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First record of catacrinid crinoid from the Lower Permian of Spitsbergen

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Abstract: An early Permian (late Artinskian–Roadian) cladid crinoid (Catacrinidae gen. et sp. indet.) is reported for the first time from the Vøringen Member of the Kapp Starostin Formation of Spitsbergen. The specimen is partly articulated and preserves a considerable part of its stalk and a complete cup, but only the proximal portions of its arms. Thus, it cannot be identified with any degree of certainty at the generic level. Despite this, our finding is important as it constitutes one of the youngest records of catacrinid crinoids to date and considerably extends the palaeogeographic distribution of this group.

Key words: Arctic, Svalbard, crinoid, Permian.

Introduction

In spite of significant progress in the study of Permian marine sediments, articulated crinoids from this period, especially cups and crowns, are relatively scarce (see Arendt 1970, 1981; Webster *et al.* 2009 and literature herein). By contrast, isolated ossicles are common and widespread in these rocks, but the value of such disarticulated material has been questioned (*e.g.*, Moore and Jeffords 1968; Jeffords 1978; Lane and Webster 1980; Holterhoff 1997). Nevertheless, an artificial (parataxonomic) classification scheme based on isolated columnals and/or pluricolumnals has been established and used mainly for the biostratigraphy of Palaeozoic sediments (*e.g.*, Yeltysheva 1956, 1959; Stukalina 1965, 1966; Moore and Jeffords 1968; Donovan 1986, 1989, 1995; Głuchowski 2002).

An analogical situation can be discerned in the case of the Permian deposits of Spitsbergen where only isolated columnal ossicles assigned to several parataxonomic species have been mentioned (*e.g.*, Yeltyscheva and Schevtschenko 1960). To date, *Platycrinites spitzbergensis* (Holtedahl, 1911) is the only crinoid species known from this area that was erected based on an articulated cup. However, this species is exclusively known from Carboniferous strata (Holtedahl 1911).

In this paper, a near complete, articulated specimen of a catarinid crinoid from the Lower Permian of Spitsbergen is reported for the first time.

Geological setting

The Kapp Starostin Formation is the main unit of the Tempelfjorden Group (Cutbill and Challinor 1965; Dallmann *et al.* 1999) in central and western Spitsbergen, Svalbard (Fig. 1). It consists of shales and siltstones interstratified by a few limestone units and glauconitic sandstones in the uppermost part (Steel and Worsley 1984; Embry 1989; Stemmerik and Worsley 1989; Ehrenberg *et al.* 2001; Hüneke *et al.* 2001; Blomeier *et al.* 2011). The strata are more or less silicified and pass locally into bedded cherts because there is a high content of siliceous sponges which are the main cause of the high silica content in the formation (Siedlecka 1970). The siliceous sequence is resistant to weathering, and hence is well exposed and represents a distinctive marker unit throughout Spitsbergen (Harland 1997).

The Kapp Starostin Formation overlies the more easily eroded Gipsdalen Group, which is characterised by evaporites and dolostones, and is succeeded by the organic-rich, dark shales and siltstones of the Lower Triassic Vardebukta Formation (Birkenmajer and Trammer 1975; Birkenmajer 1977; Gaździcki and Trammer 1977, 1978; Ehrenberg *et al.* 2001; Błażejowski 2004; Błażejowski *et al.* 2013). The Permian–Triassic boundary is situated in the basal metres of the Vikinghøgda Formation (Wignall *et al.* 1998; Mørk *et al.* 1999).

The lowermost part of the Kapp Starostin Formation (Fig. 2) is dominated by sandy bioclastic limestone banks with a rich fauna of brachiopods, bryozoans and crinoids (Ezaki *et al*. 1994). This limestone unit, which might be up to 40 m in thickness (Dallmann *et al.* 1999), represents shoreface deposits formed by transgression of barrier sequences across the marine platform and sabkha deposits of the underlying Gipshuken Formation (Worsley *et al.* 1986; Hüneke *et al*. 2001). The limestone-dominated unit was first termed the "Spirifer Limestone" by Nathorst (1910), later referred to as "Limestone A" by Forbes *et al*. (1958), before finally being defined as the Vøringen Member by Cutbill and Challinor (1965).

The Kapp Starostin Formation comprises several more or less local members (Dallmann *et al.* 1999). Since member names for all the strata in the Kapp Starostin Formation above the Vøringen Member are not particularly clear due to discrepancies in the definitions and local facies development, the strata above the Vøringen Member will simply be referred to as the Kapp Starostin Formation in this paper. The lower part of the Kapp Starostin Formation is very fossiliferous, and there

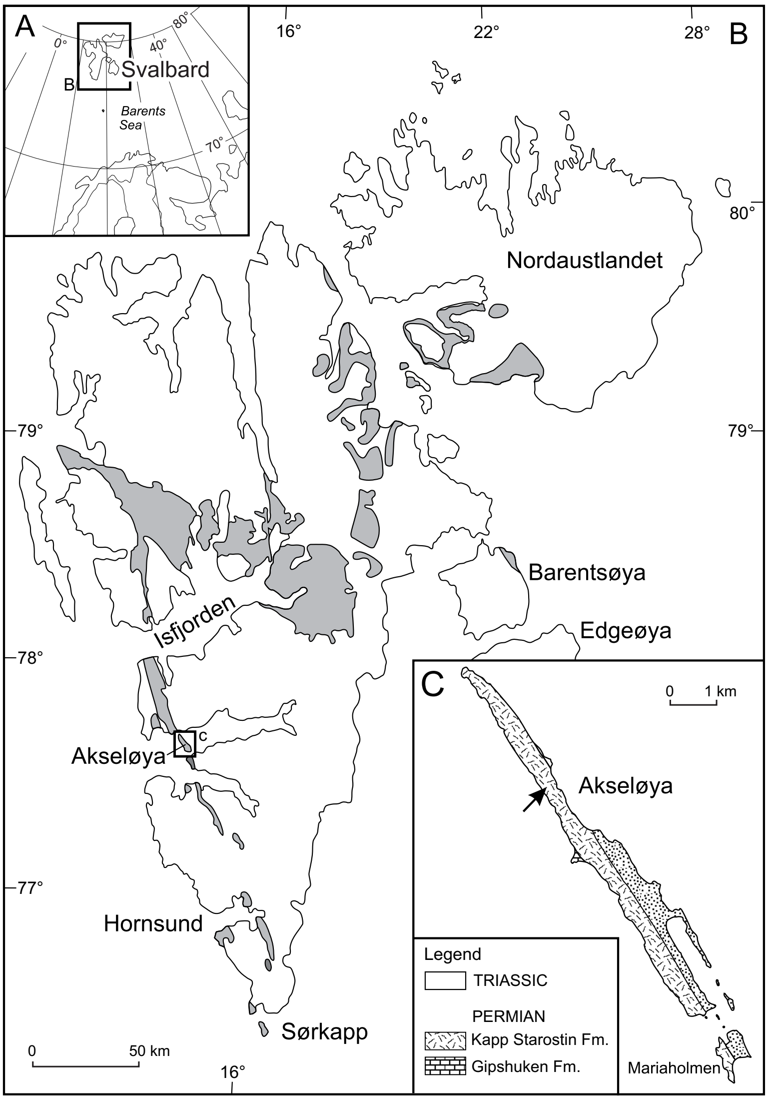

Fig. 1. **A**. Index map (upper left) shows the location of Svalbard. **B**. Map of Svalbard with exposures of Carboniferous–Permian rocks in grey. Modified from Nakrem *et al.* (1992). **C**. Simplified geological map of Akseløya showing where the catacrinid crinoid was found (arrowed).

have been many systematic investigations on various fossil groups such as trace fossils (Lofek 2012), palynomorphs (Mangerud and Konieczny 1993), ostracodes (Olempska and Błaszyk 1996), conodonts (Szaniawski and Małkowski 1979; Igo 1995; Buggisch *et al*. 2001), trilobites (Bruton 1990), bryozoans (Nakrem 1994, 1995), bivalves (Nakazawa 1999), brachiopods (Biernat and Birkenmajer 1981; Nakamura *et al*. 1987; Małkowski 1988; Stemmerik 1988; Shen *et al.* 2005) and corals (Ezaki 1997; Chwieduk 2007).

The age of the Vøringen Member is based on conodonts (Szaniawski and Małkowski 1979; Buggisch *et al*. 2001), non-fusulinid foraminiferans in the underlying Gipsdalen Group (Sosipatrowa 1967, 1969; Błażejowski 2009), palynomorphs (Mangerud and Konieczny 1993) and bryozoans (Nakrem 1995). As the upper part of the Kapp Starostin Formation has a meagre content of skeletal material, the biostratigraphic correlation of this part of the sequence is somewhat problematic. However, Nakrem *et al*. (1992) indicate a Kazanian age. Based on the similarities of the brachiopod faunas between the upper part of the Kapp Starostin Formation and the Foldvik Creek Group in East Greenland, the upper part of the Kapp Starostin Formation may be of Kazanian–early Tatarian age according to Stemmerik (1988). Because of the uncertainties with regard to the biostratigraphic correlation (see discussion by Chwieduk 2007) of the upper part of the Kapp Starostin Formation, Ehrenberg *et al.* (2010) conducted strontium isotopic dating of brachiopod shells from the Kapp Starostin Formation at Akseløya. These data indicate that the Vøringen Member has a mid-Artinskian age, and the immediately overlying part of the Kapp Starostin Formation, where the discussed crinoid was found, might be late Artinskian to Roadian.

Depositional palaeoenvironment of the Kapp Starostin Formation

The Kapp Starostin Formation at Akseløya is about 400 m thick (Ehrenberg *et al.* 2001). According to their sequence stratigraphic model, the siliciclastic-limestone intervals represent lowstands of relative sea level while spiculites are mainly highstand deposits. Above the Vøringen Member, abundant trace fossils, such as *Zoophycos* and *Chondrites*, indicate low energy as well as oxic to dysoxic bottom waters well below normal wave base (Małkowski 1988; Nakrem 2005). Based on sedimentological, palaeoecological and geochemical evidence (Małkowski and Hoffman 1979; Małkowski 1982, 1988; Nielsen *et al*. 2013), such depositional conditions were punctuated by the development of a stratified water column where anoxic and sulphidic bottom waters persisted for a short time.

During the Pennsylvanian to Late Permian, present-day Spitsbergen drifted from approximately 20°N to 45°N (Stemmerik 2000; Golonka 2011) and the accompanying climate change resulted in a shift from an arid, evaporative subtropical environment to a colder, temperate environment (Stemmerik 1995, 2000; Stemmerik and Worsley 2005). Detailed petrographical and geochemical investigations of several brachiopods belonging to the Late Permian *Horridonia* and comparisons of specimens from relatively high and low palaeolatitudes were carried out to verify seasonal variations in stable carbon and oxygen isotope values for palaeoclimatological implications (Nielsen *et al*. 2013). Analyses of the specimens from Spitsbergen show distinct cyclicity, reflecting a seasonal pattern.

Fig. 2. Steeply dipping beds in the lower part of the Kapp Starostin Formation in the northern part of Akseløya. The catacrinid crinoid was collected in the horizon in front of the person (asterisk). Photo taken by A. Uchman, August 2010.

Several depositional models have been proposed for the Kapp Starostin Formation (Małkowski and Hoffman 1979; Szaniawski and Małkowski 1979; Małkowski 1982, 1988; Ezaki *et al.* 1994; Ehrenberg *et al.* 2001). There is general agreement that the Vøringen Member was deposited as carbonate banks in a near-shore to shallow-water environment, while the spiculites were deposited in deeper water, probably below storm-wave base.

Systematic palaeontology

Classification follows Simms and Sevastopulo (1993). Brachial terms follow Webster and Maples (2008).

Class Crinoidea Miller, 1821
Subclass Cladida Moore and Laudon, 1943
Order Dendrocrinida Bather, 1899
Superfamily Erisocrinoidea Wachsmuth and Springer, 1886
Family Catacrinidae Knapp, 1969
Catacrinidae gen. indet.
(Figs 3, 4)

Material. — One nearly complete specimen (ZPAL Ca. 9/A.1).

Fig. 3. Catacrinidae gen. et sp. indet. Posterior view of a slightly distorted specimen. ZPAL Ca. 9/A.1.

Description. — Cup low and bowl-shaped with a single, large, hexagonal anal. Basals trapezoid-shaped, convex, widely outflaring. Radials pentagonal, convex, outflaring. Proximal arms biserial, isotomously branching above two? uniserial and poorly visible primibrachials. Distal arms not preserved. Brachials chisel-shaped, round transversely. The homeomorphic and non-cirriferous stem composed of low columnals with convex latus. The articular facet flat and covered with numerous fine culmina. The lumen rather small, circular.

Measurements. — Maximum cup width: 74.4 mm, maximum cup length: 32.7 mm. Maximum columnal diameter: 12.7 mm; maximum luminal diameter: 2.9 mm; maximum crenularial diameter: 3.1 mm; maximum columnal height 5.3 mm.

Occurrence. — The lower part of the Kapp Starostin Formation, above the Vøringen Member (late Artinskian–Roadian age).

Taxonomic remarks. — Although the specimen displays certain similarities with *Delocrinus*, *Endelocrinus* and *Graffhamicrinus*, its crown retains only the proximal parts of arms and is slightly distorted due to compaction. Thus, it is not possible to give a precise generic assignment.

Discussion

Taphonomic remarks. — It has been claimed that under normal marine conditions echinoderms usually disarticulate into isolated ossicles within one to two weeks, depending on intristic (*e.g.*, type of skeletal construction) and extristic (*e.g.*, water energy, scavenging, temperature) factors (*e.g.*, Meyer and

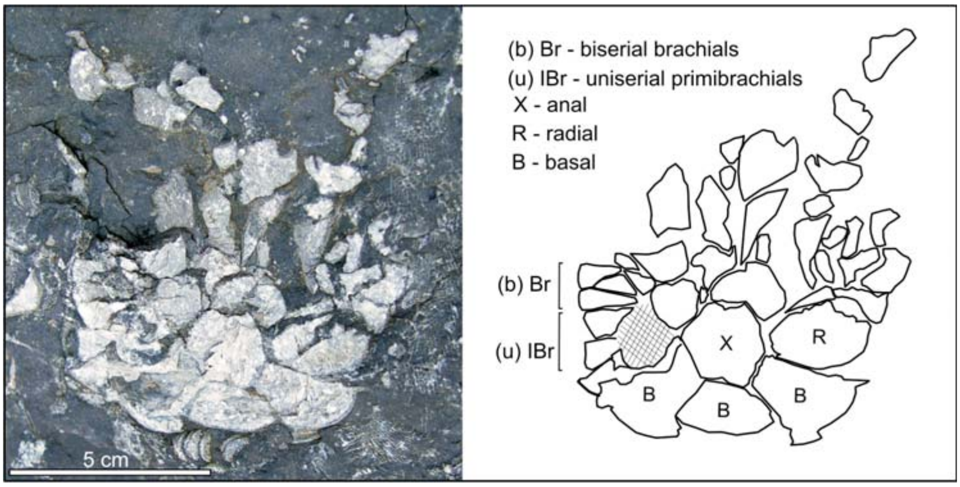

Fig. 4. Enlargement of catacrinid crown and line drawing showing plate outlines.

Meyer 1986; Allison 1990; Kidwell and Baumiller 1990; Donovan 1991; Greenstein 1991). Cladid crinoids are generally classified within the taphonomic Type 2 *sensu* Brett *et al*. (1997). This type includes echinoderms whose skeletons are partly composed of tightly sutured ossicles, whereas other portions are loosely articulated. Because of this variation in the skeletal construction, these echinoderms display a wide range of taphonomic grades. However, it is suggested that even more sutured portions of their skeletons commonly disarticulate rather rapidly (within weeks) see Brett *et al*. (1997). The partly articulated specimen described in this paper, preserved as recrystallized calcite, is slightly distorted due to lateral and slightly oblique compaction. However, it possesses a considerable part of its stalk and a complete cup, but only the proximal portions of its arms. Therefore, it can be classified in the taphonomic grade "L" *sensu* Thomka *et al*. (2011). Clearly, the lack of distal arm portions and holdfast suggests only minor, selective post-mortem disarticulation due to a rather brief period of exposure on the sea floor where the specimen was probably subject to short transport before final burial. Nevertheless, it should be borne in mind that even articulated ossicles can remain for several days after death, sufficient time for long transporation (*e.g.*, Kidwell and Baumiller 1990).

It is noteworthy that the postulated low sea water temperature in the depositional basin of the Kapp Starostin Formation (Nakrem 1994, 1995; Ezaki 1997) might have been an important factor that affected the nearly complete preservation of the described specimen as neontological experiments showed that a low temperature significantly retards disintegration rates in modern echinoderms (Kidwell and Baumiller 1990). According to these authors, the quality of preservation of echinoderm skeletons is expected to improve from low to high latitudes, primarily because of decreasing water temperature.

Stratigraphic and palaeogeographic distribution of Catacrinidae.—The catacrinid crinoid described here from the Kapp Starostin Formation, though not well preserved, is important for a number of reasons. According to Webster (2003), catacrinoids are mainly equatorial taxa in the Pennsylvanian and Permian. Nearly all the eight known catacrinid genera are endemic to North America, the exceptions being *Pyndaxocrinus*, which is also known from the Lower Permian (Asselian) of Crete, and *Delocrinus*, which was previously reported in the Lower Permian (Asselian) of Bolivia and the Pennsylvanian of China (more details in Strimple and Moore 1971; Webster *et al*. 2009; Webster 2012). The youngest known fossil records of these crinoids were from the Lower Permian (Kungurian) of Texas. These were referred to *Delocrinus major* (Weller, 1909) and *Delocrinus texanus* (Weller, 1909), but both were recombined as *Arrectocrinus major* and *Arrectocrinus texanus* by Webster (2006). Thus, the present find not only represents the first record of an articulated crinoid from the Lower Permian of Spitsbergen, but it also constitutes one of the youngest known records of Catacrinidae, thus considerably extending the palaeogeographic distribution of this group. Indeed, this is the first record of these crinoids outside the northern equatorial zone.

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