The marine reptile *Neusticosaurus* from the Eastern Alps

by
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Abstract

Whereas nothosaurians are a common element in the Middle Triassic of Monte San Giorgio (Western Alps, Switzerland-Italy) in the Eastern Alps till now only scanty remains were recovered. Recently substantial marine reptiles findings in the Carinthian Dolomites especially of the genus *Neusticosaurus* enlarge our knowledge considerably. It can be stated that in addition to the well-known *Neusticosaurus pusillus* and *Neusticosaurus peyeri* from Swiss-Italian Monte San Giorgio we encounter in the Eastern Alps with *Neusticosaurus toeplitschi* another interesting small-sized marine sauropterygia. It dominated the beach-near deep water and anaerobic abysses of this part of the ancient Tethys-Ocean, now conserved as dark and bituminous well-layered sediments.

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Historical overview

In 1881 Julius Hoser of Stuttgart handed to the German paleontologist Oscar Fraas two interesting skeletons - about 27cm and 28,5cm long - found in the German Lettenkohle Hoheneck-quarry, Middle Triassic in age. Fraas made a first classification of these "long-necked saurian" inserting them as nothosauria and comparing these marine reptiles with the just known *Simosaurus* and giving the new species name *pusillus*. It was than one year later that Harry Govier Seeley undertook the two specimen intense studies naming them *Neusticosaurus pusillus* for "swimming lizards".
Meanwhile from the Swiss-Italian region around the Monte San Giorgio in the Western Alps rich Middle Triassic vertebrate-faunas were discovered and first described in 1847 by Giulio Curioni. Especially the Italian localities Besano and Viggiù offered a lot of interesting fossils. After that Emilio Cornalia (1854) named a first marine reptile *Pachypleura edwardsii* (which in 1927 changed to *Pachypleurosaurus edwardsii* and than in 1989 was reclassified with some doubts as *Neusticosaurus edwardsii*.
Also from the Swiss part especially near the locality Meride around the year 1907 began first researches which were intensified by the young researcher Bernhard Peyer in 1919 and the following years. Several hundred complete skeletons were collected from four distinct horizons of bituminous limestones and shales. The largest and most diverse collection pertain to the Pachypleurosauridae (Nothosauria, Reptilia). They were mostly classified in base of the different strata. *Serpianosaurus mirigiolensis* comes from the oldest strata, the Grenzbitumenzone Beds. The three younger strata, all in the Lower Meride Limestone, yield three different species of *Neusticosaurus. Neusticosaurus pusillus* - just known from the German Lettenkeuper, comes from the Cava Inferiore horizon, *Neusticosaurus peyeri,* a new species honouring Bernhard Peyer (Sander, 1989), from the Cava Superiore horizon, and *Neusticosaurus edwardsii,* new combination, from the Alla Cascina horizon (Furrer, 2003).
Mainly simultaneously as Bernhard Peyer began his researches around the Monte San Giorgio, the Austro-Hungarian paleontologist Franz Baron von Nopcsa described in 1928 a first small sauropterygian from the Eastern Alps, probably from the Stadelbachgraben, about 2km west of the small Carinthian hamlet Töplitsch as new genus and species, *Psilotrachelosaurus toeplitschi*, classifying it in the marine reptiles of the Nothosauridae. The headless specimen was just found in 1844 and belonged to the Landesmuseum für Kärnten (Nopcsa, 1928).
Years later in 1993 Olivier Rieppel elaborated that the family of Pachypleurosau-

roidea (Peyer, 1934) included several different genera like *Anarosaurus, Dactylosaurus, Keichousaurus, Neusticosaurus, Psilotrachelosaurus* and *Serpianosaurus*, accepting largely that also *Psilotrachelosaurus* formed a distinct taxon, closely related to the *Serpianosaurus-Neusticosaurus*-clade of Middle Triassic marine reptiles.
Only in 1995 Rieppel changed his classification and recognized that *Psilotrachelosaurus* can be classified better as N*eusticosaurus toeplitschi*.
After that a local collector, Werner Vilgut, recovered a further specimen of *Neusticosaurus toeplitschi,* described than by Gottfried Tichy in 1998. It was found in the Kellerberg quarry, not far from the type locality of the first find the Stadelbachgraben. Now, the complete neck and skull was represent, but unfortunately badly preserved.
Beginning from 2015 Charly Weiss and Georg Kandutsch, sometimes accompanied by Michael Wachtler began intensive researches in this area. In several places but always inside the bituminous Partnach-layers they recovered a fair amount of partly exclusive preserved nothosaurians. This publication compares the well known Monte San Giorgio nothosaurians with the Eastern Alps marine reptiles and tries to elaborate an evolution line of the genus *Neusticosaurus.*

Geological setting

The exact time-scale determination and correlation of the different horizons between Monte San Giorgio as well as the Austrian Partnach-Formation is not easy. Therefore it will tried to make the attempt by first analysing in detail the Western Alps outcrops around the Monte San Giorgio and than elaborate a correlation to the Eastern-Alps marine-reptile zones.
The border between Anisian and Ladinian around Monte San Giorgio was dated on the upper part of the Grenzbitumenzone (Brack and Rieber, 1993; Brack et al., 2003) due to radiometric U-Pb-analyses on volcanic bentonites. Sparse ammonoids were classified as *Protrachyceras cf. ladinum* and *Arpadites arpadis* belonging to the Early Ladinian. The about 400m thick and fossil-rich Meride-Kalk - holding the volcanoclastic Serrata-Tuffite - overlies the Grenzbitumen and can be followed all around the Monte San Giorgio. It is succeed than by the only 1.5m thick fossil-rich Cava-inferiore-Schichten, in which a remarkable number of *Neusticosaurus pusillus* skeletons were found. Different sediments of bentonites and calcareous deposits of the Meride-Kalk follows till we reach about 15m over the base of the Serrata-Tuffite the second famous sediments, the Cava-superiore-layers - about 10 m thick - in which beginning from 1928 Bernhard Peyer with his team recovered additionally to three bigger *Ceresiosaurus calcagnii*-lariosaurids also a fair amount of small-sized *Pachypleurosaurus edwardsii* which later were reclassified by Sander (1989b) as the species *Neusticosaurus peyeri*, to differentiate them from the bigger *Neusticosaurus (Pachypleurosaurus) edwardsii* recorded in an other deposit (Furrer, 2003).
This different classification makes sense because over the time-duration - estimated in some million years - the *Neusticosaurus*-clade differentiated in diverse aspects. We can therefore presume that the most part of *Neusticosaurus*-findings pertain to the Middle to Upper Ladinian (Fassanian-Longobardian) being equivalent in the Dolomites with the youngest part of the Buchenstein-Formation, but mostly the Wengen-Formation.
The corresponding successions in the Eastern Alps are in the Dolomites the Buchenstein- overlain by the Wengen-Formation and more in the East to the Lienzer Dolomites and the Carnian-Mountains the deep-water Reifling Formation, which in turn is overlain by the clastic sediments of the Partnach Formation (Brühwiler et al. 2007). The lower part of the Reifling Formation is tentatively referred to the Late Anisian *Paraceratites trinodosus* Zone and somewhat older levels, whereas the uppermost part reaches the Ladinian *Protrachyceras archelaus* Zone. The nodular lower Reifling Formation resembles the shale-poor nodular varieties of the Prezzo Limestone (e.g. in the Bagolino section) and the siliceous nodular limestones of the Reifling Formation are hard to distinguish from their counterparts in the Buchenstein Formation. Both units contain volcanoclastic ash layers at different stratigraphical levels.
The Partnach-Plattenkalke also known as Partnachschichten (from the Partnach Gorge, or Partnachklamm near the Bavarian city Garmisch-Partenkirchen) consist of

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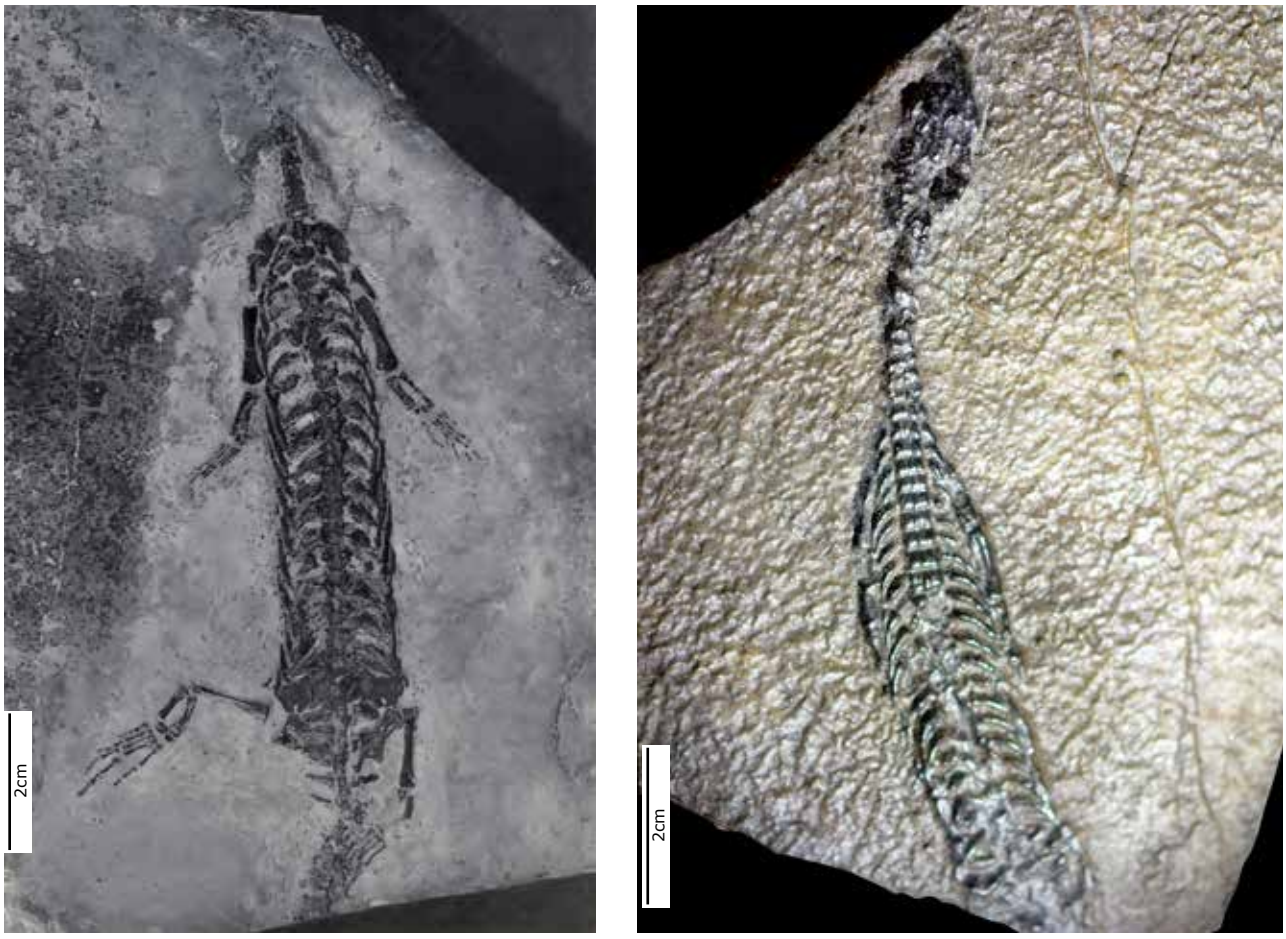
The oldest collections of *Neusticosaurus* in the University of Zürich

1. The trays holding the first collections made by Bernhard Peyer and Rainer Zangerl; 2. *Neusticosaurus edwardsii*, the biggest of the Pachypleurosauria from Monte San Giorgio (Cassina-Member) collected in 1933; 3. An old specimen of *Neusticosaurus pusillus,* Acqua del Ghiffo, Cava Inferiore, Meride, 4. *Neusticosaurus peyeri,* Acqua del Ghiffo, Cava Superiore Member described by Peyer in 1932; 5. *Neusticosaurus peyeri,* Acqua del Ghiffo, Cava Superiore Member, Excavation Peyer 1928)



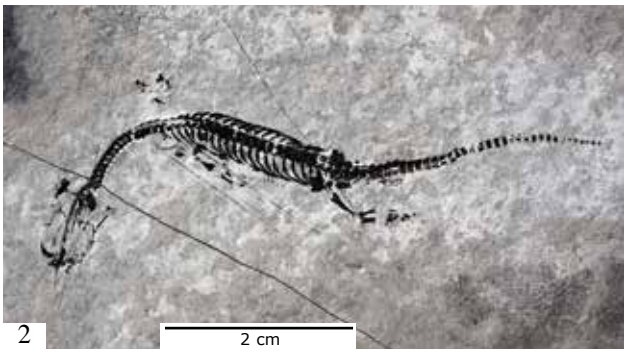
Neusticosaurus toeplitschi: Holotype and Vilgut-specimen

The holotype described by Nopcsa, 1928, as *Psilotrachelosaurus toeplitschi* from the Stadelgraben (lenght 11,6 cm), and the Vilgut-specimen from the Kellerberg (length 11cm). Both Landesmuseum fur Karnten, Dept. of Mineralogy and Geology)

a lower unit of limestone, an intercalated bed of "marly shales" at the middle of the lithostratigraphical column of the Partnach-Plattenkalk and an upper unit of limestone.
The marls and shales of the Partnach Formation appear to be finer-grained when compared with the siliciclastic Lombardian Wengen Formation of latest Ladinian age. Lithologically similar to the Partnach shales are the local occurrences of the Lozio shales in the Southern Alps. The latter unit is restricted to exposures around the middle Val Camonica and situated stratigraphically above the Wengen Formation. Its base is already Carnian in age (Brühwiler et al. 2007). Only partially and mostly in the upper parts the Partnach-Kalke with their characteristic prominent black shales between dolomitic mud- to packstones hold the well preserved vertebrate fauna.

Interesting rests of nothosaurians are concentrated around the Weissensee and the city of Hermagor in Carinthia (Kellerberg, Jadersdorf, Ochsenschlucht, Reisach and especially the new discovered St. Lorenzen/Gitschtal).The vertebrate fossils were deposited in a shallow restricted carbonate platform environment accompanied by a slightly deeper intraplatform basin with euxinic and anoxic conditions. Sometimes characteristic finely laminated limestones and marls change with intercalated volcanic ash layers. Fish-remains usually do not occur in the marine-reptile rich zones, but in separate layers. Only in rare cases the slabs broke in direction to the vertebrate faunas, usually - probably due to the fermentation gasses - a hard carbonate layer protect the reptiles, that only with difficulty - using mechanical supports - can be separated.

Neusticosaurus toeplitschi, Neusticosaurus pusillus and Neusticosaurus peyeri: hatchlings and skulls



Neusticosaurus Comparison of the hatchlings

1. Juvenile specimen of *Neusticosaurus peyeri,* Meride, Acqua del Griffo (UZH, Universität Zürich)

2. Hatchling of *Neusticosaurus toeplitschi* (6,4cm), Jadersdorf (Coll. Charly Weiss)

Neusticosaurus Comparision of the skulls

1. *Neusticosaurus pusillus* (Cava Inferiore, Meride); 2. *Neusticosaurus peyeri,* Cava Superiore, Meride (Both Coll. UZH, Universität Zürich); 3. Complete skull of *Neusticosaurus toeplitschi* (2,7cm), St. Lorenzen-Gitschtal (Coll. Charly Weiss).

If the Partnach-Formation is of Ladinian-Carnian-stage (Longobardian-Cordevolium), so it is slightly younger as the Meride-Kalke from Monte San Giorgio. Therefore *Neusticosaurus pusillus* and *Neusticosaurus peyeri* are older and the area- and time-differentiated new species-classification of *Neusticosaurus toeplitschi* makes sense and is useful to understood the evolution of these marine reptiles.

The marine reptile *Neusticosaurus toeplitschi*

Till now the most studied Nothosauridae came from the World-heritage site Monte San Giorgio in the Western Swiss-Italian Alps. Pertaining to different-aged layers *Neusticosaurus peyeri, Neusticosaurus pusillus* and due to its larger size difficult to classify *Neusticosaurus (Pachypleurosaurus) edwardsii* are the most common and known.

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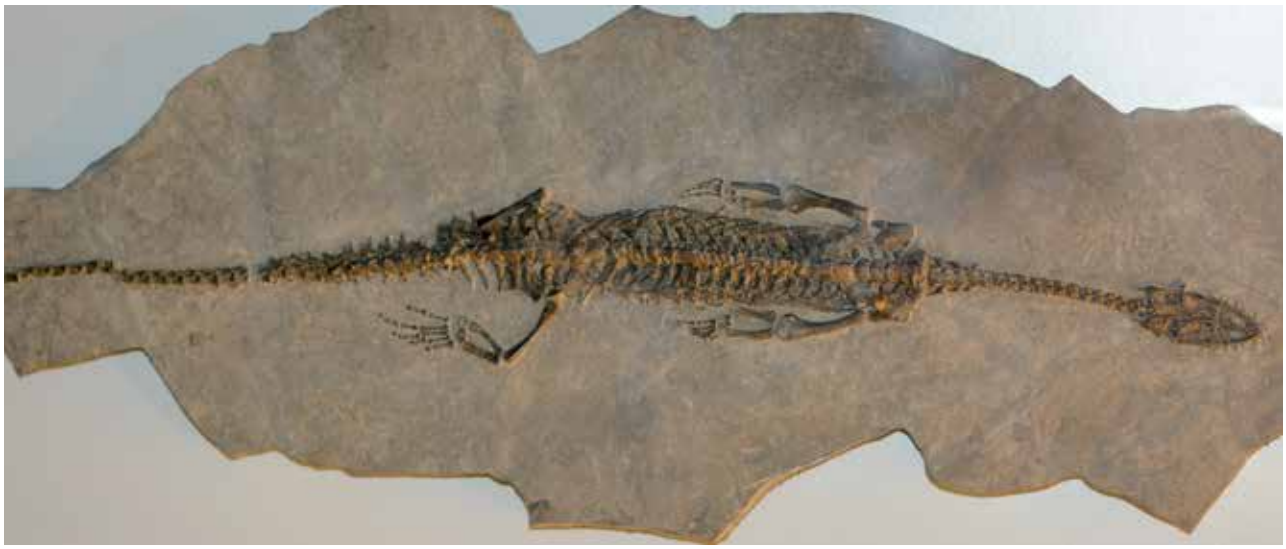
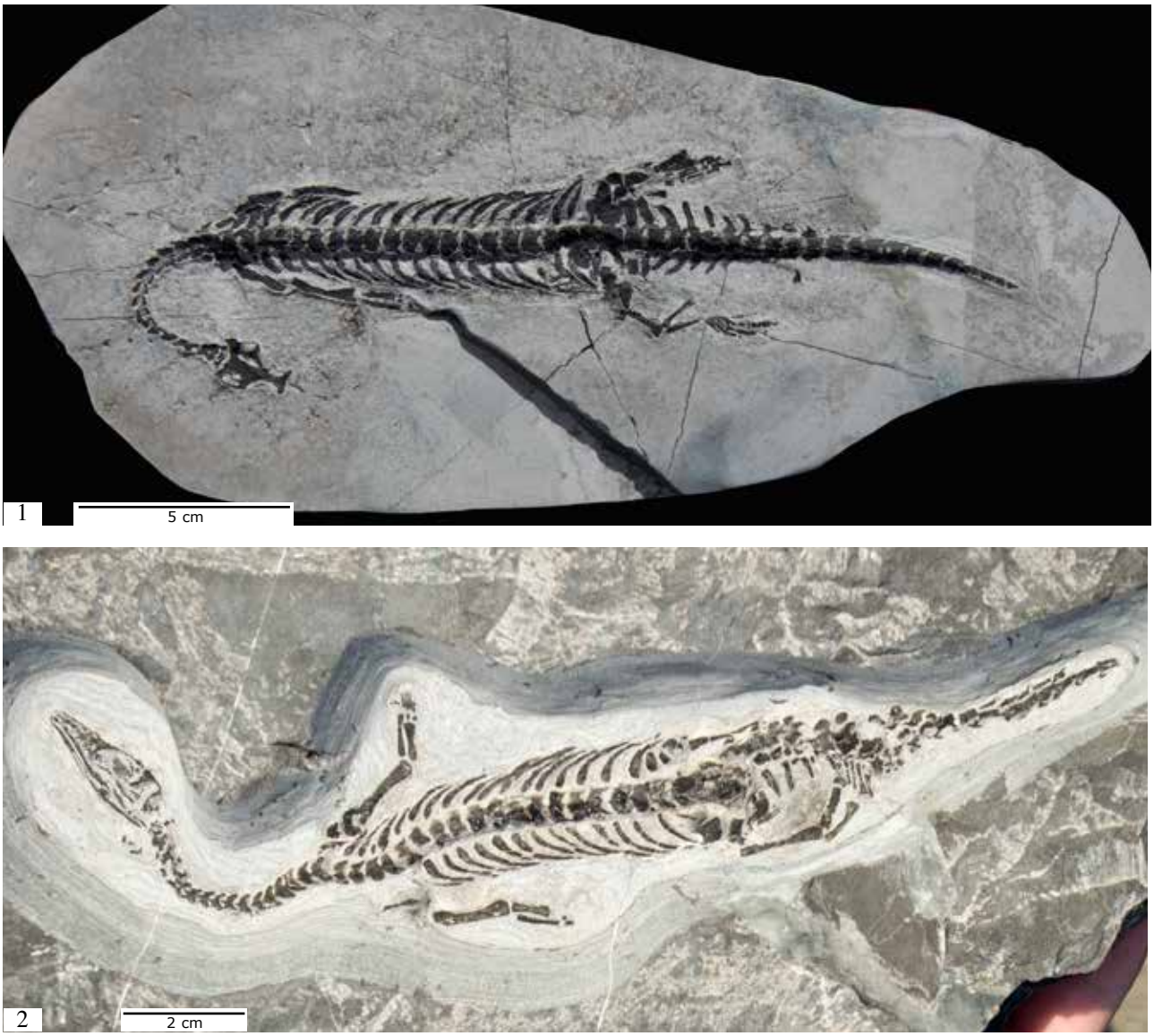


Neusticosaurus peyeri and pusillus - complete specimen

1. *Neusticosaurus peyeri,* Acqua del Ghiffo, Cava Superiore Member; 2. *Neusticosaurus pusillus,* Acqua del Ghiffo, Cava Inferiore, Meride, (UZH, Universität Zürich)

They differ from the Eastern Alps N*eusticosaurus toeplitschi* even at a first glance by their greater robustness in the skeletons. The N*eusticosaurus toeplitschi*-skull is much more fragile, also the hatchlings were more delicate. Otherwise some other feature correspond together: A total of 16 till 18 cervical vertebrae con be counted in *N. toeplitschi*, 15-16 in *N. peyeri,* 18-24 in N. pusillus. Also the number of dorsal vertebrae do not vary much: They are in *N. toeplitschi* 19-20, in *N. peyeri* 19-20 and in *N. pusillus* 22-24 (Rieppel, 1993).

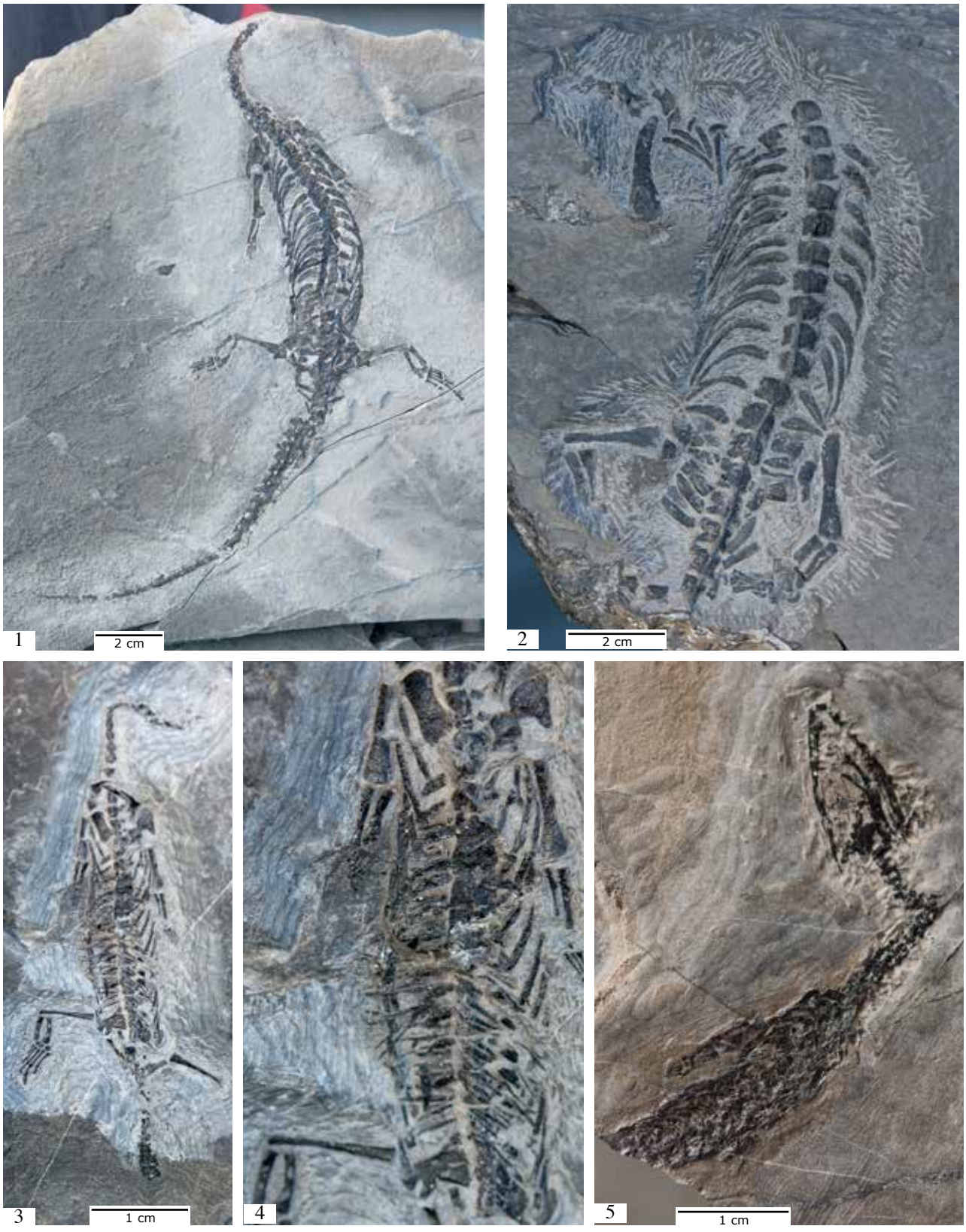
The humerus in *Neusticosaurus toeplitschi* is typically pachypleurosauroid (Peyer, 1934), and varies from 1.4-1.5cm in length. It evidence a slight curvature, a weakly developed deltopectoral crest, and a slight distal expansion. As in other pachypleurosaurs, the radius is somewhat longer than the ulna. Both are about 0,7-0,8cm long. The radius is fairly slender and evenly curved, with slightly expanded proximal and distal heads. The ulna is shorter and broader than the radius and has a more distinctly expanded proximal head. The femur - being from 1.5 till



Neusticosaurus toeplitschi - complete specimen

1. Probably a female, (head, 2,7cm; cervical vertebrae 4,5cm; dorsal vertebrae 8,3cm; caudal vertebrae 12cm; entire skeleton 27cm); St. Lorenzen-Gitschtal (Georg Kandutsch, Coll. Wachtler-Dolomythos) 2. Probably a male, (head, 2,7cm; cervical vertebrae 5cm; dorsal vertebrae 7,5cm; caudal vertebrae 6-12cm; entire skeleton 25-27cm); St. Lorenzen-Gitschtal (Coll. Charly Weiss).

2.8cm long, consist of only a slightly curved bone, with the proximal head more strongly expanded than the distal end. It is also slightly longer than the humerus. Tibia and fibula reach a length of 0.8-1.5cm, the fibula consist of a strongly curved bone, with the distal head more distinctly expanded than the proximal head, and with a strongly concave medial border.
The humerus-femur ratio is 1.0:1.25, whereas ulna-radius and tibia-fibula reach only half the size of humerus or femur. The metacarpals and the manual phalanges reach with 0.5cm in comparison to the metatarsals and pedal phalanges (1.5cm) only one third of the size.
The estimated adult specimen length of the different *Neusticosaurus*-species are (Kuhn-Schnyder, 1993):
Neusticosaurus toeplitschi: 30-40cm
Neusticosaurus pusillus: 40-52 cm
Neusticosaurus peyeri: 45-55 cm
Neusticosaurus edwardsii: about 120 cm
In that the eastern Alps *Neusticosaurus toeplitschi* seems to be characterized by its smallness.



Neusticosaurus toeplitschi - Details

1. Probably female specimen without skull (cervical vertebrae 4-6cm?; dorsal vertebrae 8,5cm; caudal vertebrae 14cm; entire skeleton 34cm?); St. Lorenzen-Gitschtal; 2. Part of the dorsal vertebrae, St. Lorenzen-Gitschtal; 3-4. Juvenile specimen with broken ribs and legs, predator attach or cannibalism?; St. Lorenzen-Gitschtal; 5. Juvenile specimen (Reisach) All Coll. Charly Weiss).

Neusticosaurus toeplitschi - Details of probably male specimen

1. Skull and neck with skin-conservation, St. Lorenzen-Gitschtal (Coll. Charly Weiss) 2. Dorsal vertebrae, femur (2,8cm), tibia and fibula (1,5cm) Ochsenschlucht (Charly Weiss, Coll. Kandutsch) 3. Dorsal vertebrae, humerus (2,2cm), ulna, radius (1,1cm) (Coll. Charly Weiss)

Sometimes the stronger ribs and a more powerful robustness suggest that in the Partnach-Formation we encounter different nothosaurian-species. Because the most well preserved specimen came from the locality St. Lorenzen-Gitschtal were the richest strata are coeval in age, it can be assumed that these can be more attributed to a distinct sexual dimorphism. To small are the differences, that we can include other families like *Pachypleurosaurus* or *Lariosaurus* in the fossil record.
Also inserting *Neusticosaurus toeplitschi* to the distinct taxon *Psilotrachelosaurus* as proposed by Nopcsa, (1928), maybe closely related to the *Serpianosaurus-Neusticosaurus* clade (Rieppel, 1993) makes no sense. In past were made attempts to find out differences in the till up to this time sparse known two partially conserved skeletons. It was suggested that *Psilotrachelosaurus* differs from *Neusticosaurus* in the broad pubis and ilium or differs in the retention of an ossified distal carpal/tarsal 4, the relatively broad ventral elements in the pelvic girdle (pubis and ischium), and body proportions, in particular a proportionately short humerus (Rieppel, 1993). All this are to minimal differences and therefore *Neusticosaurus toeplitschi* stays well in the context as being a different species additionally to the other known species from the Swiss-Italian Monte San Giorgio-locality.
Another parented genus seems to be *Keichousaurus* from the Middle Triassic of China. Skull characters as well as the structure of the sacral region indicates in direction to the neusticosauroid lineage as a member of the Nothosauridae. It can be distinguished from *Neusticosaurus* by a more distinctly curved humerus, a distinctly broadened ulna, and a transversally orientated intermedium positioned distal to the broad spatium interosseum between ulna and radius (Rieppel, 1993)
More interesting will be studying the growing stages of *Neusticosaurus toeplitschi* and the sexual dimorphism. As seen at Monte San Giorgio, *Neusticosaurus pusillus* and *N. peyeri* were very similar in their anatomy, what can be accepted also for *N. toeplitschi.* The growing rate during the first and second year was rapid. Sexual maturity was reached during the third till fourth year. The growing in length ended after about five years of life. Altogether they did not live much longer than eight till nine years (Sander 1990).
All Monte San Giorgio pachypleurosaurids are sexually dimorphic in forelimb development. Probably the female has poorly differentiated and relatively short humeri whereas the males has well differentiated and relatively long humeri. Both sexes were of about the same size and therefor the identification of gender is not so easy possible (Rieppel, 1993). This mainly equal size and length could be observed also in *Neusticosaurus toeplitschi.* Only a greater robustness of the bones are indication for male individuals.

Conclusion

- The Eastern Alps marine reptile *Neusticosaurus toeplitschi* can due to new findings inserted well in the genus of *Neusticosaurus*, till now abundantly known from Ladinian (Middle Triassic) locality from Germany and the Monte San Giorgio on the Swiss-Italian border (*Neusticosaurus pusillus, N. peyeri*).
- It is geologically slightly younger than the other, pertaining to the Ladinian-Carnium border.
- It is differentiated from the others by a more fragile skeleton, and a smaller size.

Neusticosaurus toeplitschi enlarges our knowledge about Triassic nothosaurians considerably, being till now the last known Alpine representative of the *Neusticosaurus* taxon.

Acknowledgments

I thank Heinz Furrer, curator and senior scientist from the University of Zurich, (UZH) for opening the archives and deposits of the University, holding the old specimen from Bernhard Peyer and Rainer Zangerl. Karl (Charly) Weiss and Georg Kandutsch were the first after a mainly hundred year decline, that made active prospecting in the Partnach-Formation, recovering many amazing preserved *Neusticosaurus* skeletons. They demonstrated that also today important discoveries can be done. I am grateful to their contributions.

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