

A large ichthyosaur vertebra from the lower Kössen Formation (Upper Norian) of the Lahnewiesgraben near Garmisch-Partenkirchen, Germany

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A posterior dorsal centrum of a large ichthyosaur is described and discussed. The vertebra was found in the lower Kössen Formation (Hochalm Member, Upper Norian) of the Lahnewiesgraben near Garmisch-Partenkirchen, Bavaria. The large dimension of the vertebra is remarkable and suggests a total length of the ichthyosaur similar to the giant *Sbonisaurus* of the same age. The colonization by a low-diverse, small-sized bivalve community suggests that this vertebra served as an island-like hard substrate on the seafloor for about some years prior to final embedding.

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Introduction

Ichthyosaurs are prominent components of Mesozoic marine vertebrate communities (e.g., Maisch 2010). While isolated vertebrae of small to medium-sized ichthyosaurs are common in many shallow-marine deposits, large specimens are rare and have always attracted much attention (e.g., Theodori 1854; Zapfe 1976). Isolated vertebral centra of ichthyosaurs can readily be identified in terms of their approximate position in the vertebral series (McGowan & Motani 2003). Vertebrae in which the dia-

pophysis (dp) and parapophysis (pp) lie in the lower half of the centrum probably have to be attributed to the posterior half of the dorsal series. In this article we describe an ichthyosaur vertebra from the Upper Triassic Kössen Formation from the Northern Calcareous Alps with affinities to *Sbonisaurus*. The enormous size of the vertebra, its stratigraphic position and rareness is of scientific importance.

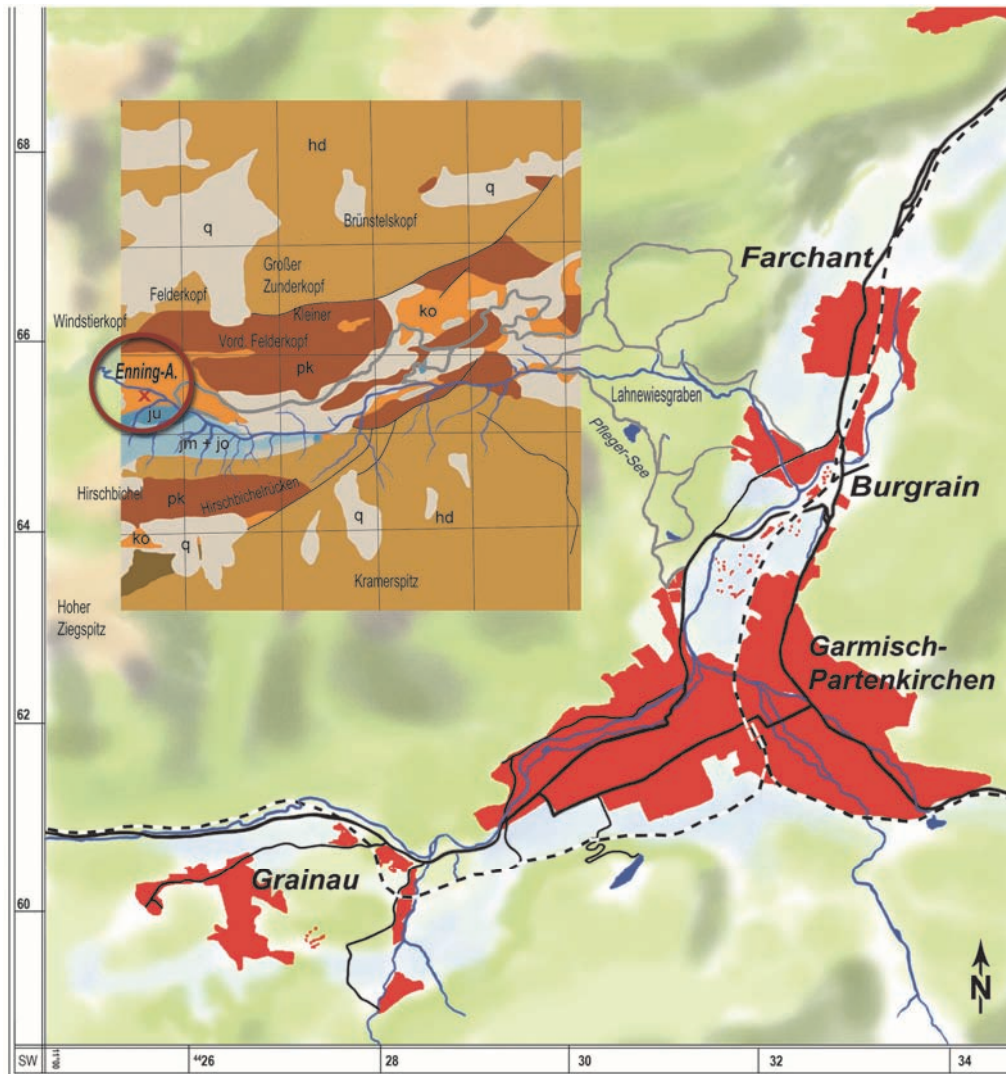


Fig. 1: Locality of the described giant Upper Norian ichthyosaur vertebra (GZG.V.26007), Fleckgraben, creek into the Lahnewiesgraben (Enning-Alm) near Garmisch-Partenkirchen, Bavaria, Germany [GPS 47311916 N; 11004870 E]. Geological map of the Lahnewiesgraben area. **hd:** Hauptdolomit Formation, **pk:** Plattenkalk Formation, **ko:** Kössen Formation, **ju:** Lower Jurassic formations, **jm + jo:** Middle and Upper Jurassic formations, **q:** Quaternary deposits.

Geological setting and stratigraphy

The Lahnewiesgraben is an alpine creek 2 km NW of Garmisch-Partenkirchen, Northern Calcareous Alps, Bavaria (Fig. 1). The upper Triassic to lower Cretaceous series of the Lahnewiesgraben area were deposited at the northern margin of the Tethys and incorporated into the upper Austroalpine nappe system (for review see e.g., Mandl 2000), specifically the Lechtal Nappe (Kuhnert 1967), during the Alpine Orogeny. One important structural geological element of the Lechtal Nappe system is the Lahnewies-Neidernach syncline. Due to the tectonically incompetent Kössen facies this syncline exhibits a strong special faulting and folding which makes it difficult to find complete stratigraphic sections. The uppermost Triassic of the Lahnewies-Neidernach syncline is represented by dark shale, marly limestones and limestones of the Kössen Formation being considered deposits of intraplateau basins

due to extensional tectonics and successive desintegration of the vast Norian Austroalpine carbonate platform. Lower facies of the Kössen Formation (Hochalm Member; Golebiowski 1990) is characterized by highly fossiliferous shallowing upward-cycles of marls and calcareous tempestites with a rich and diverse community of bivalves like *Rhaetavicula contorta* (Portlock), *Bakevella praecursor* (Quenstedt), *Gervillaria inflata* (Schafhäütl), *Modiolus minutus* (Goldfuss), *Atreta intusstriata* (Emmrich), abundant brachiopods *Rhaetina gregaria* (Suess) (Kuss 1983, Tomašových 2006), and further invertebrates. Plant remains like horsetails (e.g., *Equisetites muensteri*, *Equisetites intermedius* and *Equisetites grophodon*) have been swept into these intraplateau basins by storm events (Kühn 1940; Friebe 2000). Near the basis of the Hochalm Member, at the transition to the Plattenkalk Member of the Hauptdolomit Formation, vertebrate remains and accumulations of conchostraca have been described from shallow marine often bituminous carbonates (e.g., Faupl 2000).

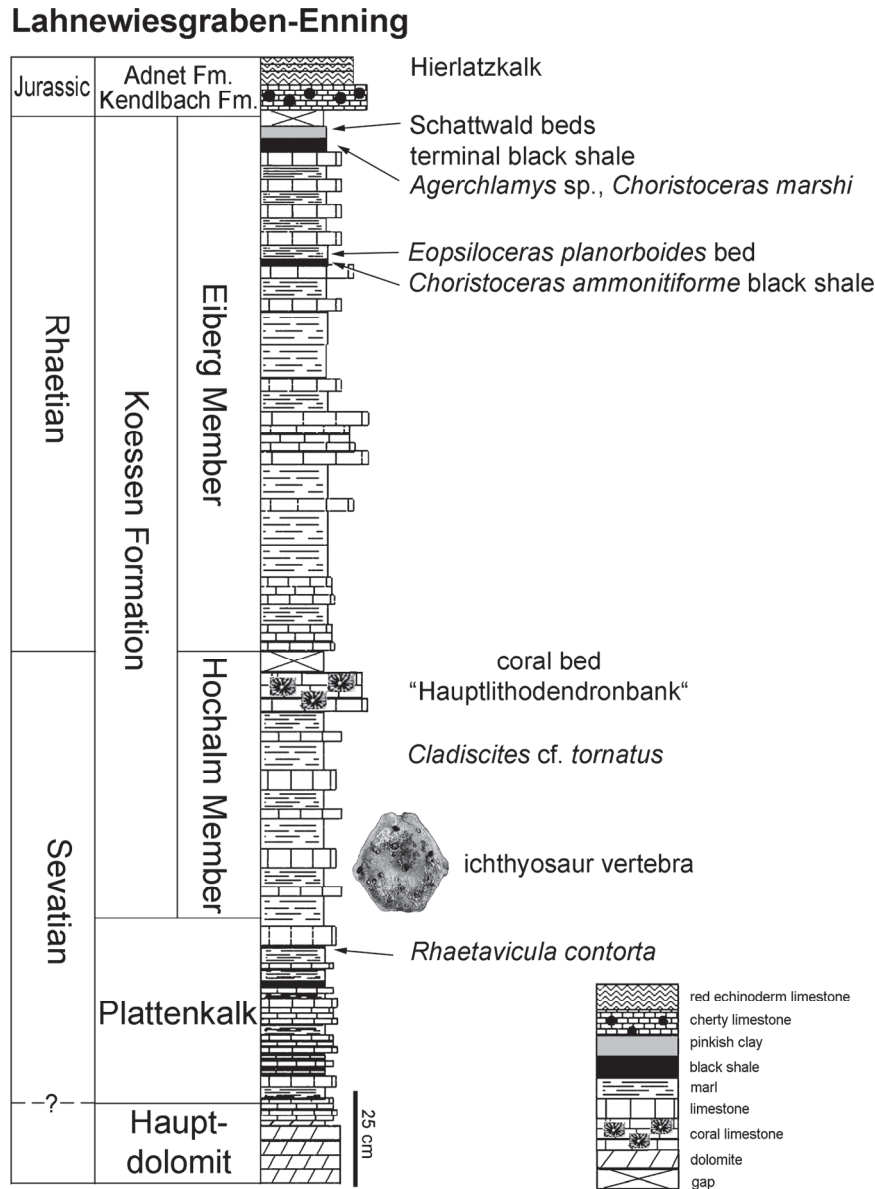


Fig. 2: Compiled stratigraphic section of the Upper Triassic of the Lahnewies–Neidernach syncline.

The top of the Hochalm Member is marked by a widespread, thick coral bed (Hauptlithodendronbank). The following Eiberg Member (Golebiowski 1990) finally reflects a further deepening with less fossiliferous marl-limestone alternations characterized by deeper-water trace fossil associations (e.g., *Zoophycos*) and a few cephalopod beds, within the Lahnewies–Neidernach syncline specifically with *Epsilonoceras planorboides* (Gümbel), *Choristoceras cf. ammonitiforme* (Gümbel) and *Choristoceras marshi* (Hauer). Remarkable are a couple of cephalopod-bearing beds near the top of Eiberg facies which is characteristic for the Lahnewies–Neidernach syncline (Reitner 1978) (Fig. 2). This couple is composed of a black shale with abundant small *Choristoceras cf. ammonitiforme* and small *Agerchlamys*-type bivalves followed up a grey bioturbated marly limestone with abundant *Epsilonoceras planorboides* specimens, the only known finding site in the Kössen beds of the North-

ern Calcareous Alps. The top of the section is characterized by a 20 cm thick oil shale with *Choristoceras marshi* and abundant *Agerchlamys* bivalves and the red to pink coloured Schattwald beds, similar to other sections of the western Eiberg Basin (Hillebrandt et al. 2007, Hillebrandt & Kment 2009). The Kössen Formation has approximately 200 m thickness (Linke 1963). However, a number of faults and folds inhibit the presentation of a continuous section. The presented section is a simplified sedimentological and stratigraphic compilation of tectonically isolated small sections of the Lahnewies–Neidernach syncline.

The vertebra described in this paper was found in September 2003 in a tributary in the eastern part of the Lahnewiesgraben (Fleckgraben) *ex situ* at basal parts of the Hochalm Member. The Upper Norian age of these basal parts is indicated by the finding of a *Cladiscites cf. tornatus* (Bronn) (Wiedmann et al. 1979) (Fig. 2).

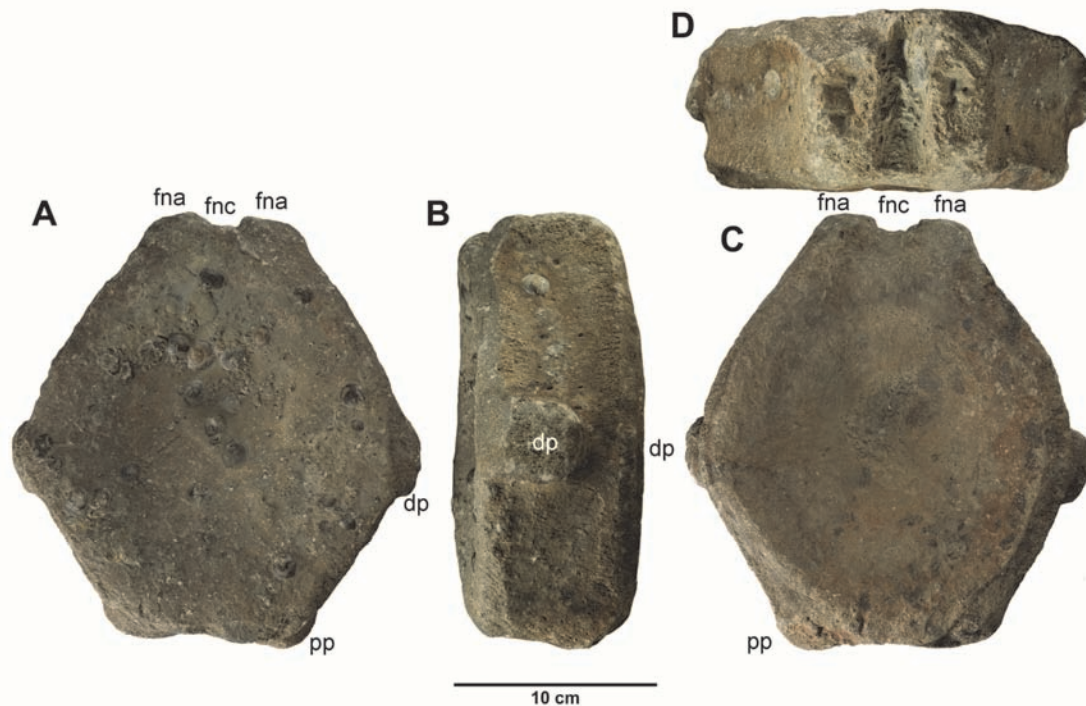


Fig. 3: Ichthyosauria gen. et sp. indet., presacral trunk vertebra from the lower Kössen Formation (Hochalm Mb; Upper Norian) of the Lahnewiesgraben near Garmisch-Partenkirchen (Geoscience Museum Göttingen collection number: GZG.V.26007). (A) anterior views, (B) lateral view, (C) posterior view, (D) dorsal view [Abbreviations: fnc = floor of neural canal, fna = facet of neural arch, dp = diapophysis, pp = parapophysis].

Short review on Triassic ichthyosaurs

Ichthyosaurs were important large marine Triassic vertebrates and their record is starting in the lower Triassic, e.g., first taxa are known from the Sticky Keep Formation in Svalbard (Olenekian). However, they were abundantly found in organic-rich sediments of the middle Triassic (Anisian–Ladinian). Important sites are known from the southern Alps of Switzerland and northern Italy (Monte San Giorgio Grenzbitumen zone and lower Meride Limestone) (e.g., Maisch & Matzke 2005; Furrer 1995; Wirz 1945), Guanling Formation of Guizhou, southern China (e.g., Li 1999), and the Ladinian/early Carnian Tschermakfjellet Formation of Svalbard (e.g., Riis et al. 2008). Haubold (2002) summarizes the known ichthyosaur taxa of the Alpine and German Triassic. Most important are the findings from the Anisian/Ladinian Grenzbitumenzone and lower Meride Limestone of the Monte San Giorgio realm with taxa of Mixosauridae (*Mixosaurus cornalianus*, *M. kubnschnyderi*, *Wimanius odontopalatus*) and Shastasauridae (*Besanosaurus leptorhynchus*, *Cymbospondylus buchseri*). From the German Basin (Anisian Röt Formation/Lower Muschelkalk), diverse remains of Mixosauridae (*Contectopalatus/Mixosaurus atavus*), questionable Omphalosauridae (*Tholodus schmidti*) are known, and from Ladinian upper Muschelkalk taxa of Mixosauridae (*Contectopalatus/Mixosaurus atavus*, *Phalarodon major*), Cymbospondylidae (*Phantomosaurus/Shastasaurus neubigi*), and Omphalosauridae (*Omphalosaurus* sp.) are known (von Meyer 1848; Peyer

1939). Nicholls & Makoto (2004) described remains of a large *Sbonisaurus* from the Norian of British Columbia.

However, upper Triassic sites with ichthyosaur remains are sparse and all new findings are of great phylogenetic importance. A general survey on the palaeobiogeography of ichthyosaurs is given by Sander & Faber (1998) and Sander & Mazin (1993), as well as on the phylogeny by Lawrence (2008) and Maisch (2010).

A large ichthyosaur vertebra (*Leptoptyrygius* sp.) is already known from the Kössen Formation with a diameter of 16 cm from the Neumühle quarry near Vienna (Zapfe 1976). Before, two small ichthyosaur vertebrae from the Kössener Schichten of Schleimser Joch in the Achental (Austria) were described by von Meyer (1856) like that of *Ichthyosaurus tenuirostris*. Up to now the following species were found in the same horizon of the present specimen in the upper Norian to Rhaetian (arrangement according to McGowan & Motani, in 2003):

- (1) *Macgowania janiceps* from upper Norian of British Columbia, only anterior skeleton parts known;
- (2) *Leptonectes tenuirostris* from upper Rhaetian of England, with round vertebrae (ca. 2.5 m);
- (3) *Leptonectes solei* from upper Rhaetian of England, with round vertebrae (large form, skull 1 m);
- (4) *Leptonectes moorei* from upper Rhaetian of England, only anterior skeleton parts known (small form);
- (5) *Ichthyosaurus communis* from Triassic–Jurassic boundary from England, moderate large form up to 2.5 m.

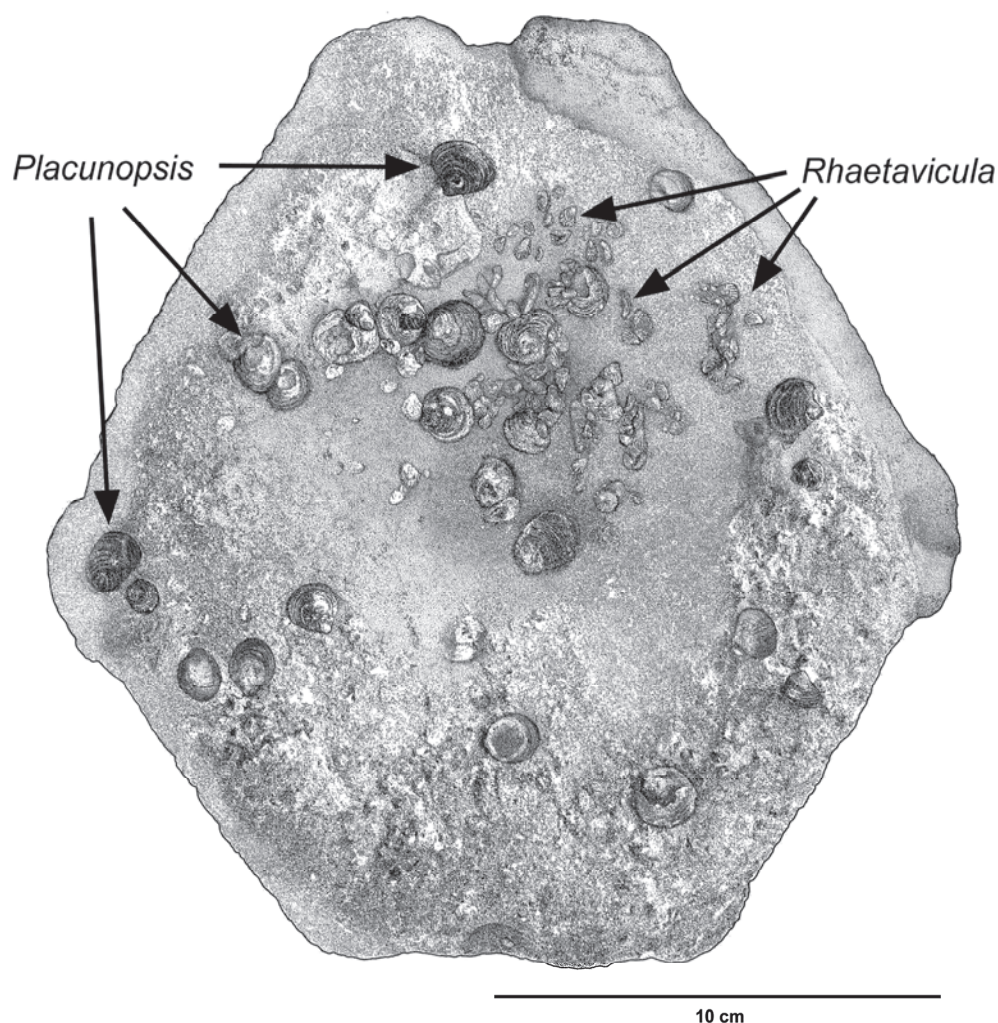


Fig. 4: Drawing of the vertebra showing the attached bivalve species *Placunopsis alpina* and *Rhaetavicula contorta*.

Description of the new ichthyosaur vertebra

It is not possible to erect a valid new taxon based on one vertebra. However, the vertebra is well preserved and exhibits some significant anatomical characters which have affinities to the *Sbonisaurus* group.

The here described presacral trunk vertebra, (Fig. 3; GZG.V.26007, leg. Eva Siedersbeck, Garmisch-Partenkirchen) was found in the Fleckgraben, a side creek of the Lahnewiesgraben close the Enning-Alm near Garmisch-Partenkirchen (Bavaria, Germany; Fig. 1). Exposed in the Fleckgraben is the Lower Kössen Formation (Upper Norian, Hochalm Member).

The general outline resembles that of the specimen depicted by McGowan & Motani (2003) and named *Omphalosaurus* sp. (BMNH 24684 d). Such vertebrae can be identified as originating from the posterior dorsal region of *Omphalosaurus* or *Ophthalmosaurus* and should clearly be

used with great caution concerning taxonomy (McGowan & Motani, 2003). In comparison with the measurements of TMP 94.378.2, *Sbonisaurus sikanniensis*, a large ichthyosaur of 21 meters in length, possibly like our new specimen, *Sbonisaurus popularis*, *Leptopterygius rheticus*, and *Leptopterygius* sp. from the Kössen Formation show the much higher compactness of our vertebra from the Lahnewiesgraben. Based on the presence of a single apophysis located on the lateral surface of the bone, the vertebra is caudal in origin and many large ichthyosaurs from the time frame in question have hexagonal caudals. Among Triassic vertebrae, only Middle Triassic and later ichthyosaurs have short vertebrae with H/L ratio greater than 1.5. The more primitive forms have H/L ratios of 0.9 to 1.2 (Motani 2000). Vertebral body size and proportions similar to *Sbonisaurus sikanniensis* presacral or posterior trunk vertebra, but in contrast to clear hexagonal outline. Also for the ichthyosaur from Lahnewiesgraben can be assumed that this was a large animal with a body length of more than 20 meters.

Table 1: Measurements and ratios of the trunk vertebra.

L	H	W	H/L	W/L
7.8	21.0	18.5	2.7	2.4

Epibiontic colonization of the vertebra

The surface of the vertebra shows a number of attached bivalve shells (Fig. 4). One intervertebral surface as well as side faces of the centrum show about 25 specimen of the fixosessile, cemented *Placunopsis alpina* (Winkler, 1859) with shell heights not exceeding 1 cm. In addition, about 150 small specimen of the epibyssate *Rhaetavicula contorta* (Portlock, 1843) with maximum shell heights of 5 mm are attached. Specimens of both bivalve species are commonly articulated and are here considered as an autochthonous association. In contrast, two valves of the shallow infaunal *Myophoriopsis isoceles* (Stoppani, 1857) which are also attached to the vertebra are clearly par-autochthonous. Attached benthos of the other intervertebral surface was removed during preparation. The observed bivalve community is typical for the Hochalm Member (Mb) of the Lower Kössen Formation.

Discussion

The vertebral body size and proportions of the here presented specimen are comparable to *Sbonisaurus sikanniensis* presacral or posterior trunk vertebra. It is a very large ichthyosaur with a length of more than 20 meters. The cluster belongs to the Lahnewiesgraben specimen, and shows the same type of vertebra in the proportions as the two corresponding of *Sbonisaurus sikanniensis*. On the other hand, it clearly differs in its shape.

The low diverse, small-sized bivalve epibiontic association suggests that the vertebra surface was exposed to the water column for about some years prior to final embedding. During that time, the vertebra constituted a hard substrate for benthic colonizers on the seafloor, similar to present-day whale vertebra in shelf and deep-sea environments (Smith & Baco 2003).

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