The youngest occurrence of ichthyosaur embryos in the UK: A new specimen from the Early Jurassic (Toarcian) of Yorkshire

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Abstract: The remains of between six and eight ichthyosaur embryos, still situated within a fragment of the rib-cage of the parent animal, are described. Each is represented by a string of vertebral centra, some with associated ribs. Other skeletal elements, including possible skull material, are represented only by isolated bones, none identifiable with certainty. The small limestone boulder in which the ichthyosaur specimens are preserved was collected from the beach at Sandsend, near Whitby, North Yorkshire, and derives from the Whitby Mudstone Formation (Hildoceras bifrons Ammonite Biozone) of the Toarcian Stage of the Lower Jurassic. The specimen cannot be identified beyond Ichthyosauria indet. However, it represents the geologically-youngest occurrence of ichthyosaur embryos thus far recorded from the UK and the first such occurrence to be reported from Yorkshire.

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The existence of viviparity in ichthyosaurs was first reported by Chaning Pearce (1846), who noted the presence of an embryo within the pelvic region of a specimen of Ichthyosaurus from the Early Jurassic (probably Hettangian) Blue Lias Formation of Somerset. Woodward (1906) provided a further account of this specimen. Small ichthyosaur skeletons found inside larger individuals had previously been described (e.g. Jäger 1824), but only after Chaning Pearce (1846) had published his short paper did they become regarded as embryos and thus further evidence for viviparity. The argument, however, for cannibalism rather than embryos continued to persist until a detailed study was provided by Böttcher (1990). Seeley (1880) discussed the occurrence of small ichthyosaur skeletons associated with two further ichthyosaur specimens from the Early Jurassic of Britain and a number from the Early Jurassic of Germany. Noting that their positions within the adult skeletons did not suggest the small skeletons were stomach contents, Seeley came to the conclusion that they represented embryos. One of the two British specimens described by Seeley cannot presently be located. Over a century later, an important paper by Deeming et al. (1993) included a detailed description of what they concluded to be a ‘mid-term’ embryo associated with an Early Jurassic specimen of Ichthyosaurus from the Hettangian of Kilve in Somerset. They concluded that, not only were the ichthyosaur genera Ichthyosaurus and Stenopterygius viviparous (embryo-bearing specimens of the latter being well-known from the Toarcian of Germany), but that ichthyosaur young were typically born tail-first – like those of modern cetaceans – and this was thought to be an aquatic adaptation to minimize the possibility of their drowning during parturition. Lomax & Massare (2012) provided a further account of one of the British ichthyosaur specimens discussed by Seeley (1880, pl. 1, fig. 1). They identified the specimen as an example of Leptonecites from either the Late Triassic (Rhaetian) or most likely the Early Jurassic (Hettangian-Sinemurian) of Street, Somerset and confirmed its embryo-bearing status. More recently, Lomax & Sachs (2017) described the largest known specimen of Ichthyosaurus somersetensis from the Early Jurassic (Hettangian) of England, which also contained an embryo.

Outside the UK, localities from which ichthyosaur embryos have been reported are few in number, but widespread in space and time. The best-known and most productive horizon and locality is the Early Jurassic (Toarcian) Posidonienschiefer of Holzmaden and the surrounding area in southern Germany, which has yielded over one hundred embryo-bearing examples of Stenopterygius (e.g. McGowan 1979). Embryos have also been recorded in the Middle Triassic (Anisian) genera Mixosaurus from Switzerland (Brinkmann 1996) and Besanosaurus from Italy (Dal Sasso & Pinna 1996). Camp (1980, p. 144) mentioned ‘embryonic material’ within a Shonisaurus from the Late Triassic (Carnian) of Nevada, USA, although he did not describe or figure it. An ichthyosaur embryo was found in the stomach contents of a plesiosaur from the Late Jurassic Sundance Formation (Oxfordian) of Wyoming, USA (O’Keefe et al. 2009). More recently, Stinnesbeck et al. (2014) described an Early Cretaceous (Valanginian-Hauterivian) ichthyosaur graveyard from southern Chile, which contained several elpithalamosaurid ichthyosaur embryos, including some inside a complete skeleton of Platypertugius haultali. The geologically-youngest ichthyosaur embryos reported to date have been described by Maxwell & Caldwell (2003) in a skeleton of Maiaspondylus from the Albian (Early Cretaceous) of the Loon River Formation in the Northwest Territories of Canada and by Kear & Zammitt (2014) in a specimen of Platypertugius australis from the late Albian of Australia.
Motani et al. (2014) recently described three embryos in a specimen of the Early Triassic ichthyopterygian *Chaohusaurus* from China. Interestingly, these embryos appear to exhibit head-first parturition, which may suggest that the tail-first procedure later seen in ichthyosaurs *sensu stricto* represents a fuller adaptation to aquatic life, although more specimens are required to confirm this. The presence of viviparity in an early ichthyopterygian also suggests, as Motani et al. (2014) pointed out, that live birth may have been characteristic of the terrestrial ancestors of ichthyosaurs.

It can thus be seen that embryos have been described, not only in an Early Triassic ichthyopterygian, but in eight genera of ichthyosaurs, ranging from the Middle Triassic to the upper part of the Early Cretaceous. In the UK, embryos have been reported in five ichthyosaur specimens, the four currently-identifiable examples of these being referable to two genera, *Ichthyosaurus* and *Leptonectes*. However, in no instance do these rare British examples of embryo-bearing ichthyosaurs post-date the Sinemurian stage of the Early Jurassic; indeed the genera *Ichthyosaurus* and *Leptonectes* have not been recorded later than the Pliensbachian (Maisch & Reisdorf 2006; Lomax & Massare 2015).

**Description**

Yorkshire Museum specimen YORYM: 2016.316 consists of the greater part of an externally-weathered boulder of grey, calcite-septarian, limestone (Fig. 1). It was discovered *ex situ* on the beach at Sandsend, near Whitby, and derives from the Whitby Mudstone Formation, *Hildoceras bifrons* Ammonite Biozone, Toarcian Stage, Lower Jurassic. The age was further confirmed by the identification of bivalves (*Biozone*). After collection by Mark Hawkes in 2013, it was acquired by fossil collector Martin Rigby. Since Mr Hawkes considered the presence of the calcite septa to preclude normal collection, Mr Rigby consulted one of the two present authors (DRL), who duly confirmed his suspicion.

The two halves of YORYM: 2016.316 are here referred to as blocks A and B (Fig. 1). These correspond to the two pieces accessioned as YORYM: 2016.316a and YORYM: 2016.316b respectively.

The shafts of at least seven ribs of an adult ichthyosaur traverse the specimen; they have been sectioned longitudinally in such a fashion that lengths of all seven appear on the polished surface of Block B and lengths of five on that of Block A (Fig. 1A and B). The truncated proximal ends of these ribs may be seen in transverse section on the edge of Block B. Although these display a distinct ‘dumb-bell’ shape, indicating that the shafts were longitudinally-grooved, this does not convey any useful information regarding the taxonomic identity of the gravid female ichthyosaur.

The polished surfaces of blocks A and B reveal a wealth of detail, much of it difficult to interpret because so many visible structures have clearly been sectioned in planes other than the precisely horizontal, transverse or sagittal. In addition, portions of the specimen are highly calcified, which also makes interpretation and description difficult (Figs 1 and 2). However, the most important structures that are clearly identifiable are six (or possibly seven) distinct lengths of vertebral column pertaining to ichthyosaur embryos. Some are visible only on the surface of Block A or that of Block B; others have been so sectioned that they appear on both blocks (Fig. 1). In places, on both blocks, embryonic ribs may be discerned, some still apparently in articulation with their vertebrae (Figs 1, 2E and 3C). Perhaps the most notable feature common to many of the centra in these ‘strings’ of vertebrae is that, where the centra are well-preserved and have been sectioned at the relevant levels, it can be seen that their notochordal foramina are still open (Figs 2 and 3), a very clear indication of their immaturity. A possible opening for the notochord was also reported in a neonate specimen of *Ichthyosaurus communis* (Lomax et al. 2017). Furthermore, the vertebrae are highly cancellous (Figs 2 and 3). It is also clear, due to the sectioning, that the centra are deeply amphicoelous in the manner characteristic of ichthyosaurs.

For purposes (and ease) of description, we have numbered these lengths of vertebral column in sequence (Fig. 1).

Column 1 is represented on both blocks A and B, although it is best preserved on B (Figs 1, 2A, B and 3A–C). It is comprised of 38 centra, with visible diameters ranging from 5.6 mm to 5.8 mm, and measures 100 mm in overall length. In addition, at least six extremely delicate ribs, the longest being under 20 mm in length, are preserved in visible association with Column 1 (Fig. 3C).

Column 2 is mostly apparent on Block A, although a couple of centra may be present on Block B (Figs 1 and 2A, C). It is made up of 27 centra, having a maximum diameter of 6.4 mm and measures 80 mm in overall length. This length includes a gap that contains a fragmentary centrum and room for at least two further centra. The gap is occupied (in part) by rib fragments (Figs 1A and 2A).

Column 3 is visible only on Block A (Figs 1A and 2D). If allowance is made for a gap that would suffice to contain four centra, it would originally have comprised 14 centra with a maximum visible diameter of 5.5 mm. Two of the ten centra that are present are lying at an angle of 90° to the others. This has a preserved length of 33 mm.

Column 4 is also present only on Block A (Figs 1A and 2E). It is the least well-preserved of the columns present on Block A and is divided, by a rib of the adult, into two lengths, with a combined total of 48 mm (Fig. 2E). An accurate total count is impossible, although at least seven centra are present in one of the lengths. The centrum having the greatest visible diameter measures 6.7 mm. Of several isolated centra, lying at 90° to those of Column 4, the largest appears to be 6.8 mm in diameter; the opening for the notochord is clearly visible in one of the centra (Fig. 2E).

Column 5 is represented only on Block B (Figs 1B and 3D). It comprises 14 visible centra, although one is partially hidden, the largest of which has a diameter of 5.7 mm; this column has an overall length of 34 mm. Several fragmentary ribs are also associated with this column (Figs 1B and 3D).

Columns 6 and (?)7 is/are poorly-preserved. They form an inverted V-shaped feature on Block B only (Figs 1B and 3E), although some poorly preserved centra of column 6 may be present on Block A (Fig. 1A). Due to the preservation, it is unclear whether the two columns represent one or two individuals, although probably the latter. That labelled as
Fig. 1. Studied specimen: YORYM: 2016.316. A cut and polished boulder containing between six and eight ichthyosaur embryos, collected from Sandsend, near Whitby, Yorkshire. (A) Block A, showing ribs of the adult, at least five (or six) embryo vertebral columns, isolated centra, ribs and more. (B) Block B, showing ribs of the adult, at least four and perhaps five independent embryo vertebral columns, and ribs. (A1 and B1) Illustrations of the identifiable sections of embryos. Note that the number of centra illustrated for columns 4 and 6 are estimates. 1–7, indicates embryo vertebral column; ?, articulated vertebral centra that cannot be assigned to an identifiable column; ?m, possible mandible element (?surangular). Scale bar equals 100 mm.
Fig. 2. Close-ups of Block A, YORYM: 2016.316a, showing ichthyosaur embryos. ‘Column’ refers to the individual embryo vertebral column described in the paper. (A) Column 1 (lower), column 2 (upper). Note the fragmentary ribs lying in a gap (to the left; arrows), separating portions of column 2. (B) Extension of column 1 with isolated centrum showing an opening for the notochord (arrow). (C) Close-up of column 2, showing variation due either to differences in centrum ossification or to the levels at which the centra have been sectioned. (D) Column 3 with a gap separating the centra. (E) The poorly preserved column 4, which is divided by a rib from the adult. Note the fragmentary ribs of an embryo, probably from column 4 or alternatively from an eighth embryo (two arrows indicate at least 9 delicate ribs), and an isolated centrum with an opening for the notochord. Scale bars equal 10 mm.
Column 6 measures 38.8 mm in overall length; the putative ‘Column 7’ has a length of 30.3 mm, making allowance for a gap in the column.

In the centre of Block A, lying between vertebral ‘columns’ 2 and 4, but nearer to the latter, is a compact and confused mass of ribs (Figs 1A and 2E). These should possibly be associated with Column 4 or, alternatively, may be seen as representing a further (eighth) ichthyosaur embryo lying at an angle widely different to those which have been described from their lengths of vertebral column. Two features of these tiny ribs are of particular interest. First, their shafts can be seen, even at this stage of their development, to bear longitudinal grooves resembling those commonly seen on the rib-shafts of adult ichthyosaurs. In addition to this, a thin, incomplete film of black mineral(s) covers some of the ribs. It is possible that this may represent degraded soft tissues, but further study is required. Similar material is also present in other areas of both blocks. As noted earlier, other bones are intermingled within both blocks, but it is near impossible to identify them. However, one bone might be a portion of a mandible (surangular) (Fig. 1).

Discussion

With respect to the studied specimen, we have also considered the potential counter-argument that the embryos
may actually be ingested prey, such as neonates or aborted embryos from another individual, thus meaning the specimen does not represent a gravid female. Due to the very incomplete nature of the adult specimen, it is impossible to argue their embryonic status merely from their positions within the body of the adult. However, we consider it inherently unlikely that an adult ichthyosaur would consume, at about the same time, at least six similarly-sized neonates (or, more likely, aborted embryos, based on their size and preservation) of its own or a distinct species – or of both. Other reasons for preferring to interpret these tiny ichthyosaurs as embryos include:

1. The absence of any signs of physical damage to the vertebral columns and ribs of the specimens.
2. The absence of any signs of chemical corrosion, such as that caused by digestive secretions.
3. The total absence, in association with the tiny ichthyosaur skeletons, of any plausible stomach contents, such as the cephalopod hooklets so commonly and characteristically seen in the stomach regions of many ichthyosaur skeletons, especially those of Early Jurassic age (e.g. Pollard 1968).

While it might be argued that six (or eight) embryos is a large number to be borne by an individual ichthyosaur, it should be noted that McGowan (1979) mentioned a specimen with four or five embryos, whereas Böttcher (1990) recorded between one and eleven embryos within the body cavity of ichthyosaurs. Finally, we would note that, not only do the specimens described here represent the first ichthyosaur embryos reported from the Lower Jurassic rocks of Yorkshire, but they are also the only undoubted reptile embryos of any kind so far described from these rocks, despite their historical and present richness in the fossils of marine crocodylomorphs, plesiosaurs and ichthyosaurs (e.g. Benton & Taylor 1984). Seeley (1887) described a group of supposed plesiosaur embryos (or juveniles) from the ‘Lias of Whitby’ but these were reinterpreted as crustacean burrows (Thalassinoides) around a concretion (Thulborn 1982). In addition, Melmore (1931) described a possible teleosaur (crocodylomorph) egg. This, along with the putative plesiosaur embryos, was reviewed by Benton & Taylor (1984), who suggested that both specimens were probably concretions and wholly inorganic in origin.

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Correction notice: After the online publication of this paper, it came to light that the original collector of the specimen was Mr Mark Hawkes of Edwinstowe, Nottinghamshire. The location of discovery has been updated to Sandsend (to the north of Whitby) rather than Saltwick Bay, which lies immediately south of the town. The year that the specimen was collected has been updated to 2013. This minor revision of the find locality makes no difference to the stratigraphic data relating to the specimen.

References
Channing Pearce, J. 1846. Notice of what appears to be the embryo of an Ichthyosaurus in the pelvic cavity of Ichthyosaurus communis (communis’). Annals & Magazine of Natural History (First Series), 17, 44–46.