Ordovician gastropods from pebbles in Cretaceous fluvial sandstones in south-east Disko, West Greenland

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The gastropods Sinuopea sp. and Lecanospira cf. compacta (Salter 1859) of probable early Ordovician age are described from cherty limestone clasts within fluvial strata of the Cretaceous Atane Formation of south-east Disko, central West Greenland. The record of Sinuopea possibly suggests an earliest Ordovician (Tremadocian) age, slightly older than the Floian–Dapingian age suggested by the oldest known conodont assemblages described from West Greenland. The determinations provide supporting evidence for a former periodic cover of Ordovician strata in the Archaean terrane of south western Greenland, extending deep into the heart of the Laurentian landmass.

Keywords: Greenland, Disko, Cretaceous lags, Atane Formation, Ordovician gastropods.

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The notable discovery by Asger Ken Pedersen in 1984 of fossil gastropods in cherty limestone clasts from within Cretaceous fluvial deposits on the island of Disko provided significant new evidence of the former widespread distribution of Ordovician strata in West Greenland (Pedersen & Peel 1985). The localities are found on the slopes of the mountain Tuapaat Qaqqaat, south-east Disko, around 69°24’N, 52°40’W; Fig. 1. The specimens are derived from the Skansen Member (Cenomanian) of the Atane Formation, according to the regional lithostratigraphic synthesis of Dam et al. (2009). Subsequently, the occurrence of similar material from the Annertuneq Conglomerate Member of the Kangilia Formation (Maastrichtian) on the north coast of Nuuussuaq was reported by Dam et al. (2009, p. 111).

In 1965 geologists of Kryolitselskabet Øresund A/S discovered blocks of fossiliferous sediments at a locality (65°23’N, 51°32’W) 50 km east of Manitsoq (formerly Sukkertoppen) in southern West Greenland. Following its announcement (Poulsen 1966), the locality became known as Fossilik (Fig. 1) and represented a sensational indication of the former extent of the Lower Palaeozoic deep within the present day Archaean terrane. Information concerning the fauna was expanded by Poulsen (1967a,b) who suggested a middle Ordovician–early Silurian age for faunas collected from a variety of sediment blocks within a breccia zone, but the material was not described. Stouge & Peel (1979) described a small conodont fauna of general middle–late Ordovician age from limestone samples collected by Brian F. Windley during 1967. In 1977, Stig Bak Jensen and Jan H. Allaart made additional collections (GGU samples 182176 and 182180) from the locality on my behalf during field work by the Geological Survey of Greenland (GGU), with a focus on carbonate samples that could be processed for conodonts. This material formed the basis for the analysis of conodont faunas presented by Smith (1988) and Smith & Bjerreskov (1994). In addition to conodonts, the samples yielded sponge spicules and silicified crinoid ossicles, with rare fragments of orthid brachiopods. Secher et al. (2009) considered the Ordovician blocks to lie within a carbonatitic–ultramafic breccia tuff associated with the Qaqqarsuk carbonatite complex which was emplaced during the Jurassic.

At the time of its discovery, Fossilik lay more than 1000 km from the nearest known onshore outcrops of Lower Palaeozoic sediments in western Baffin Island (Fig. 1) and almost twice that distance from fossiliferous Cambro–Ordovician sections in North-East Greenland described by Poulsen (1932, 1937) and Cowie & Adams (1957). To the north, fossil-dated Lower Palaeozoic strata in Greenland were first encountered in Inglefield Land and Daugaard-Jensen Land, astride Humboldt Gletscher (Poulsen 1927).
On a larger scale, the significance of the West Greenland discoveries to the understanding of Ordovician palaeogeography in north-eastern Laurentia is evident from reconstructions of the distribution of landmasses during the early (Tremadocian) and late (Sandbian) Ordovician (Cocks & Torsvik 2011; Derby et al. 2012; Fig. 1). Baffin Bay, Davis Strait and the Labrador Sea occupy a central swathe of the subaerially exposed Laurentian continent in these reconstructions, in the centre of which lie the fossiliferous lag conglomerates of the Nuussuaq Basin (Fig. 1).

This paper describes the best preserved specimens from the small collection of gastropods from the chert clasts of Disko, revising the preliminary identifications by Pedersen & Peel (1985). Specimens assigned to Sinuopea sp. and Lecanospira cf. compacta (Salter 1859) suggest an early Ordovician age in general accord with the oldest conodont assemblages reported by Smith (1988), Smith & Bjerreskov (1994) and Stouge et al. (2007).

Systematic descriptions

Material. Specimens were whitened with ammonium chloride sublimate prior to photography. GGU prefix indicates a sample of Grønlands Geologiske Undersøgelse (Geological Survey of Greenland), now a part of the Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark. MGUH prefix denotes a specimen deposited in the palaeontological type collection of the Natural History Museum of Denmark, Copenhagen.

Class Gastropoda Cuvier 1797

Discussion. Classification of Palaeozoic gastropods above superfamily or family level is in a state of flux, with the system employed by Knight et al. (1960) no longer apposite. Relevant overviews include Wagner (2002), Frýda et al. (2008) and Frýda (2012), and an online database is maintained by Wagner (2017). The most recent listing is that of Bouchet et al. (2017). However, large numbers of Palaeozoic families are left unassigned.

Family Sinuopeidae Wenz 1938

Genus Sinuopea Ulrich 1911

Type species. Sinuopea sweeti (Whitfield 1882) from the Trempealeau Formation (Furongian) of Wisconsin, USA.
Sinuopea sp.
Fig. 2C,D

Figured material. MGUH 33399 from GGU sample 327036, locality 1984/61 of A.K. Pedersen at altitude 270 m a.s.l. on the slopes of Tuapaat Qaqqaat, south-east Disko. Chert clast in sandstone of the Atane Formation, Skansen Member.

Discussion. This single internal mould, preserved in buff coloured chert, is rounded by erosion such that the apex and one side (not visible in Fig. 2) are missing. The maximum preserved height of the turbiniform shell is 30 mm, consisting of parts of three whorls which are slightly shouldered. Shallow channels on the internal mould indicate thickening of the apertural margin which has a broad sinus low on the outer whorl face (arrows in Fig. 2C). Other oblique and rather irregular channels probably result from differential chert formation on the shell interior, reflecting either burrows in the original sediment fill or possibly epibions attached to the shell interior (arrow in Fig. 2D).

Rohr et al. (2000) commented that Sinuopea is a common gastropod in upper Cambrian and lower Ordovician strata of eastern and central North America and Greenland. The Disko specimen is wider, with more convex whorls than the specimen of the type species, Sinuopea sweeti (Whitfield 1882), figured by Knight (1941) from the Trempealeau Formation of Wisconsin, U.S.A., or from Sinuopea sp. from the upper Cambrian–lower Ordovician of western Newfoundland figured by Rohr et al. (2000, pl. 2). Sinuopea basiplanata Ulrich & Bridge 1931 in Ulrich et al. (1931) from the lower Ordovician Van Buren Formation of Missouri, USA, has similar whorl proportions to the internal mould from Disko.

In Greenland, Sinuopea is known from the Cass Fjord Formation of Daugaard-Jensen Land (Poulsen 1927) and the Poulsen Cliff Formation of southern Washington Land (Fortey & Peel 1990), western North Greenland, of Tremadocian age. Specimens from the Cass Fjord Formation are too poorly preserved for closer comparison, while the single specimen from the Poulsen Cliff Formation (Fortey & Peel 1990) is higher spired and less globose than the Disko specimen. In North-East Greenland, Sinuopea was described from the Antiklinalbugt Formation by Poulsen (1937) of Tremadocian age (McCobb et al. 2014). The holotype of Sinuopea whittardi Poulsen 1937 from the Antiklinalbugt Formation is lower spired (Poulsen 1937, pl. 1, fig. 9), with well-developed lamellose growth ornamentation, but growth lines are not known from the Disko specimen.

Superfamily Ophiletoidea Koken 1897

Family Ophiletidae Koken 1897

Genus Lecanospira Butts 1926

Type species. Ophileta compacta Salter 1859, from the Beauharnois Formation (Beekmantown Group), Ordovician of Québec, Canada.

Discussion. Knight et al. (1960) considered Lecanospira Butts 1926 to be a macluritid, and ophiletids to be pleurotomarioids, while Rohr et al. (2003) placed Lecanospira with the euomphalids. Wagner (2002) assigned Lecanospira to the euomphaline Superfamily Ophiletoidea Knight 1956. Peel (2019) considered Koken (1897) to be the author of Ophiletidae and Ophiletoidea.

Lecanospira cf. compacta (Salter 1859)
Fig. 2A,E,G

Figured material. MGUH 33397 from GGU sample 327039, MGUH 33400 from GGU sample 327040, loose pebbles of chert on the south-east slope of Tuapaat Qaqqaat, altitude about 50 m a.s.l., collected by A.K. Pedersen in 1984. Atane Formation, Skansen Member.

Discussion. Through an unfortunate error, it was reported by Pedersen & Peel (1985) that both the specimens placed here were sectioned through the axis of coiling; only one specimen was sectioned (Fig. 2E). The more complete specimen (Fig. 2A,G) is an internal mould with diameter 30 mm that is closely similar to a specimen illustrated as Lecanospira compacta (Salter 1859) by Rohr et al. (2003, pl. 3) from the Boat Harbour Formation, St. George Group, of Port au Port Peninsula, western Newfoundland, and to the type specimen illustrated by Knight (1941, pl. 76, fig. 5a–c) from Québec. Only the upper surface is visible in this Disko specimen and in Knight’s (1941) illustration, but the transverse section (Fig. 2E) shows the form of early whorls and the shallowly concave base seen also in the specimen from Newfoundland (Rohr et al. 2003, pl. 3). This lower surface differs from that of a specimen from the Beauharnois Formation assigned to Lecanospira (Lecanospira) compacta by Desbiens et al. (1996, pl. 2, fig. 18), the latter being flat and having more numerous and slowly expanding whorls.

Poulsen (1927, pl. 18, fig. 17) illustrated in apical view, but did not describe, a poorly preserved specimen from the Cape Clay Formation (Tremadocian) of Daugaard-Jensen Land which resembles the internal mould from Disko (MGUH 33397).
Superfamily Eotomarioidea Wenz 1938

Undetermined eotomarioidean sp.
Fig. 2B,F

Figured material. MGUH 33398 from GGU sample 327037, locality 1984/67 of A.K. Pedersen, 1.5–2 km north-north-west of Nuuk, Tuapanat Qaqqaat, at about 130 m a.s.l. in Atane Formation, Skansen Member.

Discussion. This specimen has a diameter of about 23 mm and is embedded in chert such that the umbilical surface is visible (Fig. 2B). The earliest whorls are covered by matrix and the final one third of the whorl and the aperture are damaged. The specimen appears to represent a lenticular, widely phaneromphalous gastropod with a deep emargination. Fine growth lines sweep adapically with high obliquity to join a raised peripheral band on the internal mould (pb in Fig. 2B). An acute circumbical ridge is present at the junction between the base and the umbilical surface (r in Fig. 2B,F). In terms of its acuteness, it resembles the spiral trace of a shell retractor muscle scar and similar spiral traces have been described on gastropod internal moulds by Knight (1947), Peel (1976, 1982, 1986, 2019) and Horný (1997a,b, 1999). However, such a trace is a feature of the shell interior and its preservation together with growth lines from the shell exterior would require interpretation of the specimen as a composite mould.

The slower rate of expansion of the whorl, obliquity of growth lines on the base and the wide umbilicus distinguish the specimen from many species of the common Ordovician genera *Liospira* Ulrich & Scofield 1897 and *Eotomaria* Ulrich & Scofield 1897. Lenticular specimens described from the Cape Calhoun Formation, Morris Bugt Group, of Washington Land, North Greenland, and assigned to *Liospira* by Troedsson (1928, pl. 2, fig. 6a,b), appear to have a wide, open, umbilicus, but co-occurring specimens show a solid umbilical plug in the narrower umbilicus (Troedsson 1928, pl. 2, fig. 8).

![Fig. 2. Ordovician gastropods in cherts from Cretaceous lag conglomerates on Disko. A, E, G: *Lecanospira* cf. *compacta*, MGUH 33397 in apical (A) and oblique apical (G) views. E: MGUH 33400, drawing of transverse cross-section. B, F: undetermined eotomarioidean sp., MGUH 33398 in umbilical view (B) with detail (F): pb indicates peripheral band, r locates circumbical ridge. C, D: *Sinuopea* sp., MGUH 33399, lateral views with arrows in C locating thickened apertural margin and arrow in D locating differential preservation of a probable burrow within the shell infill. Scale bars all represent 5 mm.](image-url)
Paraliospira Rohr 1980 includes shells with a more inflated base than both Liospira and the Disko specimen and its umbilicus may vary from widely phaneromphalous to cryptomphalous. A coarse circumbilical spiral ridge may be present (Rohr 1980, pl. 5, fig. 16) but the angulation between the upper whorl surface and the base usually lies above the whorl periphery, in contrast to the peripheral band in the specimen from Disko (pb in Fig. 2B). Growth lines on the base in the latter specimen are much more strongly oblique than in Paraliospira.

The widely distributed early Ordovician Ceratopea Ulrich 1911 is known from North Greenland (Poulsen 1927, pl. 19, figs 6–8; Yochelson & Peel 1975; Peel & Yochelson 1979) and North-East Greenland (Rohr et al. 2015). It has a lenticular shell with a broad open umbilicus and may show a rounded circumbilical ridge (Rohr et al. 2004). However, it lacks the strong obliquity of growth lines on the base seen in the Disko specimen.

Age of the fauna

Smith & Bjerreskov (1994, p. 19) recognised three discrete Ordovician conodont faunas from Fossilik, of which the stratigraphically youngest probably corresponds to that recognised by Stouge & Peel (1979). The oldest assemblage (communis Biozone) of late Ibexian age correlated with the basal Wandel Valley Formation of North Greenland, while younger faunas were correlated with the Kap Jackson and Børglum River Formations (aculeata Biozone, basal Mohawkian) and with the velicuspis Biozone (Cincinnatian). These correspond to the Floian, Sandbian and Katian Stages of current international subdivisions of the Ordovician (Bergström & Ferretti 2017).

Stouge et al. (2007) noted that most of the dredged samples from the Davis Strait High yielded conodonts of late Ordovician (Katian Stage) age, but they also recorded sparse Whiterockian (Floian–Dapingian, Darrwiillian Stages) and Mohawkian (Sandbian Stage) assemblages.

Inferring age from the rare gastropod material from the chert clasts within the Atane Formation is fraught with uncertainty. It cannot be assumed that the clasts were derived from rocks of the same age and it must be recognised also that gastropods do not offer the same chronostratigraphic resolution as conodonts. However, the occurrence of Sinuopea sp. and Lecanospira cf. compacta strongly suggests that at least these clasts from Disko are of early Ordovician age. The presence of Lecanospira cf. compacta suggests equivalence to the oldest assemblages (Floian–Dapingian) documented by Smith & Bjerreskov (1994) and Stouge et al. (2007). Sinuopea, however, is generally indicative of somewhat older strata (late Cambrian–earliest Ordovician) and Greenland occurrences (Cass Fjord Formation, Antiklinalbugt Formation) described by Poulsen (1927, 1937) are of basal Ordovician (Tremadocian) age (Smith & Bjerreskov 1994; Stouge et al. 2013; McCobb et al. 2014). The other gastropod specimens from Disko do not provide precise indications of age, but the undetermined eotomarioidean sp. (Fig. 2B,F) is probably of Middle Ordovician age.

Within the Hudson Platform successions in Canada, to the west, strata of Dapingian age are known from Baffin Island (Ship Point Formation) but around Hudson Bay, farther to the west, the oldest Ordovician is of late Ordovician Katian age (Armstrong et al. 2018). In North Greenland, a relatively complete Ordovician platform succession is known north of Humboldt Gletscher, cropping out from Daugaard-Jensen Land eastwards to Peary Land and the eastern coast of Greenland, but Ordovician platform strata older than Floian–Dapingian (Wandel Valley Formation) are not known from the Peary Land region (Higgins et al. 1991; Smith & Bjerreskov 1994). Lower Ordovician strata are well represented in North-East Greenland (Stouge et al. 2002, 2013; Smith & Rasmussen 2008; Smith et al. 2004) but the succession terminates in the Sandbian (Smith & Bjerreskov 1994).

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