# Teleostei (bony fish) from the Paleocene of the Norwegian North Sea Drillings

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Two Upper Paleocene species of 'salmoniform' fishes from Norwegian North Sea drillings are identified as the two most common species of the ash-bearing Mo-clay Formation, DK. The same two species are found in Forties field, UK. Summary descriptions indicate that one is a primitive argentinoid, the other probably an osmeroid.

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Teleostean skeletons have been discovered in two sectors of the Norwegian North Sea where cores have been recovered from part of the Lower Tertiary. The sectors are 25/10 in the Balder field area (Frodesen et al. 1981, Myhre 1976) and further to the north 25/4 in the Heimdal field (Frodesen 1981). These fishes were mentioned by Bonde (1979). The locations are in well 25/10-2 (operated by Esso) in core no. 2 (Frodesen et al. 1981, fig. 5) and in well 25/4-1 (operator Elf Norway) in core no. 1 (Frodesen 1981, p. 8).

Skeletons of two species have been identified from 25/10-2. Both were found in a dark grey, laminated silt/mudstone in the Sele Formation below the main volcanic ash series which is an important marker horizon, named the Balder Formation with type locality in well 25/11-1, only 10–20 km further eastwards (Deegan & Scull 1977). From well 16/1-1, about 30 km south of 25/10-2, a core with ash layers of the Balder Formation has been figured (Myhre 1977).

Well 25/10-2 is situated at the eastern rim of the Viking Trough, just west of the structural high called Vestlands ridge (see Bergsager 1980). 25/4-1 is also in the Viking Trough; the fish was here found in the upper part of the ash series in the Balder Formation in shale at a depth of 1938 m (Frodesen 1981, p. 8). It has been identified from a photograph as conspecific with the argentinoid described below.

The two fish skeletons in 25/10-2 were found at a depth of 6557 feet (the osmeroid) and between 6563 and 6566 feet (the argentinoid), that is about 2000 m. Being below the main ash series (= Balder F.) they belong in the Sele Formation, which also contains slightly tuffaceous sediments (Deegan & Scull 1977).

The age is Upper Paleocene, as the ash series in the North Sea (Jacqué & Thouvenin 1975). The equivalent ash series of the Mo-clay Formation is uppermost Paleocene (Hansen 1979), and is exclusively within the *A. hyperacanthum* Zone, that is NP9, as subsequently shown by Heilmann-Clausen (1981), both in disagreement with Thiede et al. (1980, p. 169).

The Mo-clay Formation (= Fur Formation, see Pedersen 1978) with a thickness of 50–60 m is composed of diatomite with a few horizons of limestone boulders (or layers) and an extensive series of nearly 200 ash layers (Bøggild 1918, Pedersen et al. 1975). A few thin stringers of laminated, dark silt/mudstones are found only in the lower third of the formation (Gry 1940), which contains only a few ash layers. Like the rest of the formation, the mudstones often contain fish bones and occasional complete skeletons. The bones may be preserved in these mudstones in much the same way as in the North Sea cores.

Underlying the Mo-clay Formation in NW-Jutland is a grey, non-calciferous clay (Dinesen et al. 1977), which, according to dinoflagellates, is also Upper Paleocene, NP9 (Hansen 1979). No macrofossils have been found in this clay. Deep tests in Jutland (Viborg 1 – cf. Thiede et al. (1980), and the more recent Harre well) indicate to Heilmann-Clausen (cf. 1980) that this laminated, dark clay is equivalent to the basal part of the Mo-clay Formation with very few ash layers, and that it corresponds to the lower part of NP9 (and

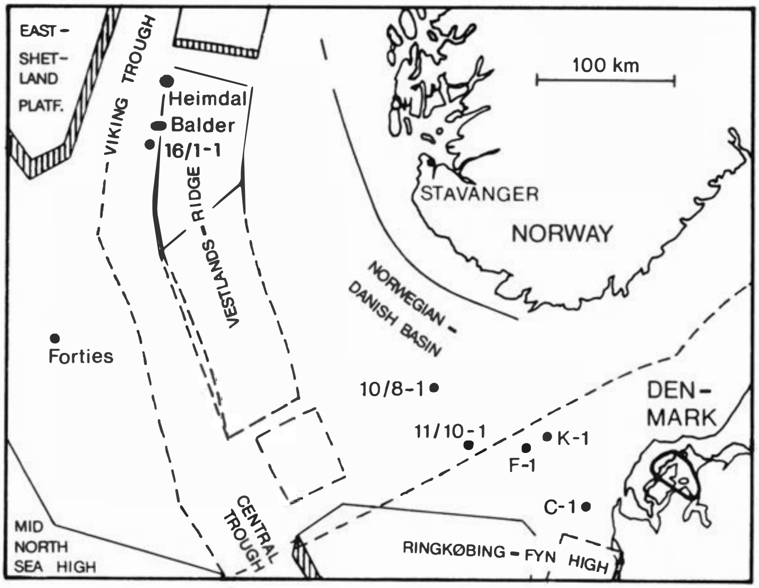


*Fig. 1.* Map of the North Sea with localities, well-sites, and structures mentioned in the text. (Egelund, based on maps in Bergsager (1980) and Rasmussen (1974, 1978)). Approximate extent of the 'Mo-clay area' indicated in North Jutland. The late Paleocene shore line probably was not far from the present west coast of Norway and was bending along the Fenno-Scanian border-zone through the northern tip of Jutland (cf. Bonde 1973, 1979).

may well be a lateral equivalent to the Sele F. in the North Sea – Heilmann-Clausen, pers. comm.).

## Paleo-oceanographic models

Two partly conflicting models of the sedimentological environment during deposition of the diatomite have recently been proposed. Bonde (1973, 1979) suggested that the diatomite was deposited very rapidly in an anoxic basin due to upwelling in an extended zone parallelling the Norwegian coast, the Mo-clay Formation being the southernmost part of this area.

Pedersen (1981 and unpublished thesis, Copenhagen 1978) suggests much slower sedimentation in a much smaller, local basin, which is periodically anoxic and is bounded by salt diapirs and gradually filled. It is therefore less anoxic during the last part of the infilling.

One sort of test of the two models could be provided by the North Sea drillings close to the Norwegian Coast (see Bonde 1979). So far the sediments of Balder Formation have been described as 'shale', also in the wells closest to land like 11/10-1 (Strass 1979). The distance from the 'paleo-coast' may still be too great, however, to provide a conclusive test of a coastal upwelling zone. (In the case of well 10/8-1 (Strass 1980), in a similar position, the sediment of the 'Balder F.' is sandstone, but as no tuffs are indicated in it, the identification of this formation as Balder F. must be considered dubious.) In 11/10-1 the Balder Formation contains few foraminifera and abundant diatoms, radiolaria and sponge spicules – 'similar assemblages have been found around the ash beds in many other wells' (Strass 1979, p. 9) and are not restricted to near-coastal waters. Species of the diatom genus, *Coscinodiscus,* are used as guide fossils in most of the North Sea area, where they occur in abundance around and in the ash series (e.g. Benda 1965, Jacqué & Thouvenin 1975, King 1981). It is not obvious that this relative richness in diatoms can be correlated to specific upwelling zones, unlike the true diatomite, the Mo-clay deposit. It should be noted, however, that although the sediments of the ash series in the Danish North Sea sector are called clay or claystone (Rasmussen 1974, 1978) in the three relevant wells west of Limfjorden – C–1, F–1, and K–1 – at least in C–1 the lower half of the 'Eocene' interval (481–505 m in Rasmussen 1974:26) contains basaltic ash, proper Mo-clay (diatomite), and 'cement stone' (limestone boulder) with diatoms (I. Bang pers. comm. 1979). Diatoms and fish remains are also found just below the tuffaceous layers at 511 m (Rasmussen 1974, p. 29). This western extension at least doubles the size of the Mo-clay 'basin' as known from inland exposures, but it is still within an area of salt diapirs (Rasmussen 1974, figs. 3–4), so it is not a crucial test.

## The fishes

The two species found in core 2 of 25/10-2 are the two most common ones in the Mo-clay Formation, with the small argentinoid being the most common macrofossil and accounting for more than 90% of the fishes.

The argentinoid reaches a total length of about 8.5 cm (7.5 cm, standard length). It is a slim, presumably pelagic plankton feeder which occurred in large schools. These small fishes and their juveniles were the main food for most of the other fishes, including the bigger osmeroid. The argentinoid is often found as stomach content of other fishes, e.g. scombrids (figs. in Christensen & Brock 1981, Breiner 1974). A remarkable case is a complete ca. 9 cm osmeroid with the argentinoid inside found at a depth of just over 2000 m in Forties field also in a dark laminated mudstone below the ash series (in unit III of Thomas et al. 1975).

The smaller osmeroid individuals found are about the same size as the largest argentinoids – ca. 8–9 cm. If the jaws and the anal fins cannot be clearly seen in such fishes, the two species may easily be confounded. Short descriptions follow with a few illustrations (detailed descriptions in unpublished theses by Bonde 1965 and Primdahl 1973 will be published elsewhere).

*The argentinoid* (identified as 'clupavid' by Bonde 1966), fig. 2–4. – Maximum total length about 8.5 cm, slim with rather uniform body height slightly above 1 cm, tapering a little behind the dorsal fin.

The skull with very little ossification of the ethmoid region. One huge supraorbital; frontals narrow in front with supraorbital sensory canal having a median pore and a parietal branch; parietals fairly large, meeting in midline. Opercular with characteristic slightly concave posterodorsal and posteroventral outline. Preopercular with long horizontal limb and bent through about 100°.

Jaws toothless with slim premaxilla and much expanded maxilla carrying only one supramaxilla, which is big with the anterior process pointing upwards at a characteristic angle. Lower jaw very high with a 'clupeiform', subtrapezoidal shape. The tongue has slim non-sutured ceratohyals without foramina and a large toothless plate carried by the basihyal (one or two teeth seen in a halfgrown specimen).

The vertebral column comprises c. 55 thin, subcylindrical centra of which 32 are abdominal and two are free ural centra. In a few specimens the first ural centrum seems fused to the first preural centrum ($pu^1$). The neural spine of the second preural centrum varies in length, from less than half to the entire length of the spine in front. Only two small epurals. Beginning over $pu^1$ a huge median lamina is fused to the dorsal

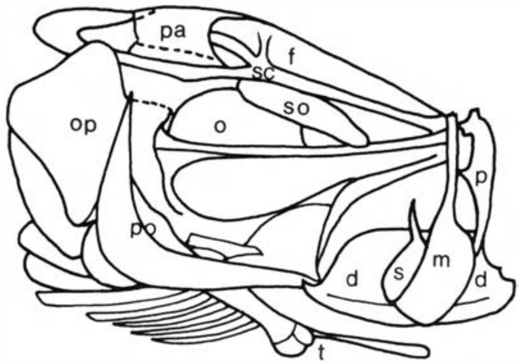

*Fig. 2.* Argentinoid, sketch outlining the skull bones, based on specimens from Mo-clay Formation, DK. Infra-orbitals excl. (Egelund after Bonde, dissertation 1965). d: lower jaw; f: frontal; m: maxilla; o: orbit; op: opercular; p: premaxilla; pa: parietal; po: preopercular; s; supramaxilla; sc: sensory canal; so: supraorbital; t: tongue.

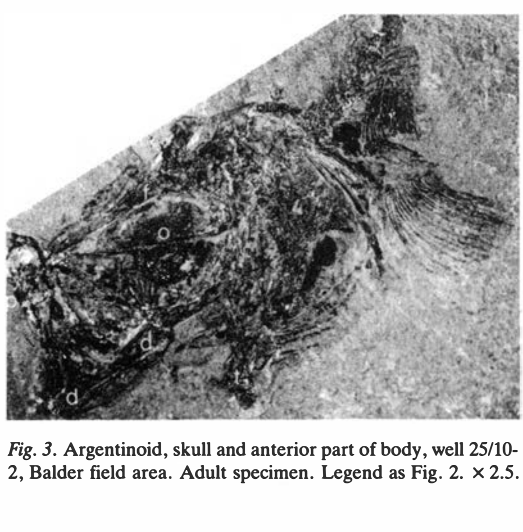

*Fig. 3.* Argentinoid, skull and anterior part of body, well 25/10-2, Balder field area. Adult specimen. Legend as Fig. 2. × 2.5.

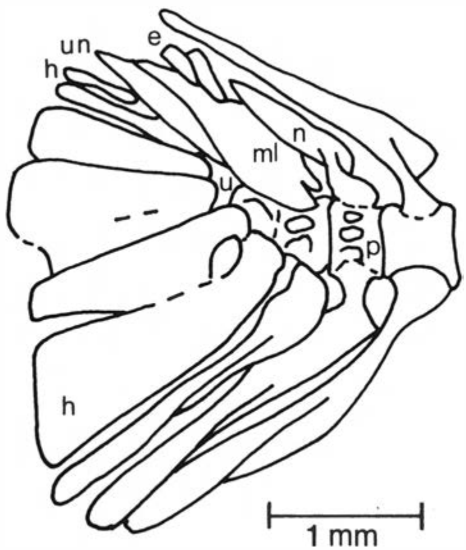


*Fig. 4.* Argentinoid, caudal skeleton based on specimens from the Mo-clay Formation, DK. (Egelund after Bonde). Small adult, first ural and preural centra (partly?) fused, short n. e: epurals; h: hypurals; ml: median lamina; n: neural spine on p: second preural centrum; u: second ural centrum; un: uroneural. Geological Museum, Copenhagen, no. MGUH VP 2927, Færker, Fur, DK.

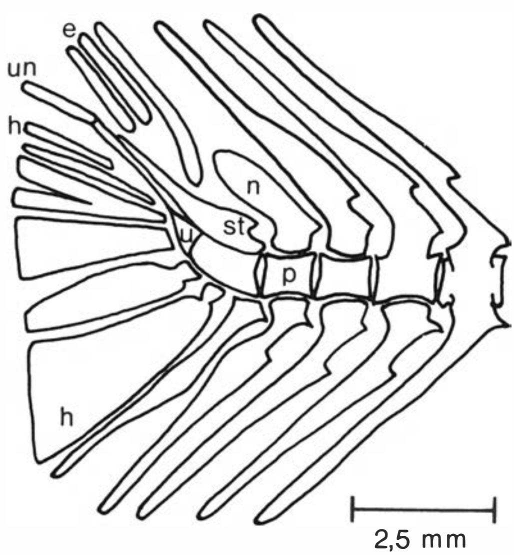


*Fig. 5.* Osmeroid, sketch of caudal fin support, based on specimens from Mo-clay Formation, DK. (Egelund after Primdahl, thesis 1973). Subadult? Legend as Fig. 4 and st: stegural.

edge of the large first uroneural. In a few specimens the lamina seems in part developed as a separate neural arch of $pu^1$. A second and possibly a small third uroneural can be seen. There are 6 hypurals and median flanges on the last few neural and hemal spines. No urodermal.

The caudal fin has 19 principal caudal rays with 17 branched. The dorsal fin with 13–15 rays is placed just behind the middle of the back; the anal with 14–16 rays is placed much further back. Ventrals with about 10 rays, placed below the dorsal fin. Pectorals with about 20 rays. No adipose dorsal fin seen.

Scales large and cycloid, about 10 in a transverse row, the third or fourth from the dorsal midline pierced by the lateral line.

The structure of the caudal fin indicates that this abundant species is a primitive argentinoid. It can be matched quite closely with caudals of microstomatines and bathylagines (Greenwood & Rosen 1971, figs. 13A, B & 14B), but is more primitive in usually having a separate $pu^1$ centrum.

This very common species in and just below the U. Paleocene ash series is the earliest argentinoid known from skeletons (L. Eocene otoliths are known), unless the true *Clupavus* from the Moroccan Cenomanian should prove to be an argentinoid too, as hinted by Patterson (1970).

*The osmeroid* (called 'coregonin' by Bonde, 1966); fig. 5–7. – The specimen from well 25/10-2 was figured by Bonde (1979) and Frodesen et al. (1981). It is a fish of total length about 10 cm, but the anterior half of the head has been cut off by the drill. The following description is based mainly on specimens from the Mo-clay Formation.

Size range known from about 8 cm to above 40 cm. Depth of body c. 15–20% of total length. A few larvae are probably identified.

In the ethmoid region there are lateral and mesethmoid ossifications, the latter covered by a separate rostral. Below, the region is covered by a toothed vomer and the front end of the parasphenoid, which carries a small basisphenoid behind the eye. The rest of the braincase is not well preserved, but the supraoccipital extends forwards to the frontals, beneath small parietals, which meet in the midline. The triangular frontals almost reach the end of the snout, and there is a small orbitosphenoid. The eyeball was protected by an anterior and posterior sclerotic ossification. The infraorbitals are badly preserved;

A

B

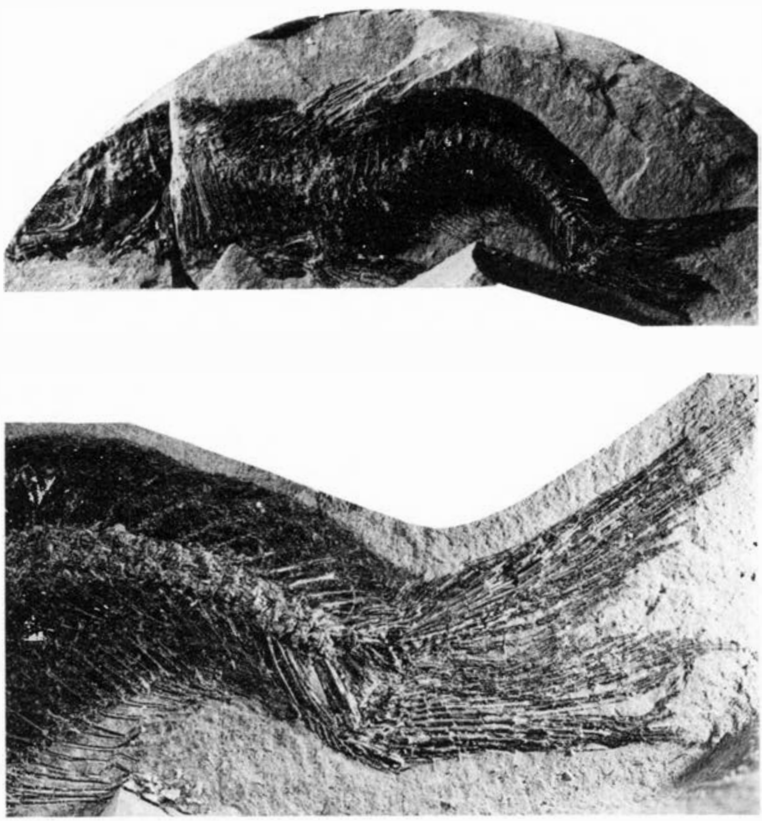

*Fig. 6.* Osmeroid, subadult? A: entire fossil; × 4/3. B: anal and caudal fins; × c.3.5. Well 25/10-2, Balder field area.

their number cannot be determined, but the lachrymal is fairly big. The supraorbital is long and there may be a small antorbital.

The upper jaw is characteristic, with a slim premaxilla occupying half its length and carrying fairly strong teeth. The toothless maxilla is much expanded behind the premaxilla, and there is an oval anterior supramaxilla below the long process of the large, platelike posterior supramaxilla. The lower jaw is subtriangular with a moderately high dentary provided with strong, pointed teeth like those on the premaxilla. The jaw articulation is below the middle of the eye.

The quadrate and metapterygoid, characteristic 'spongy' endoskeletal bones, had a little cartilage between them. The ecto- and endopterygoid are without teeth while the palatine has a row of pointed teeth. The hyomandibular shaft is fairly slender with an undivided head and a thin anterior lamella pointing toward the metapterygoid.

The opercular is large with an evenly rounded upper and posterior edge, while its posteroventral edge is almost straight. The sub- and interopercular are fairly large plates; the latter is extensively covered by the preopercular, which is large and broad and bends through about 120°. The tongue has a small, oval basihyal plate, apparently without teeth. The distal ceratohyal has a very characteristic 'quasi-perforate' shape with an incomplete dorsal rim of the perforation. There are about 9 branchiostegals and a slender urohyal.

The vertebral column comprises about 52 vertebrae, including a free second ural centrum. $26 \pm 1$ vertebrae are abdominal, all with epineurals, while epipleurals are found only on the last 8 ribs. The first ural and preural centra are fused into one elongate centrum ($pu^1 + u^1$) without neural arch rudiments. This centrum supports the last hemal arch and two lower hypurals; there are 4 upper hypurals. The last few neural and hemal spines have medial flanges on their anterior faces. The second preural neural spine is bladelike and only half as long as the spine in

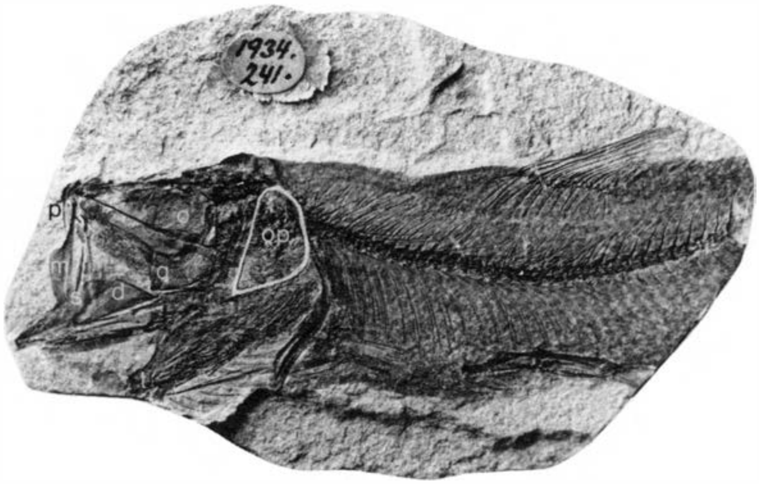


*Fig. 7.* Osmeroid, subadult? Skull and abdominal region, imprint in diatomite, Mo-clay Formation, DK. Geological Museum, Copenhagen, no. MGUH VP 3024, Skarrehage, Mors. The opercular is indicated in outline. Legend as Fig. 2 and q: quadrate. × 1.1.

front. There are one big and two small epurals. First uroneural covers $pu^1 + u^1$ and is big with a strong dorsal ridge which appears to be part of a *stegural* structure (Primdahl 1973, cf. Greenwood & Rosen 1971). The second and third uroneurals are smaller (Fig. 5).

There are 19 principal caudal fin rays, 17 branched. The dorsal fin has about 13 rays, and the anal is long with about 20 rays. There are c. 10 rays in the ventral fin placed below the dorsal fin. The pectoral fin comprises c. 16 rays, and the girdle has a mesocoracoid arch and two postcleithra.

The scales are fairly big, cycloid, suboval with 3 weak lobes at the basal (anterior) end and a subcentral nuclear area, which is even and slightly elevated above the rim of the scale. There are c. 9 scales in a transverse row on the body. The lateral line scales are difficult to see in most specimens because they tend to be pressed into the vertebral column.

This species is obviously a 'salmoniform' fish and osmeroid relationships (Primdahl 1973), at least in a wide sense, seem indicated by the stegural, combined $pu^1 + u^1$, and the long anal fin (how the two southern 'salmoniform' groups, prototroctids and retropinnids are involved in this relationship is unclear). This fossil species is rather more primitive than the Recent groups, and although not quite as primitive in many skull features as the two Cretaceous species of probable osmeroid affinity discussed by Patterson (1970), in his diagram of caudal structure (Fig. 47) it would fall in the same field as those two species and have a much less advanced caudal than one of them, *Gaudryella.*

The summary descriptions make it possible to identify these two common species from the Paleocene of the North Sea area. Furthermore, an idea of their probable relationships is offered, but new and better skull material found in the Mo-clay, especially of the osmeroid, may offer a firmer base for conclusions about its phylogenetic position (Bonde & Primdahl, forthcoming).

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