithographiques du Kimméridgien supérieur de Cerin (Ain, France). *Geobios*, 16, 61–70.
- [141] Whitenack, L. B. and Motta, P. J. 2010. Performance of shark teeth during puncture and draw: implications for the mechanics of cutting. *Biological Journal of the Linnean Society*, 100, 271–286.
- [142] Whitenack, L. B., Simkins, D. C. and Motta, P. J. 2011. Biology meets engineering: the structural mechanics of fossil and extant shark teeth. *Journal of Morphology*, 272, 169–179.
- [143] Woodward, A. S. 1888. XLIII.—On some remains of the extinct Selachian *Asteracanthus* from the Oxford Clay of Peterborough, preserved in the collection of Alfred N. Leeds, Esq., of Eyebury. *Journal of Natural History Series 6*, 2, 336–342.
- [144] Woodward, A. S. 1918. On two new elasmobranch fishes (*Crossorhinus jurassicus* sp. nov. and *Protospinax annectans* gen. et sp. nov.) from the Upper Jurassic lithographic stone of Bavaria. *Proceedings of the Zoological Society of London*, 13, 231–235.
- [145] Woodward, A. S. 1919. On two new elasmobranch fishes (*Crossorhinus jurassicus*, sp. nov. and *Protospinax annectans*, gen. et sp. nov.) from the Upper Jurassic lithographic stone of Bavaria. *Proceedings of the Zoological Society of London*, 13, 231–235.