First ichthyosaur remains from Denmark within glacial erratics

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Ichthyosaurs were widespread and diverse across Europe from the Triassic to the beginning of the late Cretaceous. However, they are relatively rare within Scandinavia, with specimens only known from Arctic Norway. In Denmark, plesiosaur fossils are known from the Jurassic of the island of Bornholm, but no ichthyosaur remains have ever been published either *in situ* or *ex situ*. Here we report, for the first time, an ichthyosaur vertebra found in a loose block on the shore at Lodbjerg Klint in western Jylland, and a second block containing ribs from an indeterminate marine reptile, most likely a plesiosaur. The vertebra can be identified as originating from the anterior portion of the tail in a thunniform ichthyosaur and shows similarity to several Jurassic taxa including *Ichthyosaurus communis, Eurhinosaurus longirostris, Temnodontosaurus trigonodon* and *Ophthalmosaurus,* although an exact determination is not possible. The most prolific sites for ichthyosaurs in the neighbouring countries, in the UK and Germany, are ruled out as a source due to long distance, and lack of glacial transport from these directions. We postulate the origin of the specimen is from Jurassic outcrops within the Skagerrak–North Sea region, transported by south and south-westerly flow of Pleistocene glaciers.

Keywords: glacial transport, ichthyosaur, marine reptile, Jurassic, vertebra, Pleistocene

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Ichthyosaurs were secondarily aquatic vertebrates with a global distribution from the Early Triassic (Kear *et al.* 2023) to the early Late Cretaceous (Bardet 1992; Fischer *et al.* 2016). Fossil remains of ichthyosaurs have been collected and studied throughout Europe for centuries, with Early-Middle Jurassic taxa being the most frequently found (e.g. Home 1818; Godefroit 1994; McGowan & Motani 2003; Roberts *et al.* 2014; Fischer *et al.* 2016; Moon & Kirton 2016; Moon 2017; Moon & Kirton 2018; Delsett *et al.* 2019; Zverkov & Prilepskaya 2019). Preservation type varies from disarticulated, single bones to complete and flattened or three-dimensional specimens, and they are usually excavated from sedimentary layers. However, until now, no ichthyosaur remains have been reported from Denmark.

The west coast of Jylland is well-known for glacially deposited fossil material (Myrvold *et al.* 2018; Cotton 2025) including a number of specimens within the Danekræ collection of the Natural History Museum Denmark. The majority of these specimens are collected from Esbjerg harbour or from Hanstholm, having been dredged from Jyske Rev, and range in age from Ordovician to Miocene, with Miocene specimens being the most common, and Mesozoic material being comparatively rarer. Skeat & Madsen (1898) investigated Danish boulders from the Jurassic and Cretaceous describing a molluscan fauna within numerous blocks, but with no mention of vertebrate fossils. These blocks were thought to originate from Skagerrak, from where they were glacially transported in the Pleistocene (Forchhammer 1863; Noe-Nygaard 1967; Sjørring 1989). However, little work on Jurassic erratics in Denmark has been carried out since. Jurassic boulders with invertebrate and plant fossils were found and studied more recently, albeit from much farther north in the Sortland region of northern Norway (Fürsich & Thomsen 2005), again with no vertebrate remains. The closest record of large vertebrate fossils in glacially transported material are plesiosaurid remains within glacial erratics within northern Germany and on the eastern side of Denmark, with a probable Baltic origin (Sachs *et al.* 2016).

Here we describe an ichthyosaur vertebral centrum, which was found as a loose block at Lodbjerg

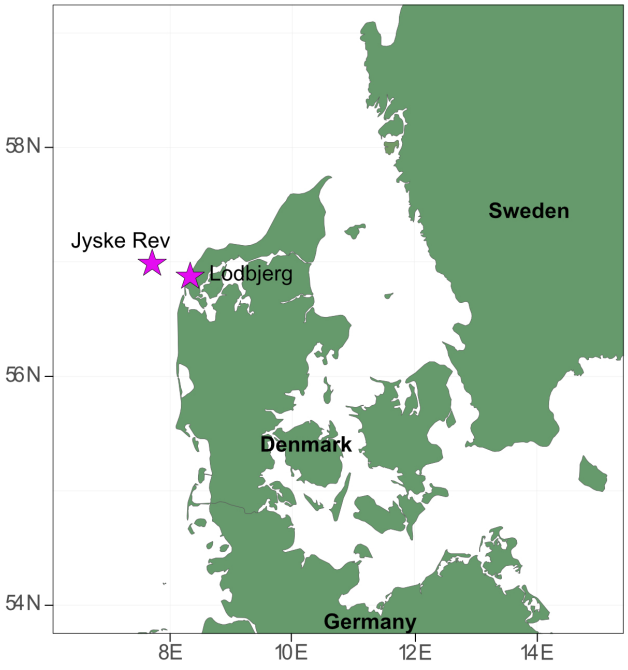


Fig. 1. Map showing location of Lodbjerg Klint, on the eastern coast of Jylland. Jyske Rev, a well-known offshore source area for fossiliferous glacial erratics is also marked.

Klint in Thy from the northern part of the west coast of Jylland and document rib fossils found in a second block at the same site. Both specimens are housed within the Danekræ collections of the Natural History Museum Denmark. Although the source rocks of the specimens are not certain, we discuss potential regions for their origin. The rarity of ichthyosaur remains in the Scandinavian region, and complete lack of specimens from southern Norway, Sweden and Denmark, means that any identifiable ichthyosaur remains from the region – even if not *in situ*, are valuable. More knowledge about disarticulated vertebral centra are also of general interest, as they are the most common ichthyosaur fossils found by the public and held in museum collections.

Material and methods

The ichthyosaur vertebra was found in a loose block on the beach, south of Lodbjerg Fyr, Thisted municipality, on the northwest coast of Jylland at approximately 56.818 °N, 8.249 °E (Fig. 1.). It was found by collector Christian Bach Hansen in 2025 and submitted to the Natural History Museum Denmark (NHMD) where it became part of the Danekræ collection in 2026, with specimen number NHMD002041604/DK 1348. Danekræ are Danish geological specimens found by collectors and avocational palaeontologists, which are deemed to have scientific or exhibitional importance. The specimen was prepared prior to submission to NHMD and very little matrix remains. The remaining matrix is visible in the center of the centrum and consists of a pale blue-grey micritic limestone, with some possible shell fragments visible.

A block containing marine reptile ribs was also collected by Christian B. Hansen from the same locality, and approved as Danekræ in 2018, specimen number NHMD00625522/DK 1006. The ribs are also within a pale blue-grey micritic limestone and were prepared by the finder.

Both specimens were photographed using a Nikon Zf camera set-up with Helicon pro software at the collections storage facility of NHMD and measured using digital calipers. Small amounts of the matrix were removed using a microdrill and prepared as smear slides for nannofossil biostratigraphy analysis. Unfortunately, samples were barren and no dating of the matrix was possible.

Results

DK 1006 – marine reptile rib fragments

The specimen consists of eight disarticulate rib fragments that vary in length from three to fifteen centimetres (Fig. 2), with a subcircular to oval cross-section up to a maximum two centimetres in maximum diameter. Some of the fragments show clear pyritisation. The microanatomy visible in some of the cross-sections shows a medullary area that is more cancellous than the somewhat compacted outer portion. As they are incomplete and disarticulated, it is not possible to know with certainty whether the rib fossils belong to a plesiosaur or an ichthyosaur. Based on their robustness, size and oval cross-section, a plesiosaur origin is seen as most likely (e.g. Pereyra *et al.* 2025), however ichthyosaurs cannot be ruled out, as similar microanatomical features can be seen in Jurassic ichthyosaurs, and cross-section varies along the rib length (Krøglid *et al.* 2026).

DK 1348 – Ichthyosaurian vertebra

The specimen consists of a single, isolated vertebral centrum (Fig. 3) that can be confidently identified as belonging to Ichthyosauria, due to the diagnostic traits of deeply concave articular faces, the subcircular outline, and the short centrum length compared to height and width (McGowan & Motani 2003, Moon 2017).

Preservation

No associated skeletal elements are preserved, indicating that the vertebra was isolated prior to final

deposition and most likely transported away from its original locality. Surface preservation shows a combination of strong abrasion, differential rounding, and absence of matrix, although the latter is likely largely due to preparation. The outer margins have irregular fracture surfaces indicating mechanical removal of portions of the cortical bone, exposing some internal canals and porous bone, especially affecting one of the articular surfaces (Fig. 3b).

Morphology

The centrum has a height (dorsoventral, CH) of 84.4 mm and a width (mediolateral, CW) of 93.0 mm, whereas centrum length (anteroposterior, CL) is 29.6 mm. The centrum is amphicoelous, with deeply excavated articular faces. In articular view, the centrum is rounded, with dorsally directed articulations for the neural arch, and a depression at the midpoint of the ventral margin (Fig. 3a). The peripheral margin is robust and thickened. The dorsal surface preserves the neural canal as a broad, concave area between the raised facets for the neural arch (Fig. 3a, b, e). The arch itself, which is never fused to the centra in ichthyosaurs, is absent. The rib facets are situated in the ventralmost portion of the lateral surface, and are raised and confluent with one of the articular surfaces (Fig. 3a, b, c, d). There is one facet on each side (synapophysis). The ventral surface bears a shallow anteroposteriorly directed groove and one large canal opening (Fig. 3f). Chevron (haemal arch) facets are found in the anterior portion of the caudal series in some ichthyosaurs (McGowan & Motani 2003; Fischer *et al.* 2011), but are not present here.

Discussion

Taxonomy of the ichthyosaur vertebra

Ichthyosaur vertebral centra vary in morphology and dimensions through the column. The morphology of this specimen indicates an anterior to mid-caudal vertebra (preflexural, see Holm *et al.* 2022 for definitions) as the single rib facet is situated at the ventral most part of the lateral surface (Buchholtz 2001; McGowan & Motani 2003; Holm *et al.* 2022). The centrum is also relatively anteroposteriorly short compared to typical values for more anterior centra, and wider than tall especially in the ventral half, which is typical for anterior caudal centra (Buchholtz 2001; McGowan & Motani 2003; Fischer *et al.* 2011). The height/length ratio of the centrum is 0.35, similar to the minimum value from this part of the vertebral column in Lower Jurassic *Ichthyosaurus communis* and *Eurhinosaurus longirostris* specimens, somewhat lower than in *Stenopterygius quadriscissus*, and similar to average tail centra in *Temnodontosaurus trigonodon* (Buchholtz 2001). The relation between H/L and H/W also corresponds well to those of anterior-mid caudal centra in Middle-Late Jurassic *Ophthalmosaurus* and Early Cretaceous *Keilhauia nui* and is somewhat relatively anteroposteriorly shorter than the Juras-

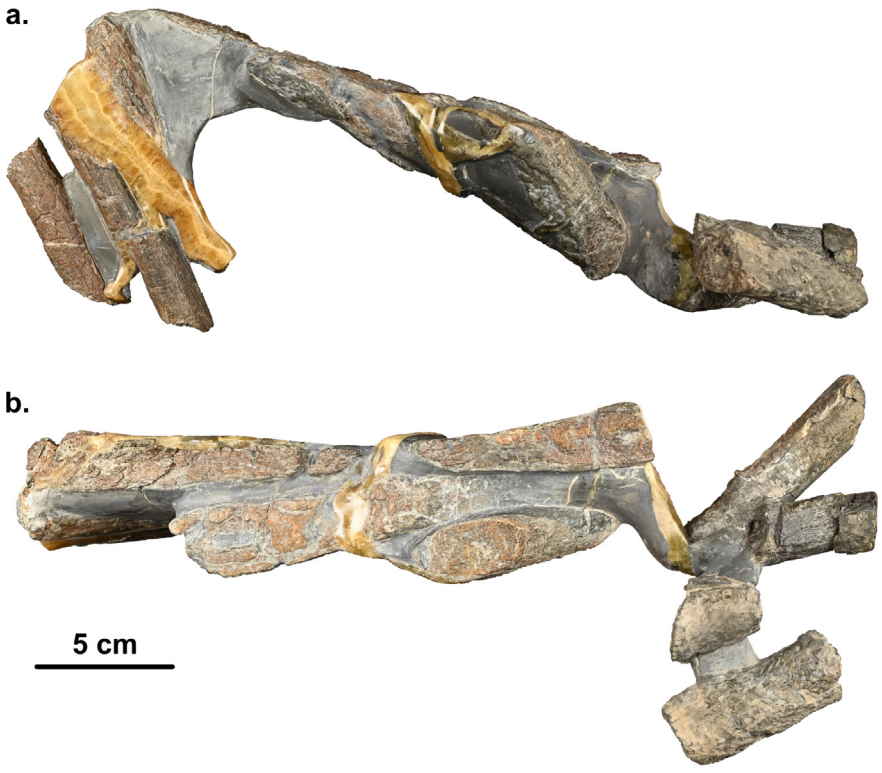


Fig. 2. DK1006 rib fragments of a marine reptile, likely a plesiosaur, prepared out of blue grey limestone, with calcite veins. Shown in a) side view and b) from above, with cross sections of some ribs visible.

sic–Cretaceous ophthalmosaurids *Ophthalmosaurus natans*, *Platypterygius americanus* and *Sveltonectes insolitus* (Holm *et al.* 2022).

Ichthyosaur vertebrae are relatively simple skeletal elements and are commonly not useful for taxonomic assignment (McGowan & Motani 2003; Vakil *et al.* 2020; Holm *et al.* 2022). Some Early Triassic ichthyopterygians have somewhat anteroposteriorly elongated centra, whereas all in-group Ichthyosauria have short centra compared to height and width. The anatomy of the Lodbjerg Klint specimen resembles those of thunniform ichthyosaurs from the Jurassic. Thus, the centrum is certainly from the anterior portion of the tail in a thunniform ichthyosaur, with a strong resemblance to Jurassic taxa in terms of dimensions. All Cretaceous ichthyosaurs, except one species, were also thunniform taxa in the Ophthalmosauridae family together with most Late Jurassic taxa, and based on morphology alone, Cretaceous taxa cannot be ruled out.

Centra from the anterior caudal portion of the vertebral column are usually the largest centra in the column (McGowan & Motani 2003) and the size of the Lodbjerg Klint specimen suggests a relatively large-bodied ichthyosaur in a Jurassic context. The absolute dimensions of this centrum are larger than those of *Ichthyosaurus communis*, *Stenopterygius quadriscissus*, *Eurhiniosaurus longirostris* and *Suevoleviathan disinteger* specimens in a previous study, all with a body length of up to three meters, however smaller than the enormous *Temnodontosaurus trigonodon*, reaching up to ten meters in total body length (Buchholtz 2001).

Origin of the specimens

The bedrock geology of the Lodbjerg Klint region consists of Miocene sediments (Rasmussen *et al.* 2010), with Cretaceous sediments to the north (Asch 2003). As the vertebra and the ribs were found as loose blocks on the beach they have been transported from elsewhere. Within Denmark, the only known large marine reptile fossils consist of plesiosaur remains found within the Jurassic sediments on Bornholm (Smith 2008; Kinzella *et al.* 2025) and mosasaur

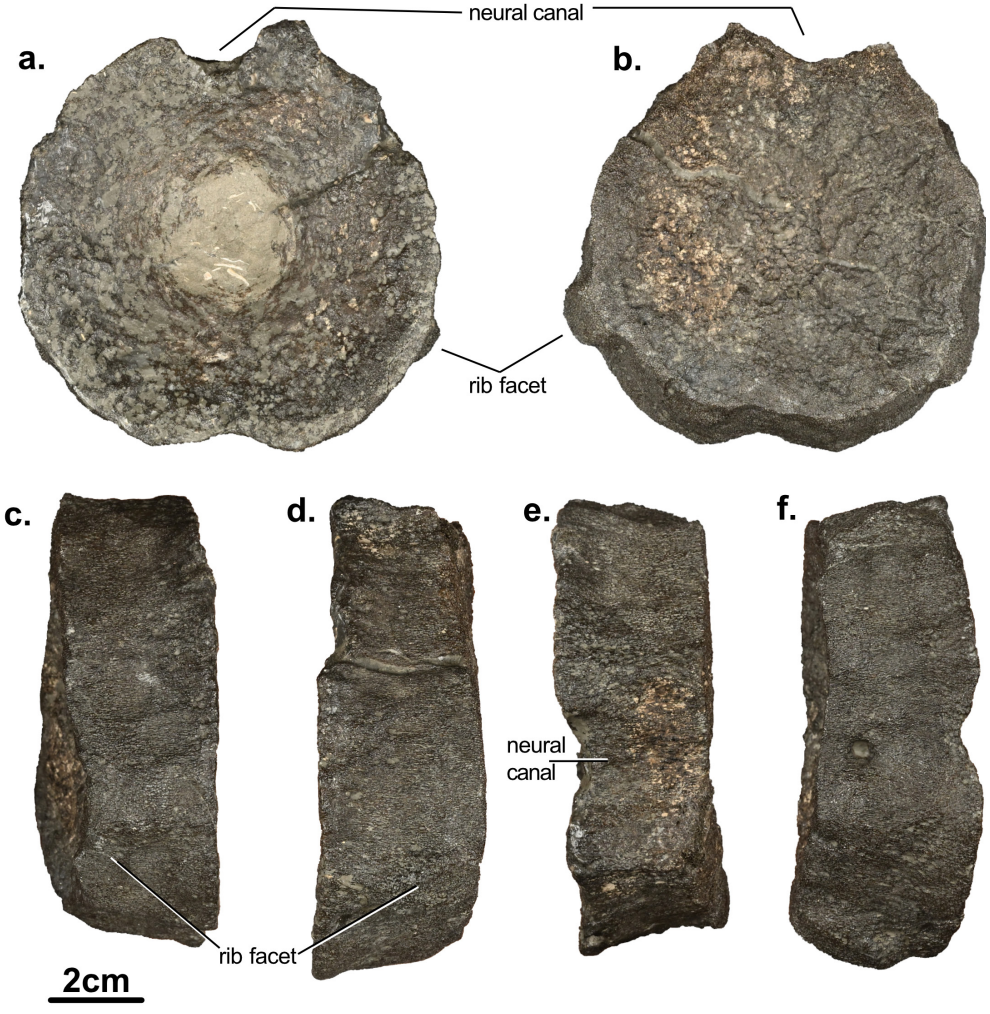


Fig. 3. Vertebra DK1348 a) and b) articular views with anterior towards the top, with b) being partly eroded; c) and d) lateral sides, note the single rib facet; e) anterior surface; f) ventral surface.

remains within the Cretaceous chalk (Lindgren & Jagt 2005; Voiculescu-Holvad *et al.* 2026), which are lithologically incompatible to be a source for the blocks discussed here. Ichthyosaur finds are also rare in several neighbouring countries.

Jurassic sediments outcropping onshore in Sweden are largely shallow marine-fluvial facies (Vajda & Wigforss-Lange 2009) and no Swedish ichthyosaurs have been reported, likewise no ichthyosaurs are known from the Netherlands. Norwegian ichthyosaur fossils are from Svalbard, except a single specimen found at Andøya in Northern Norway (Ørvig 1953; Druckenmiller *et al.* 2012; Delsett *et al.* 2016). Ichthyosaurs are well known and numerous from Germany (e.g. Maxwell 2012) and the United Kingdom (Moon 2017; Lomax *et al.* 2017), and specimens also occur in Belgium and Luxembourg (Godefroit 1994). However, localities in Germany, Luxembourg and Belgium are relatively far south and inland, which rules out both transport by modern coastal erosion and by Pleistocene glacial redeposition. The dark colouration of the bone, presence of pyrite in the rib fossils and pale blueish grey of the matrix does resemble the preservation and lithology of the Jurassic of the UK. These rocks crop out on both the south and east coasts, but only extend a short way offshore (Asch 2003) and would require over 600 km of transportation across the North Sea to reach the west coast of Jylland. There are also no known glacial thrust vectors, which could move material in this direction. The glaciers depositing material in northern and offshore Jylland come from the north and northeast (Houmark-Nielsen 2007, 2011).

A more likely solution is, therefore, that the blocks were glacially transported from Jurassic sediments in the Skagerrak- North Sea area. A similar origin was also previously concluded by Sjørring (1986) for other blocks found in the region within morain clays containing Upper Jurassic invertebrate fossils, and showing striations on the underside. We also note within the NHMD invertebrate collections there are a number of blocks with similar limestone matrix lithology containing bivalves and ammonites of Jurassic age (Kimmeridgian), which were found around the Hirtshals and Lodbjerg areas, although, to our knowledge, no work has been published on this material. Lower to middle Jurassic sandstones, and Upper Jurassic claystone can be found beneath Quaternary sediments in a band around the southern and western coast of Norway (Asch 2003). These sediments would have been directly within the path of glaciers traveling southwards toward Denmark (Houmark-Nielsen 2007, 2011), suggesting they could have been a source. Additionally, the northern and offshore Jylland areas are known to have experienced extensive deformation by salt tectonics, which heavily impacted the structural geology of the Fur formation (Pedersen 2000). This process is also suspected to have created topographic highs offshore (K. Dybkjær, pers. comm.) and may have led to further Jurassic exposure.

Conclusion

Despite being a single vertebra found as a redeposited block, the presence of this specimen as the first known ichthyosaur deposit from a glacial erratic in the region is scientifically valuable. It is possible to identify the specimen as an anterior caudal vertebral centrum of a relatively large Jurassic ichthyosaur, highlighting that including isolated vertebrae in studies can still provide valuable information. Particularly in regions where ichthyosaurs are otherwise rare or absent, such as in southern Scandinavia. This find therefore indicates that ichthyosaurs did occur in the region, and suggests that ichthyosaur bearing Jurassic sediments may be present in the North Sea-Skagerrak region. Rib fossils found close to the ichthyosaur centrum likely originate from a plesiosaur, but as they are disarticulated, this is not certain. For Jurassic marine reptile fossils found in loose blocks on the Danish west coast, the most likely origin is glacial erratics from Skagerrak-North Sea outcrops of this age, as transport from onshore localities is unlikely due to long distances and lack of glacial transport in these directions.

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