Supplementary material for: Thomsen E., Rasmussen T.L., Sztybor K., Hanken N.-M., Tendal O.S. & Uchman A. 2019. Cold-seep fossil macrofaunal assemblages from Vestnesa Ridge, eastern Fram Strait, during the past 45 000 years. *Polar Research 38.* Correspondence: Elsebeth Thomsen, The Arctic University Museum of Norway, UiT—The Arctic University of Norway, NO-9037 Tromsø, Norway. E-mail: elsebeth.thomsen@uit.no

Taxonomy

Porifera
Cladorhizidae indet.
Stylocordyla sp.
Axinellidae indet. (spicules)
Demospongiae indet. (spicules)

Annelida
Polychaeta (tubes)
Spiochaetopterus sp. perhaps *Spiochaetopterus bergensis* Gitay, 1969
Siboglinidae indet.
Polychaeta indet.

Arthropoda
Cirripedia
Verucca stroemia (Müller, 1776)

Mollusca
Bivalvia
Yoldiella solidula Warén, 1989
Yoldiella lenticula?
Yoldiella sp.
Rhacothyas kolgae Åstrøm & Oliver, 2017
Thyasira sp.
Archivesica arctica Hansen et al., 2017
Isorropodon nyeggaensis Krylova, 2011
Cuspidaria glacialis (G.O. Sars, 1878)
Bivalvia indet.

Gastropoda
Skenea sp.
Pseudosetia sp.
Alvania scrobiculata (Möller, 1842)
Alvania sp.

Frigidoalvania sp.
Euspira sp.
Gastropoda indet.

Cephalopoda
Cephalopoda indet.

Echinodermata
Echinoidea
Echinoidea indet.

Ophiuroidea
Ophiuroidea indet.

Vertebrata
Pisces
Pisces indet.

Trace fossils
Oichnus cf. *O. ovalis* Bromley, 1993
Winding burrows (? *Helminthoidicnites* isp.)

Incertae sedis
Tubes of unknown affinities and/or burrow fill/lined tubes, both made of authigenic carbonate. The tubes could be inhalant tubes as seen in a figure of *Thyasira equalis* in Oliver & Killeen (2002).

Taxonomic and other notes on the macrofossils and trace fossils

Note 1

The occurrence of a large vesicomyid bivalve in two cores, also from the Vestnesa area, have been published by Ambrose et al. (2015) under the tentative name *Phreagena* sp. Hansen et al. (2017) elucidate the taxonomy of the specimens from the cores in the present study from Vestnesa: it is a new species *Archivesica arctica* Hansen et al., 2017.

Note 2

The small *Isorropodon nyeggaensis* Krylova in Krylova et al. 2011 is a chemosymbiotic bivalve (see Rodrigues et al. 2012). *Isorropodon* is known from seeps associated with pockmarks in the North Atlantic (Oliver & Drewery 2014), the Nyegga seep area on the Vøring Plateau in the Norwegian Sea (Krylova et al. 2011) and the Vestnesa area (Ambrose et al. 2015; Hansen et al.

2017). The specimens from our cores from Vestnesa Ridge have only been found as fossils. So far, no records of live specimens from Svalbard exist (see references in Hansen et al. 2017).

Note 3

The small epifaunal gastropods, in particular *Frigidoalvania* sp., are common in core HH12-928PC and between 136 and 110 cm in core HH12-929GC. The systematic determination is not entirely certain and we think it could perhaps be a new species. Rissoid gastropods (see Warén 1974; Ponder 1984) comprise a large number of species mostly known from shallow water, but also found on the slope and in deeper water. Pimenov et al. (2000) and Åström et al. (2017) both noted the occurrence of small gastropods (< 1 cm), probably rissoid gastropods accumulated amongst microbiological mats (see Sen et al. 2019).

Note 4

Thyasirids have been studied by Dando & Southward (1986), Dando & Spiro (1993), Oliver & Killeen (2002), Oliver & Holmes (2006) and Oliver & Drewery (2014). According to Oliver & Drewery (2014), the larger thyasirids in the North Atlantic, with the exception of *Thyasira sarsi* (Philippi, 1845*)*, are associated with the occurrence of cold seeps within pockmarks. Recently, Åström et al. (2017) studied material collected from surface sediments from two other seep-localities on the western Svalbard shelf and found that it comprised one new genus—*Rhacothyas* Åström & Oliver, 2017—and two new species—*Thyasira capitanea* Åström & Oliver, 2017 and *Rhacothyas kolgae* Åström & Oliver, 2017. Their specimens were all fossil. Here we show that *R. kolgae* was also common as a fossil in deep-sea core records from Vestnesa Ridge.

Note 5

Bromley (2004: 466) suggested that *Oichnus* may be a junior synonym of *Sedilichnus* Müller, 1977. Following this suggestion, Zonneveld & Gingras (2014) included *Oichnus* into *Sedilichnus*. However, this decision was contested (e.g., Klompmaker et al. 2015) and Wisshak et al. (2015) pointed out that *Oichnus* is a valid name. The occurrence of *Oichnus* was investigated in core HH12-928PC (see Fig. 8).

Oichnus cf. *O. ovalis* Bromley, 1993, form A (Fig. 9a, b in *Frigidoalvania* sp. is a perpendicular hole in the next-to-last whorl of a gastropod shell with slightly uneven, elliptical outline, larger in the outer opening than in the inner opening. The longer axis of the ellipse is 0.43 mm and 0.20 mm, and the shorter axis is 0.36 and 0.12 mm long, in the inner and outer openings, respectively. The surface between the entrance and outlet is formed by small, flat areas, less than 0.1 mm wide, well visible in the upper part of the hole. There, the elliptic outline of the outer opening is composed of zigzag segments. The areas are probably the faces of the calcite crystals. The elliptical shape points to *O. ovalis,* but concavity of the surface of the hole between openings, a typical feature of this ichnospecies, is not obvious. *Oichnus ovalis* was interpreted as a predation hole of octopods (Bromley 1993), except for small forms that are interpreted as made by foraminifera (Zonneveld & Gingras 2014). Recent octopods can also produce subcircular and irregular drillholes (Klompmaker et al. 2015 and references therein). *Oichnus ovalis* is a Cenozoic to Recent, cosmopolitan ichnospecies, produced in skeletons of different invertebrates (Zonneveld & Gingras 2014).

Oichnus cf. *O. ovalis* Bromley, 1993, form B (Fig. 9c, d in *Frigidoalvania* sp. is an elliptical hole in the middle of the apertural whorl of a gastropod shell, with the outer opening wider than the inner opening. The longer axis of the ellipse is 0.46 mm and 0.38 mm long and the shorter axis is 0.36 and 0.22 mm long, in the inner and outer openings, respectively. Periostracum is wrapped out along a part of the margin of the hole. In proximity of the ribs running along the whorl, the margin of the ellipse is protruded inwardly at the ends of its shorter axis, thus the inner opening tends to form the outline of cipher eight. This is probably an effect of the intersection of the hole with the ribs. The concavity of the surface of the hole between openings, a typical feature of *O. ovalis*, is not obvious.

Oichnus cf. *O. ovalis* Bromley, 1993, form C (Fig. 9e–h, 9f–h in *Frigidoalvania* sp.) is a slightly uneven elliptical hole in the middle apertural whorl of a gastropod shell with example of sizes: 0.5 x 0.7 mm, 0.5 x 0.6 mm, 0.7 x 1.0 mm, 0.35 x 0.5 mm. The margin of the hole is slightly jagged. Surface adjacent to the outer opening can be etched in a discontinuous zone up to 0.15 mm wide (Fig. 9h). The shell is too thin to observe concavity of the surface of the hole between the opening, but the elliptical outline suggests *O. ovalis*.

Note 6

Vertebral ossicles of ophiuroids (brittle stars) are quite common in core HH12-928PC. It is well known that brittle stars usually disarticulate into isolated ossicles shortly after death. However, the ossicles are well preserved, without any sign of mechanical abrasion. This indicates very little post-mortem transport, implying that the skeletal remains are autochthonous or paraautochthonous. In fact, ophiuroids are the most abundant modern megafauna on the soft-bottom plains outside pockmarks (Åström et al. 2017).

It is difficult to identify brittle stars solely from loose ossicles, but analysis of megafaunal assemblages from Vestnesa by Soltwedel et al. (2009) has shown that *Ophiocten gracilis* is very common and is the only species of brittle stars in this area. *Ophiocten gracialis* is an upper bathyal species in the North Atlantic Ocean and can constitute a substantial part of the biomass in soft bottom habitats (Piepenburg & von Juterzenka 1994; Sumida et al. 2000), where they feed on flocculent organic material, often containing diatom frustules, and foraminifera (Pearson & Gage 1984).

The ossicles show growth bands. Gage (2003) has described similar growth bands, and it was indicated that the pattern is due to a seasonal cycle in growth. During spring/summer there is a rapid skeletal growth with coarse-pored stereom followed by slow growth in autumn/winter, a pattern in nutrition and reproduction that determines the resources for skeletal and is presumably somatic with the development of fine-pored stereom. These differences were attributed to a strongly seasonal growth. However, the growth bands in our material are much broader, indicating a more even supply of food, which can be attributed to the high primary organic production in the methane seep community compared with areas outside active pock marks. This, however, remains to be verified.

Note 7

Burrows in the unlithified core material are poorly preserved because of a combination of precipitation of gas hydrates rupturing much of the primary sedimentary structures and possible little lithological contrast between burrows and matrix sediment. However, burrows have been partly preserved in some carbonate concretions in core HH12-929GC (from 192 to 195 cm) indicating that the presence of burrows is underestimated when based only on visual examination and x-ray photographs of the core material.

The concretions display evidence of burrowing on their surfaces and in polished surfaces. On the surfaces, thin, tubular, winding, unbranched burrows, 0.3–0.4 mm in diameter, can be observed (Fig. 10a). They have sharp margins and are not filled. Entrances to empty burrows of this size can be observed in many places of the concretion surfaces. In polished surfaces, burrows of this size are filled with sediment of slightly different colour and porosity (Fig. 10b). The polished surfaces also display a non-uniform, lumpy fabric, which can be interpreted as an ichnofabric that was produced in soft sediment and transformed partly by diagenetic processes (Fig. 10b). It is not impossible that the larger holes in the concretions, about 1 cm in diameter, can be attributed to larger burrows. All these features show that the concretions resulted from an early diagenetic precipitation of calcium carbonate in such a way that the original fabric was partly preserved.

The tracemaker(s) is (are) not known, but it is probably one or more species of annelids, which are well known from the Vestnesa area (Bergmann et al. 2009; Soltwedel et al. 2009, Bergmann et al. 2011).

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