FACULTY OF SCIENCE
UNIVERSITY OF COPENHAGEN

Master's thesis

Bitten Bolvig Hansen

Description and analysis of a Rhaetian vertebrate coprolite assemblage of the Kap Stewart Formation, Jameson Land, East Greenland

Academic advisor: Gilles Cuny, Statens Naturhistoriske Museum, København

Additional advisor: Jesper Milàn, Geomuseum Faxe

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Abstract

The study of coprolites was established as a scientific field in the 19th century when coprolites were first identified as fossilized faeces by William Buckland. The examination of coprolites can reveal details about the behaviour of extinct animals that is not obtainable from body fossils alone. Even so, the coprolitic field has never gained a wide popularity and only few palaeontologist devote their time to the study of pre-Palaeogene vertebrate coprolites. This projects presents an overview of important literature on the subject through a short historical review and a presentation of recent terminology. In a case study, Late Triassic vertebrate coprolites from East Greenland are examined and described in detail. The coprolites are divided into the following types: Round to sub-round coprolites, spiral/coiled coprolites and irregularly wrapped and structureless coprolites. A sub-type of irregularly wrapped coprolites contains nodular textures not earlier described from coprolites. Fossil food remains in the coprolites are identified as scales from actinopterygian fish while loose fragments of dermal bone are ascribed to large temnospondyls and a single loose shark tooth is recognized as coming from *Rhomphaiodon minor*.
Keywords: Vertebrate coprolites, spiral coprolites, Rhaetian, East Greenland.

Resume

Studiet af koprolitter blev etableret som videnskabeligt fag i det 19. århundrede, da koprolitter første gang blev identificeret som fossile ekskrementer af William Buckland. Undersøgelsen af koprolitter kan afsløre detaljer om uddøde dyrs adfærd, som kropsfossiler alene ikke giver. Alligevel har koprolitfaget ikke vundet synderlig popularitet og kun få palæontologer vier deres tid til studiet af pre-Palæogene koprolitter fra vertebrater. I dette projekt gives et overblik over vigtig litteratur indenfor feltet i form af en kort historisk gennemgang og en opsamling af den seneste terminologi. Et casestudy fremlægger en undersøgelse og grundig beskrivelse af Østgrønlandske vertebratkoprolitter fra Sen Trias. Disse koprolitter inddeles i de følgende typer: Runde til semirunde koprolitter, spiralsnoede koprolitter og irregulært pakkede og strukturløse koprolitter. En undertype af de irregulært pakkede koprolitter indeholder en tekstur af kugler, som ikke tidligere er beskrevet i koprolitter. Fossile rester af føde i koprolitterne identificeres som skæl fra strålefinnede fisk, mens løse fragmenter af fossilt hudpanser tilskrives store temnospondyler og en enlig hajtand genkendes som kommende fra *Rhomphaiodon minor*.
Nøgleord: Korpolitter fra vertebrater, spiralsnoede koprolitter, Rhaetien, Østgrønland.

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1. Introduction

In the summer of 2012 members of the Geocenter Møns Klint Dinosaur Expedition searched for Triassic vertebrate fossils and ichnofossils at localities in Jameson Land just west of Carlsberg Fjord in East Greenland. Apart from fossilized bones and footprints, a large quantity of fossilized faecal material was brought back from the area. This material consists of more than 300 well-cemented nodules that are most often dark grey and cylindrical in shape. The collected specimens have various sizes and some contain prey remains while others are homogenous without any inclusions. Some have obvious layered structures, some are massive and some appear to consist of small pellets. A few have been recovered intact but most of the nodules are highly weathered and fragmented. At first glance these nodules may not appear different from regular sedimentary concretions or fossilized burrows, but certain features indicate that they are actually ancient faeces. The proper scientific term for a fossilized faeces is 'coprolite'. The science of studying coprolites do not have a widely used official name but 'palaeoscatology' have been used by some (e.g. Monastersky 1998, Hunt & Lucas 2005) and 'coprolitology' by others (e.g. Ford & O'Conner 2009). Here, 'palaeoscatology' is preferred. When a specimen of faecal material was fossilized still within the body cavity of its producer, it is not, strictly speaking, a coprolite. 'Bromalite' is a more general term that can be used about all types of fossilized food material and is often applied when there is uncertainty about the extrusion of a specimen prior to its fossilization (Hunt & Lucas 2012a). Coprolites and other bromalites are often regarded as curiosities without any major importance within the field of palaeontology. They are trace fossils that can usually not be tied to a producer on the level of species or even genera and do therefore not have any application in cladistics. Because of this, vertebrate coprolites are rarely collected and brought home from excavations and only few scientists devote time to describe and interpret these kinds of fossils. However, coprolites are as trace fossils unique imprints of animal behaviour preserved in rock. Thus, understanding coprolites can provide a window into past ecologies not accessible through the study of body fossils alone. A specific palaeoenvironment might be better understood by both studying the shapes and contents of its preserved coprolites along with their history of transport and taphonomy. Faecal shape is dependent on the intestines of the producer but is also influenced by food source and certain environmental conditions. Content is a direct evidence of food source but the degree of fragmentation and gastric damage is dependent on the producer. Trapped gas vesicles, desiccation cracks and traces of coprophagic organisms are all clues that can help establish a depositional environment as for instance desiccation cracks are only found in sub-aerially deposited faeces (Northwood 2005). Vertebrate coprolites may also preserve small material as pollen and seeds, fragile bones or even soft tissue that is normally never preserved. Thus, they have the potential to provide new pieces of data to our usually very fragmentary knowledge of palaeoecologies (Hunt et al. 2012a).

This project presents a short review of coprolitic literature with discussions of terminology and descriptions of the key discoveries dominating the field of palaeoscatology. This is followed by a case study of the coprolitic material brought back from East Greenland in 2012. This material will be described and interpreted using some of the latest methods in palaeoscatology in order to add new data to the interpretation of the palaeoenvironment of East Greenland.

2. Review

2.1. Introduction

Vertebrate coprolites are found in deposits around the world and are known from both the Palaeozoic, Mesozoic and Cenozoic. The oldest putative specimens are from the Ordovician (Aldridge et al. 2006). From Mesozoic deposits, vertebrate coprolites are common in the Cretaceous, locally common in the Jurassic and widespread in the Permo-Triassic where they are often associated with redbeds (Hunt et al. 2012a).

Coprolites have been known since the 19th century where they were first described by William Buckland (1784-1856). He initially recognized cave deposits in Kirkland, England as the prey remains and fossilized scat of Pleistocene hyenas. Few years later, in 1829, he realized the faecal origin of curious pinecone-shaped nodules (at the time known as 'bezoar stones') found in the Jurassic Lias Formation in England. It was then that Buckland coined the term 'coprolite' (Buckland 1829, Duffin 2006). Coprolites have been studied continuously since their discovery but never by an extensive body of scientists and rarely from deposits older than the Palaeogene. Through much of the twentieth century the most important studies performed on coprolites were based in archaeology and focused on human faeces. Archaeologists examined the contents of human coprolites to establish prehistoric diets and identify health issues (e.g. Wakefield & Dellinger 1936).

For long, these methods remained mostly unused by palaeontologists. Not until the 1990's did the coprolitic field expand and vertebrate coprolites older than the Palaeogene were studied more thoroughly (Hunt et al. 2012a). For instance, Chin and co-workers started assessing Cretaceous coprolites focusing on the faecal remains of dinosaurs (e.g. Chin et al. 1998) while Hunt and Lucas started collecting large samples of coprolites for general description, especially from the Triassic (e.g. Hunt 1992, Hunt et al. 1998).

2.2. Terminology

There are various types of coprolites but the spiral are without a doubt the most extensively described. The first studies made by Buckland in the nineteenth century were done primarily on spirally coiled coprolites. Early in the twentieth century, Neumeyer (1904) realized that spiral coprolites could be divided into two main categories. He named the evenly coiled coprolites 'amphipolar' spiral and the ones with coils concentrated towards one end 'heteropolar' spiral. Heteropolar are the most common spiral coprolites throughout the fossil record (Hunt & Lucas 2012b). The heteropolar coprolites can be further divided into 'microspiral' and 'macrospiral' depending on how much of the total length is dominated by coils. If the coils only constitute 50% or less of the length, the specimen is microspiral. If the coils constitute between 50% and 75% of the length, the specimen is macrospiral (Hunt et al. 2007).

Buckland (1829) introduced the term coprolite to describe all fossilized faecal remains but Hoernes (1904) proposed that only actual extruded faeces were termed coprolites while faecal remains that were fossilized still within the intestines were instead termed 'enterolites'. Fritsch (1907) proposed the term 'enterospirae' for the same kind of fossils and later, Northwood (2005) proposed the term 'gastrolite' for food material fossilized specifically within the stomach. Agassiz (1833) had long before introduced the term 'cololite' to describe fossilized intestines. There have been little consistency in the use of these terms among authors and as more terms have been proposed for specific kinds of faecal trace fossils, the terminology needed a thorough revision. Palaeontologists with an interest in coprolites are now working on establishing a constant use of nomenclature in palaeoscatology, while expanding the field in general. In 2012 New Mexico Museum of Natural History & Science published a collection of articles on coprolites (Hunt et al. 2012b). Several of these focus on the history of palaeoscatology and the importance of a consequent terminology. In two articles, Hunt and Lucas provide thorough overviews of the various terms that have been used in palaeoscatology until this point. One article (Hunt & Lucas 2012a) evaluates the terms used to distinguish between the various types of faecal trace fossils. The authors set up an ordered classification of the terms they propose to be use in the future (fig. 1). For instance, all ingested food material fossilized within the body cavity is termed 'cunsumulite'. Depending on the exact position in the digestive system the fossilized material can be either an 'oralite' (mouth region), an 'esophagolite' (digestive system anterior of the stomach), a 'gastrolite' (stomach) or a 'cololite' (digestive system posterior to the stomach). Cololite can be further subdivided depending on the mode of preservation and 'enterospirae' is now used to describe a cololite preserved specifically within a spiral valve.

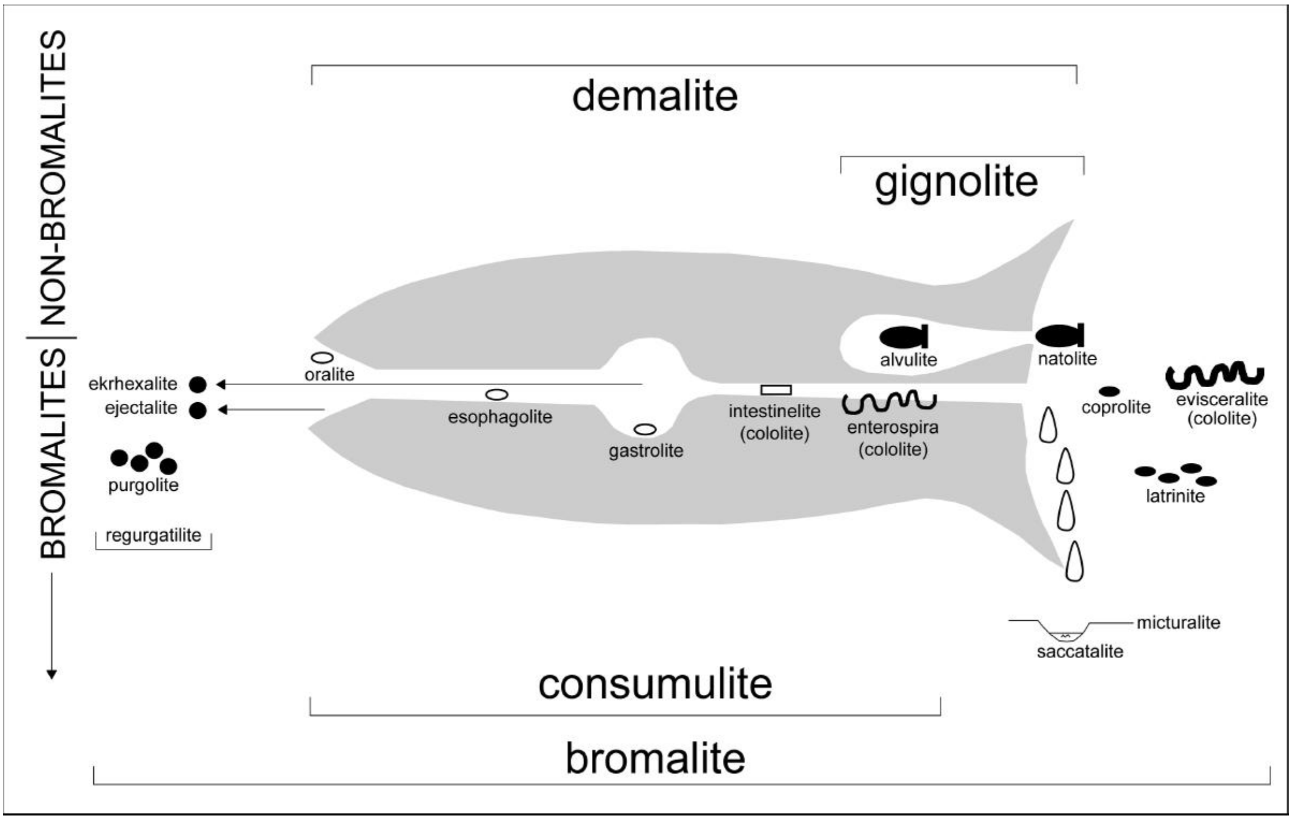

Fig. 1. Classification scheme of bromalites (Hunt & Lucas 2012a).

The other article by Hunt & Lucas (2012b) provides an overview of the various shapes and structures that have been described for coprolites and recent faeces and sets up a system of morphotypes with matching ichnotaxa and possible producers. The authors also discuss the way in which spiral coprolites are depicted in the literature. It has been the general tradition to show the coprolites in lateral view with the coiled end pointing upwards. However, from what is known from recent animals with spiral valves, the end with the tightest coils is likely to be the end first extruded at defecation. The authors recommend a change of practice so that spiral coprolites are depicted with the coiled end downwards to aid a general understanding of the morphology. Furthermore, the ends should be appropriately named according to their original orientation. The end with tight coils is thus the 'posterior' end (or posterior spire) as it pointed away from the producers head at production and the end without coils is the 'anterior' end (Hunt & Lucas 2012b).

Thulborn (1991) applied the terms 'isopolar' and 'anisopolar' to non-spiral coprolites to describe shapes with similar ends and dissimilar ends respectively. Anisopolar coprolites generally have one broad end that was extruded first and one pinched end that was extruded last. The pinched end would, according to Hunt and Lucas (2012b), be the anterior end. Northwood (2005) uses the terms 'initial' and 'terminal' end to describe all coprolites that have a recognizable orientation. The initial end is the one that was first extruded and would for spiral coprolites describe the end with tight coiling. Northwood also distinguishes between a coprolite's 'dorsal' and 'ventral' side when one side is flattened and from resting upon the substrate prior to fossilization. This side that was turned downwards is the ventral side.

2.3. Methods and significant findings in palaeoscatology

Buckland (1829) was a very thorough scientist and did not base his identification of coprolites solely on their morphological resemblance to modern scat. He had samples of coprolite chemically tested, he examined coprolites in cross section to determine their contents and he did actualistic studies by filling intestines of recent sharks with roman cement. It was when the chemical analysis showed that his samples contained large amounts of 'phosphate of lime' (calcium phosphate) that Buckland could draw a parallel between the diet of coprolite producers and the coprolites fossilization potential. Buckland deduced that animals that ingested bones were more likely to leave faeces in the fossil record, as bones themselves can be very durable. Buckland also showed that the coprolite producers had had a bone-containing diet as he found both bone fragments and vertebrae of aquatic reptiles along with scales, bones and teeth of fish in the coprolites. The casts that Buckland made from shark intestines were quite similar to actual spiral coprolites. However, Buckland was convinced that his Liassic coprolites were produced by aquatic reptiles, especially ichtyosaurs, and he deduced that these animals must have had intestines similar to those of modern sharks instead of assigning the coprolites to sharks.

The origin of spiral coprolites has been discussed by numerous authors and various producers have been proposed. Duffin (1979) reviews the literature on the subject and lists all the proposed producers. Besides Buckland's ichtyosaurs, both selachians, actinopterygians, dipnoans, amphibians and reptilians have been proposed as the culprits. Another thing that has been discussed for long is the exact biophysical origin of the spiral coprolites. Are they true coprolites - faeces completely expelled from the body of the producer before fossilization - or are they rather some kind of consumulite - processed food material fossilized within the digestive system?

Williams (1972) argue that at least the heteropolar spiral coprolites are not true coprolites but in fact cololites (as was first suggested by Fritsch 1907). Williams argue that spirally coiled bromalites are food material that have fossilized within the spiral valve found in the intestines of some animals and should be termed enterospirae. In his article, he describes heteropolar spiral coprolites from the Permian of Kansas. In cross section, he shows the presence of what he interprets as mucosal folds that have been preserved from the walls of the intestines. He further compares the fossil specimens with the intestines of recent sharks and finds that the genus *Scyllium* (now *Scyliorhinus* (web source - see reference list)) posses spiral valves that resembles the fossils quite well.

Jain (1983) also describes spiral coprolites in detail and considering what is known about recent animals with spiral intestines valves. In lungfish spiral valves are of the scroll type but their faeces do not form compact pellets - in fact, their faeces tend to unwind shortly after excretion. According to Jain, shark faeces that were more than soft material which quickly dissolve have never been observed. Jain does not conclude whether or not spiral coprolites are true coprolites but find them unlikely to be.

The opposite stance was taken by McAllister (1985) who thoroughly examined the intestines of *Scyliorhinus canicula*, a shark that is actually observed to expel compact spirally coiled faeces. McAllister finds that the processed food material is compressed into a curling ribbon in the spiral valve and as this ribbon passes from the valve into the colon it is wound into the spiral form known from heteropolar coprolites. The material hardens during its movement through the intestines and seems to harden even further while in the colon. The result is that the faecal material can be expelled from the anus without being distorted. Furthermore, he rejects the interpretation of folded microstructure within coprolites as mucosal folds (as proposed by Williams 1972). It is unlikely that parts of the intestine would be preserved between the coils of faecal material and the proposed mucosal folds are also much longer than seen in any recent animals. McAllister does not reject that spiral coprolites can have fossilized as they were still within the body of the producer, but they would then have lied in the colon and not in the valve and should not be termed enterospirae.

Spiral valves are found within the following living vertebrate groups: Agnathans, chondrichthyans, actinopterygians and of the sarcopterygians: dipnoans and actinistians. In fossils, the following groups have been found with preserved spiral valves: placoderms, actinopterygians, dipnoans and actinistians and the identification of the producer of a specific spiral coprolite is rarely possible (McAllister 1985).

Non-spiral coprolites have even more possible producers than the spiral do and to narrow down the possibilities, actualistic studies are of tremendous value. An example is the study done on recent crocodiles by Milàn (2012). By feeding a controlled diet to different species and examining the scat from each individual, Milàn establishes which features are common in all crocodilians and can be used when identifying coprolites. Crocodiles have very effective digestives systems and bones are generally completely disintegrated, whereas partly dissolved hair and feathers can sometimes be found in the scat. Furthermore, the size of crocodile faeces tends to depend on the size of the producer and coprolites identified as fossilized crocodile scat can potentially be used to infer the size of the producer. For the identification of Palaeogene terrestrial coprolites, a work like that of Chame (2003) is invaluable. Chame has collected descriptions and figures of the faeces of important recent mammalian groups from Africa, North America, Europe and North-eastern Brazil to aid the comparative analysis of assumed mammalian coprolites.

The fact that faecal material can pertain its shape long enough for fossilization processes to initiate can seem rather counterintuitive. Buckland (1829) early on suspected that a bone-containing diet was an important factor for the durability of an animal's faeces. Edwards (1973) examined coprolites of a carnivorous origin through x-ray diffraction and found that the mineralogical contents was indeed comparable to that of bones. The minor elements that Edwards found in the coprolites when using x-ray fluorescence (namely Sr, Fe, Y, As and Ba) are also commonly found in bones. As minor elements are easily removed during mineral replacement, the presence of elements associated with bones indicates that these faeces were in fact fossilized by the re-crystallization of minerals already present. However, dung of herbivorous animals has also appeared in the fossil record, though much rarer, and the main factor in the preservation of faeces is not simply the contents of digested bone. Hollocher and Hollocher (2012) examined coprolites using thin section photomicrographs and SEM among other methods. They suggest that one of the important factors in the fossilization of dung is the activity of bacteria. It is usually assumed that rapid burial is necessary to preserve all organic materials but burial alone does not guarantee the fossilization of faeces. In the dung of herbivorous animals, there is always a high degree of bacterial activity as microorganisms degrade whatever organic material is left. Under the right conditions, bacteria will actually aid the precipitation of minerals by changing the chemical composition of their nearest surroundings as they access nutrients. In this way, although the faecal material is being gradually removed on a microscopic scale, the overall shape can be preserved long enough for the long-term fossilization processes to take effect.

As the processes involved in the creation of coprolites become gradually better understood and new technical possibilities are developed, the knowledge that can be extracted from these trace fossils increase. Recently, the advances in ancient DNA methods have made it possible to obtain very specific data from Quaternary coprolites. Wood et al. (2012) have examined dried faeces from the extinct moa that thrived in New Zealand until humans arrived about 700 years ago. Through ^{14}C-dating and DNA analyses, the coprolites can not only be placed in time but their producers can also be distinguished from each other. Furthermore, seeds, pollens and plant remains contained in the coprolites are identified and the combined data is used to reconstruct the ecology of the moa. Wood et al. (2012) refer to the reconstruction of palaeoecologies based on coprolites as coproecology. This type of study combines several scientific fields and methods into a very detailed reconstruction but, of course, only relatively young material of extremely well-preserved condition is appropriate for DNA analysis.

3. Case study

3.1. Introduction

The coprolites gathered on the Geocenter Møns Klint Dinosaur Expedition in 2012 were briefly described by Milán et al. (2012) in a preliminary report. They are the first to be described from the Late Triassic of Greenland and the focus of this project is to present a thorough description of the entire material. The coprolites were all found at a locality at the east side of Wood Bjerg (GPS coordinates: N 71°24.800′, W 22°33.160′)(fig. 2). Here, shales from the basal part of the Late Triassic Kap Stewart Formation is exposed in an outcrop. Most of the faeces were gathered as loose material from the weathered surface but a few pieces were excavated *in-situ* from small profile trenches dug into the sedimentary rock. The expedition had its focus on vertebrate bones and foot prints and the body fossils gathered from the shale deposits at the Wood Bjerg location include bone fragments, vertebrae, scutes and teeth and skull parts of large temnospondyls (maybe capitosaurs, considering the large size and tusk-like teeth), one small hollow longbone, presumably from pterosaur or theropod, a putative phytosaur scute and some yet unidentified teeth (Milán et al. 2012).

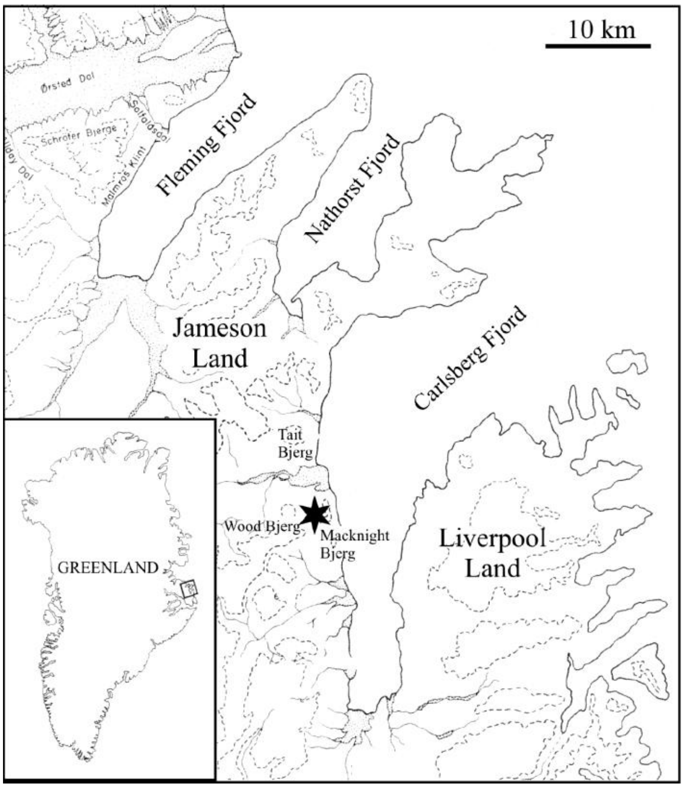

Fig. 2. Locality map showing the site where the coprolites were collected (Milán et al. 2012).

To best reconstruct ancient ecologies, data from as wide a range of sources as possible is preferable. The palaeoenvironment of East Greenland in the Late Triassic has already been reconstructed via descriptions and interpretations of the sedimentary deposits (e.g. Dam & Surlyk 1992, 1993, Clemmensen 1976), plant fossils (e.g. Pedersen & Lund 1979) and vertebrate fossils (e.g. Milan et al. 2012, Jenkins et al. 1994). The focus of this project is to describe the coprolites from the Kap Stewart Formation in detail with regard to morphology and contents. In this way their possible producers may be identified and a new piece for the local palaeoecological puzzle can be created. As Triassic coprolites have not earlier been found in Greenland, this project will also make material from a new area available for global studies in palaeoscatology.

The material was examined and described through visual characterization and all important features were collected for data analysis. A number of specimen were sampled in order to have their composition examined using x-ray diffraction. Both coprolite and sediment samples were included in this mineralogical analysis. This was done, not only to examine the coprolitic mineral contents, but also to establish if coprolites are mineralogically distinct from their surrounding sediments and to see if it is possible to differentiate between coprolites and sediment filled burrows.

3.2. Geological context

The coprolites of the present study come from sediments of the Kap Stewart Formation exposed at the east side of Wood Bjerg in East Greenland, Jameson Land. They were collected from an approximately 10 meter thick unit of shaly mudstone located some 30 meters above the base of the formation (Milan et al. 2012).

The Kap Stewart Formation is part of the Late Triassic-Early Jurassic Jameson Land Group, which is distributed across the whole of Jameson Land. The Kap Stewart Formation overlies the Fleming Fjord Formation of the Scoresby Land Group (Late Triassic) and is overlain by the Neill Klinter Formation (Pliensbachian-Toarcian) (Surlyk et al. 1973).

Surlyk (2003) has later elevated the Jameson Land Group to Supergroup level and the Kap Stewart Formation to group level. He has subdivided this new Kap Stewart Group into the Innakajik Formation, the Primulaelv Formation and the Rhætelv Formation according to their depositional environment. However, the specific sedimentary succession of the exposure from which the coprolites were collected has not been thoroughly described or divided into units. It is therefore not known with accuracy from which of the formations in the Kap Stewart Group the coprolites originate. In this project, the Kap Stewart sequence will continue to be treated as a formation in accordance with all other sources to avoid confusion.

The Kap Stewart Formation was first dated by Harris (1937) based on macroplant fossils gathered from sediments exposed in the southern part of Jameson Land. Later, palynological analysis based on micro-plant fossils was applied to obtain a stronger dating. Samples were taken from cliffs along the western shore of Hurry Inlet which holds a rich palaeoflora. The flora in the sediments from East Greenland is comparable to that of NW Europe from the same period. It can be divided into 2 zones where the lower is from the Rhaetian (latest Triassic) while the upper is from the Hettangian (earliest Jurassic) (Pedersen & Lund 1979). As the coprolite-bearing unit lies close to the base of the formation, the coprolites are ascribed to the Rhaetian age. The exact positions of the boundaries of the Rhaetian stage is still disputed and the extent of the stage has thus not yet been clearly defined in absolute time. One possible chronology is that of Muttoni et al. (2010) that is based on marine sediments exposed in the Alps. The authors compare biostratigraphic and magnostrategraphic stages and place the lower boundary of the Rhaetian between ca. 207 Ma and 210 Ma. The upper boundary is placed at 202 Ma, giving the stage a length of about 5.5-8.5 myr. Ogg et al. (2013) have later argued for a Rhaetian stage of an approximately 8 myr span with a lower boundary at 209.5 Ma and an upper boundary, in part defined by the CAMP (Central Atlantic Magmatic Province), at 201.3 Ma.

The Kap Stewart Formation comprises intermingled sandstones and mudstones of terrestrial origin. The sequences described from the south of Jameson Land contain both mudstones, conglomeratic sandstones and sand and silt stones with abundant plant remains and both rootlet horizons and coal seams can be found. In contrast, the sequences from the northern part contain much less plant remains and the mudstones, which are more abundant, are sterile. The generally extensive lamination of the mudstones with thin laminas indicates a depositional environment with low energy and anoxic conditions at the sediment/water interphase (Clemmensen 1976).

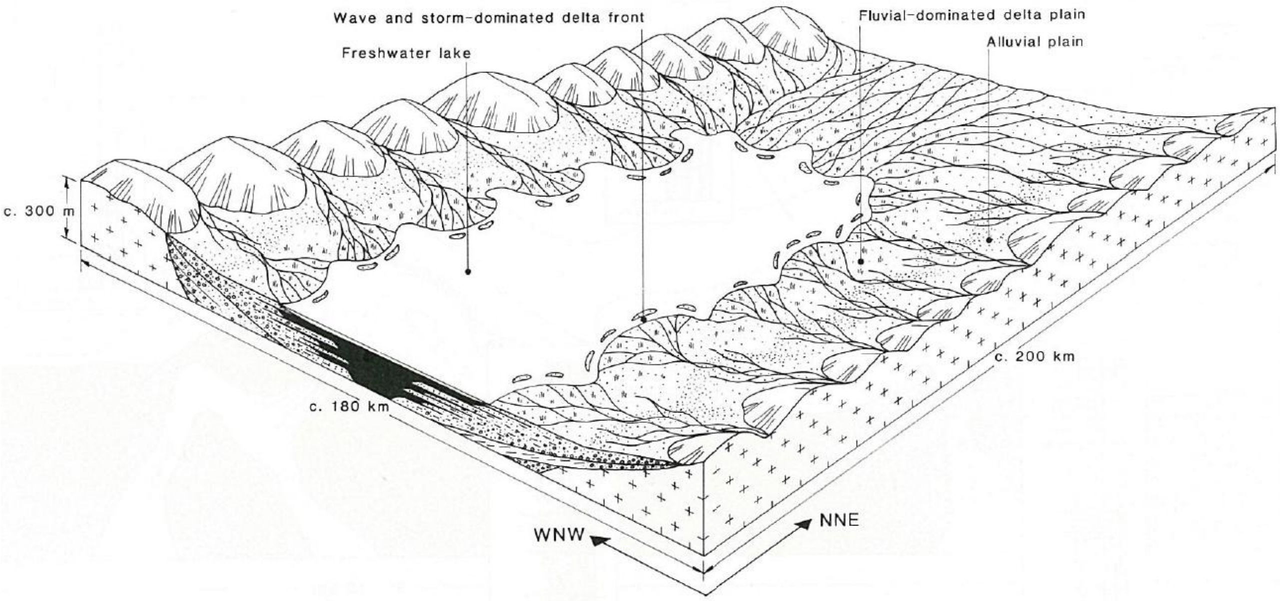

Fig. 3. Depositional reconstruction for the Kap Stewart Lake (Dam & Surlyk 1993).

The sediments are interpreted as the deposits of a perennial lake with large delta systems on its shores and alluvial systems beyond (fig. 3). The lake was extensive and may in periods have covered more than 12,000 km^2. It lay in the southern end of the East Greenland rift basin which formed as Pangea started to split apart to later form the Atlantic Ocean. Lake margins appear to have be controlled by major fault systems to the north, east and west, while nature of the south border is less known. The lake formed in the Rhaetian when the regional climate became temperate and the conditions changed from semiarid to humid. This climatic change was a result of the northward drift of the entire Laurasian continent (Dam & Surlyk 1992, 1993). The Jameson Land area lay at a paleolatitude of approximately 40.9°N around 209 Ma. In the period between 235 Ma and 200 Ma the Laurasian continent drifted northward with a speed of about 0.6 ° pr. million year (Kent & Tauxe 2005).

The Kap Stewart lake experienced large cyclic changes in water depth as is seen from the sudden shifts to coarser material in the fine-grained open lacustrine mudstones. The laminated mudstones were deposited under conditions of high-stand where the lake must have been several tens of meters deep - possibly over a hundred meters deep. Anoxic conditions formed on the lake bottom in these periods as the deep waters became stratified. Occasional horizons with burrows are seen in the sedimentary sequence as evidence of short periods of more oxygen rich conditions during storms. In periods of low stand, the lake was as shallow as 15 meters or less and deltaic sandstones were deposited far into the basin. The closest modern analogue to the Kap Stewart lake is possibly the East African rift lakes which can also be very deep and seem to have experienced large fluctuations in lake level in the past. The changes in water level that have been implied from the Kap Stewart Formation seem to correlate to known eustatic sea level changes from the same period. If lake level and sea level can in fact be calibrated, absolute ages can be tied to horizons in the lake sediments. A very tentative dating of the sedimentary sequence has given the following ages: Basal sequence boundary: 215 Ma. Maximum flooding surface between the two floral units (as defined by Pedersen & Lund (1979)): 211 Ma. Upper sequence boundary between the Kap Stewart Formation and the Neill Klinter Formation: 195 Ma (Dam & Surlyk 1992, 1993).

The coprolites examined in this study are minimum 201.3 million years old but are likely to be about 207 million - or perhaps as much as 215 million - years old depending on which ages are found to be most correct for the Rhaetian stage.

3.3. Methods

3.3.1. X-ray diffraction

X-ray diffraction analysis is performed using a x-ray diffractometer. X-rays are generated in a cathode ray tube. Rays are sent through a ‘filter’ – a monochrometer – to block out most wavelengths and ensure a pure signal. Filtered rays hit a powdered sample and are diffracted from the various atomic planes inside the minerals. At certain angles the rays are reflected and can reach a detector at the opposite end of the diffractometer. X-rays are only effectively reflected when the rays stay in phase during the diffraction. This happens when the wavelength of the x-ray (λ) and the angle of incidence (θ) corresponds to the distance (d) between atomic planes in a mineral as described by the Bragg equation (see Nesse 2000, fig. 8.4):

$$n\lambda = 2d \sin \theta$$

The x-ray source is stationary but the detector moves in relation to the sample in order to detect rays reflected into different directions. The detector covers all angles of 2θ between 5° and 70° as these normally encompass all first order reflections.

Sample:

A small amount of powdered rock sample is placed in a sample holder. The holder is a round disc with a depression in the middle. The powder is not glued to the disc but gently stuffed into the depression and smoothened on top. The minerals in the powder are lying mingled and juxtaposed between each other with internal mineral planes pointing in all directions. In this way, the travelling x-rays will have a higher chance of meeting a mineral plane in a proper orientation.

X-ray diffraction:

As the ray hits a mineral in the sample, it will be effectively diffracted only if the angle of incidence 'fits' the internal build-up of the mineral. The distance between two atomic planes in the mineral structure determines which angles of incidence will give refractions and as all minerals are different, the detection of refracted angles provides a mean for determining the minerals present in a sample.

Data:

All the diffracted x-rays counted by the detector are collected by a computer and saved in a file. The data is presented in a chart where one axis is the measured angles (2θ) and the other axis is the number of counts (intensity as 'counts pr. second'). Each mineral is identifiable from the location and size of its specific intensity peaks. In a sample of mixed minerals, the chart can be very complex. Through computer analysis, one mineral can be identified and its specific data removed from the file thus simplifying the identification of the rest. The minerals are identified through comparison with diffraction data of known mineral standards (Nesse 2000 p. 160-168).

In this project many minerals are only identified to group level. The various mineral structures within each group can be very similar and precise identification is rarely possible without a supporting chemical analysis (for instance using x-ray fluorescence). It is common to use one or two representatives for each mineral group in the interpretation of x-ray diffraction data. For instance, muscovite is used as representative for the micas. This means that the identification of muscovite in a sample proves that micas are present but not necessarily the specific mineral muscovite.

3.3.2. Polished sections

Coprolites were polished using a Knuth rotor from Struers. As the material was already quite fragmentary the coprolites were not cut in half prior to polishing. Only one coprolite (H007) was sectioned using a diamond saw. Coprolites were polished using the three grit sizes: 80, 180 and 800 (CAMI).

3.3.3 Visual investigation

A stereo zoom trinocular was used in addition to a hand lens (x10) and bare eye investigation. A vernier caliper was used to measure the material. The caliper could measure objects down to 1mm with precision. However, in the material investigated in this project, various features that needed description were smaller than 1mm. In these cases, where the sizes had to be estimated and there was a large risk of imprecision, object were only ascribed to three sizes: 0.5 mm, 0.2 mm and 0.1 mm. These sizes are mostly used as a means of ranking and are not reliable measurements. 0.5 mm object were fairly easy to estimate as filling half the distance between millimetre marks on the vernier caliper. Object that did not fill much more than a millimetre marks on the vernier caliper were judged to be 0.1 mm. Objects larger than 0.1 mm but obvious smaller than 0.5 mm were assigned to a size of 0.2 mm.

3.4. Material

3.4.1. Introduction

The material consists of more than 300 coprolites and coprolite fragments along with 10 small sedimentary concretions, 6 pieces of loose fossil bone material, 4 pieces of fossilized burrows and 3 sedimentary blocks that contain *in situ* coprolites. Only very few coprolites are intact and a large fraction of the material is too fragmentary for reliable diagnostic purposes. All coprolites and coprolite fragments were measured and described. Measurements were taken in three planes describing a maximal diameter, a flattened diameter if present and the preserved length of the coprolite. Diameter was taken perpendicular to the extrusion direction while length follows the inferred extrusion direction. Some coprolites that are flattened and have an oval cross section are described using two perpendicular orientated diameters. Coprolites are considered flattened when the two measured diameters deviate by at least 2 mm. One coprolite with a diameter of only 9 mm is considered flattened even though the short diameter is 8 mm. The specimens were measured to the nearest half millimetre which means they are automatically is sorted into small groups even though they may be slightly different sizes. Measurements are all collected in appendix 1.

50 of the collected specimens were too poorly preserved to be reliably identified and were left out of the study. This unnumbered material consists of specimens both with and without visible food remains along with samples of all the textures seen in the numbered material. The largest piece is 43 mm in diameter but many pieces are less than 10 mm. Some of the small pieces are possibly sedimentary debris. Hopefully, the unnumbered pieces do not contain any biases in regard to texture, structure or original coprolite size. Of the three coprolites embedded in sedimentary matrix one was measured, polished, described and used in the x-ray diffraction analysis while the other two were initially measured and described but later excluded from appendix 1 and further analysis. Eleven coprolites in the material have earlier been described and numbered (MGUH30357-MGUH30367) by Milán et al. (2012). Specimens that are described in this project are named as follows:

Coprolites: H001-H313 ('H' is taken from the author's last name due to joking egocentrism).

Burrows: N1-N4 ('N' is for 'none-coprolitic').

Coprolites embedded in sediment and not included in analysis: SED1-SED2 ('SED' is for 'sediment').

A large part of the material had a cross section polished in order to access the interior. Both because the structural built-up and the contents of food remains in coprolites are more obvious in cross section, but also because the material generally is weathered to a degree where surface features are obscured and fossil fragments are lost. In order to preserve the material as much as possible, all specimens were polished as little as possible taking advantage of already broken surfaces. This means that they are not necessarily polished in an optimally oriented plane (i.e. cross section perpendicular to the longitudinal axis). Some coprolites are polished in planes nearing a cut along the longitudinal axis. This means that it is not sensible to compare specimens directly on the basis of the number of fossil inclusions visible in the polished surface. For this reason, the content of fossil fragments in each specimen is not given in exact numbers but in a valued estimate (no, few, some or numerous fragments). These estimates are very imprecise but will to suffice for this project.

As coprolites were polished, several fossil fragments turned up in specimens that were thought to be fossil-free. There is a high probability that fossil fragments are easily overlooked in a material that is weathered to the degree that the present material is.

3.4.2. Coprolites

Coprolites were examined thoroughly and their traits were noted in a excel sheet (see appendix 1). The specimens are each described in terms of size, shape, structure, texture, contents and preservation. Each trait is restricted to as few possible variants as possible in order to enable comparison between specimens and to help recognize trends.

Size:

The best way to describe coprolite size is by measuring the volume of each specimen. Length and thickness are highly variable traits even in specimens produced by the same individual and volume is a more reliable trait for comparison (Chin 2002). However, the state of the present material makes it impossible to estimate the original volume of more than a few specimen. Instead, the maximal diameter is used as it is a relatively well-preserved trait even in very fragmented specimens.

Shape:

All coprolites of the present material can be described as intermediates between 'cylindrical', 'round' and 'bulbous'. 'Bulbous' is a 'catch-all' category for coprolites with unidentifiable shapes. Many specimens are so fragmented that only a slice with a round shape is preserved. These are all included in the category 'cylindrical' as that is a quite common coprolite shape but there may of course be misplacements on this account.

Structure:

Animals can have very different digestive systems and thus equally different faecal products. Some produce faeces that consist of intricate overlapping layers while others produce simple masses without any structures. When faeces are fossilized these structural differences are sometimes preserved in great detail. In the present material coprolites are seen with the following three structural built-ups: few to many irregularly wrapped layers (fig. 4), one continued spirally coiled layer (fig. 5) and structureless mass. A few spirally coiled coprolites are preserved well enough to be identified as true spiral coprolites while many are too fragmented and are merely noted as having a 'coiled' structure. As the material is strongly weathered there is a high possibility that some original structures have been obscured and that there is a certain degree of misplaced coprolites. It is especially coprolites with no apparent structures that may in reality belong with the spiral or irregularly wrapped specimens. Likewise, coprolites that are identified as irregularly wrapped from minor fragments could in rare instances be spiral/coiled coprolites.

Fig. 4. Specimen H052 (irregularly wrapped coprolite).

Fig. 4. Specimen H052 (irregularly wrapped coprolite).

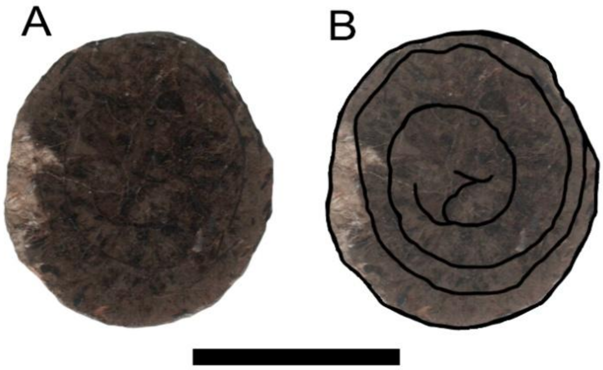

Fig. 5. Specimen H006.A: Photo. B: Interpretational sketch. Scale bar: 1 cm.

Texture:

The coprolites of the present material contains a large number of specimens with a unique texture not earlier described (pers. comm. Jesper Milán 2013). The specimens consists of small pellets (up to 6 mm wide) that are almost white on weathered surfaces and black in the centres (fig. 6).

Fig. 6. Specimen H187 (nodular texture). Scale bar: 1 cm.

The pellets are rounded on the surface of the coprolites but angular where they are squished tight up against neighbouring pellets implying that they were initially quite soft. Some specimens only contain pellets in limited regions and have a different texture in the rest of the volume. Pellets can also be found as single scattered bodies floating in a matrix of different texture. As pellets have various shapes and do not always have well-defined borders when seen in cross section, the term 'nodular' is used here to describe a texture consisting of rounded bodies of material. The other textures seen in the material are 'massive' and 'swirly'. 'Massive' is a fine-grained texture without any pattern of colour difference. 'Swirly' is fine-grained as well, but the texture consists of swirls and twirled patterns of dark and light material. Some specimens are made up of a single texture but more often specimens are made up of a mix of two textures and for each specimen it is noted which texture is most dominant. For instance specimen H026 is noted in appendix 1 as 'massive' which means it only consists of massive material. Specimen H113, on the other hand, has a 'swirly-nodular' texture which means that swirly material dominates but there are some nodules or pellets present. When a specimen is all 'nodular' it consists of pellets.

<u>Contents:</u>

For all specimen it is noted whether or not any fossil food remains are present. If fossil fragments are present the amount is estimated and the largest fragment is measured. The amount of fragments is described by assigning each specimen to one of four categories. These are: '0' for fragment-free specimens, '1' for specimens containing only a few fragments, '2' for specimens containing some fragments and '3' for specimens containing numerous fragments. This method is quite imprecise as category 1 to 3 have open definitions which are prone for large overlap. However, it is not possible to compare the contents of specimens directly by count as they are rarely cut in the same plane. The presence of scattered nodules is also noted and the largest nodule is measured.

<u>Mineral grains:</u>

The contents of mineral grains on the surface and in the interior of coprolites is also examined. On the surface some mineral grains can be recognized as adhesive material that was attached to the specimen prior to fossilization. In the interior some mineral grains can be recognized as mineral in-filled pore spaces. Some mineral growths are however not formed in original pores but rather in holes that appeared later because original material was removed. Fragments of food can also be removed during fossilization. Here, minerals that appear to have grown inside or in the surface of the coprolite sometime after initial burial are noted. Adhesive material is difficult to recognize when minerals have grown in and on the coprolites during burial. However, mineral grains on the surface that appear rounded are interpreted as sand grains that got stuck to the faecal mass prior to burial and fossilization.

<u>Preservation:</u>

The preservation of each specimen is noted in appendix 1 as the number of ends preserved, the colour of the surface and the interior and the thickness of eventual alternation rims. The alternation rims are divided into dark and light rims. A dark rim is the course of chemical alteration that took place during the fossilization and continued burial of the coprolite. A light rim is the result of weathering processes that attacked the surface of the coprolite as it lay exposed to the elements.

3.4.3. Burrows

During the description and sorting of the material, three cylindrical specimen (N2, N3, N4,) were found to be somewhat different from the rest of the material and it was hypothesised that they were in fact fossilized burrows. They are preserved as short, flattened and very similar pieces with obliquely broken ends and a peculiar creased surface. The creases lie at an angle of 60°-70° to the longitudinal axis. There are also thin and tightly-spaced longitudinal lines that run across the creases - a trait not seen in any other specimens. Polished sections of N2 and N3 revealed grainy and structureless interiors that support a burrow origin. Another specimen (N1) was initially thought to be a coprolite but the polished section revealed a grainy interior similar to that of N3 and N4 and it was instead included with the burrows. The four burrows have maximal diameters of 19-20 mm and all have a flattened diameter of 16 mm. The high degree of similarity indicates a similar origin and N2, N3 and N4 could even be fragments of one large burrow.

3.4.4. Fossil fragments in coprolites

There are fossilized food remains in 236 coprolite specimens. Most of these food remains are too fragmented to be identified but some specimens contain fragments of considerable size. The largest fragments found are 10 mm long. Mostly fragments of 3 mm or more are examined here. Generally, the fossil fragments in the coprolites of the present material are small and poorly preserved. The fragments that sit in the original coprolite surfaces are weathered and their structures are often worn away. The fragments that lie within the coprolites are visible in broken surfaces and polished sections. In the broken surfaces the conditions are mostly the same as on the coprolite surfaces. Fragments exposed in polished sections are not damaged by weathering but on the other hand each fragment can only be examined from one randomly cut cross section. It has not been attempted to free any fragments using acids (as in Northwood 2005). There are at least four main shapes recognized in the fossil contents of the coprolites of the present material:

- Slim to lenticular bodies that are often curved and sometimes have wavy outlines. These shapes can be tiny or large and have lengths of up to 10 mm. They are seen in cross sections.
- Flat rectangular scales with a triangular point on one of the short sides and a matching indentation on the opposite short side. The scales have lengths up to about 4.5 mm. They are seen on the surfaces (fig. 7).
- Thick bodies that are triangular to quadratic and appear to be concentrically built (fig. 8). These are seen in cross sections and on surfaces. In H313 there are several shapes of thick bodies, some are almost cylindrical and can be up to 8 mm long (fig. 9).

- Tiny scales of about 1 mm that link together in rows that are up to about 6 mm long. These are only found for certain on the surface of H075. The individual pieces appear flat and each has a central groove that connects with the one on the scale in front. The pieces are not rectangular as the length is displaced along the central groove so that the pieces are like tiles that fit perfectly together (fig. 10).

The slim lenticular bodies and the thick rectangular bodies are possible related and rather the endpoints in a spectrum of shapes than separate types. There are some fragments that have residues of black coating preserved on their surfaces. This coating sometimes preserves short, narrow and tightly spaced grooves that run from the edge and towards the central ridge and has an appearance slightly like a comb (fig. 11-12). It is mostly on the surface of the coprolites that these coated fragments can be seen. The shapes of the fragments are often obscured because of poor exposure or weathering but they can be at least 4 mm long. In specimen H006 there are almost quadratic scale of about 1x1 mm with thick dark brown to black coating. These are some of the smallest scales that preserve coating.

Fig. 7. Specimen H009. Detail of flat rectangular scales with a triangular point.

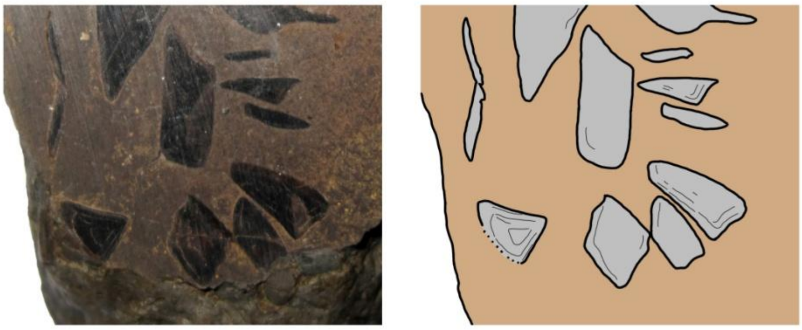

Fig. 8. Specimen H029. Detail of thick triangular to quadratic scales that appear concentrically built.

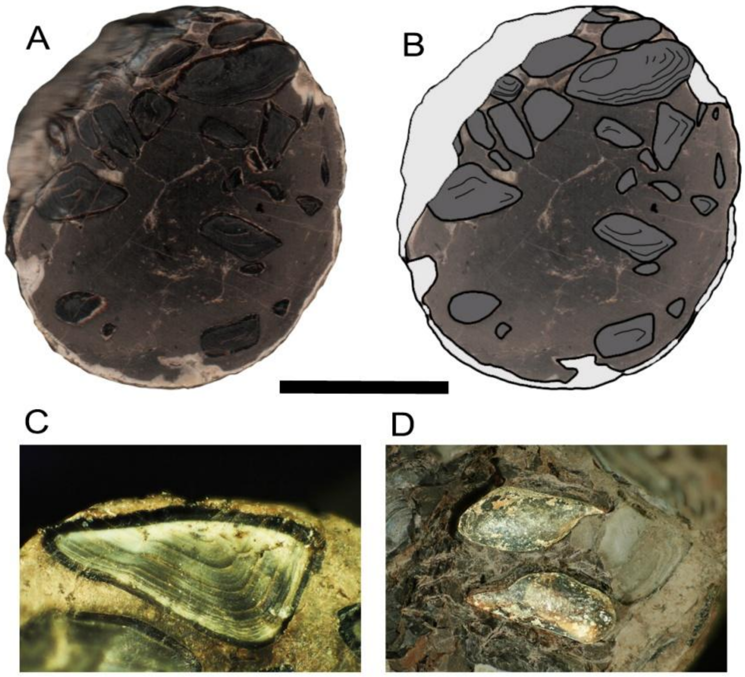

Fig. 9. Specimen H313.
A: Photo. B: Interpretational sketch. C: Concentrically built fragment (photo by Werner Schwarzhans).
D: Cylindrical fragment are highlighted (photo by Werner Schwarzhans).
Scale bar: 1 cm.

Fig. 10. Specimen H075 (round coprolite) with interpretational sketch of scales. Scale bar: 1 cm.

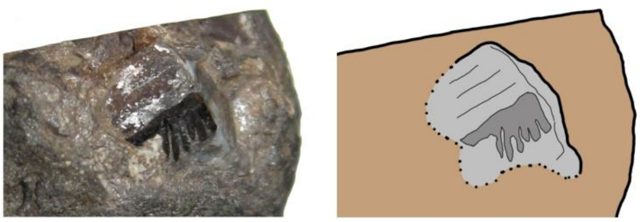

Fig. 11. Specimen H254. Detail of scale with furrowed coating.

Fig. 12. Specimen H043. Detail of scale with furrowed coating.

3.4.5. Loose fossil fragments

Dermal bone:

The material contains six fragments of dermal bone. Five of the fragments are shallow while one is thick. Largest shallow fragment measures 21.5x18x5 mm. One surface has a pattern of shallow closely-spaced lines that converge slightly towards on end. The other side of the bone fragment is mostly smooth but has a few irregular lines following the general pattern on the other side. The interior of the fragment is porous.

The thick fragment is 33 mm long, about 14 mm wide and 19 mm thick. One surface has a pattern of uneven, windy and diverging ridges that run in a general direction following the short axis. On the other side of the fragment, scattered lines run in the same direction.

Shells:

Shells on sediment blocks: One is 20 mm long and 10.5 mm wide. The shell appears flat. It has an oblong shape with rounded ends. The umbo sits about 5 mm from one end. Another shell is 4 mm long, 2 mm wide. It is also oblong with rounded ends. The umbo is about 0.5 mm from one end.

Sediment with imprints of possible shells: Largest imprint is 16 mm long and 8 mm wide. The imprint has a quite flat surfaces without much relief or pattern. Possible umbo is visible at one end.

Bone fragments:

Bone fragment in sediment: 26 mm long and 19 mm wide. The fragment has a cylindrical shape with a smooth surface and a slight decrease in diameter towards one end. Cross section: bean-shaped with a thickness of about 3 mm. Interior is slightly porous.

Fig. 13. Tooth identified as belonging to the shark *Rhomphaiodon minor*.

Tooth:

On the other side of the sediment with bone fragments there is a black shark tooth (fig. 13). The tooth is about 3 mm wide and 2 mm high and partly covered in matrix. The root is large and bulges out below the crown. The crown leans slightly forwards over the root which could indicate that the exposed side is the lingual side (the 'backside'). The crown consists of three separated cusps (there might have been one more lateral cusplet that have been lost). The central cusp is about 1 mm tall and the two flanking cusplets are half the height - one is almost entirely hidden in sediment. The central cusp is slightly rounded at the tip. The crown bears deep ornamentation ridges that are running from the apex of the cusps to the base. On the root very short furrows run in the same direction as the crown ornamentation.

Imprint:

Sediment with imprint of large tooth or part of dermal bone: The imprint is 19 mm long and about 10 mm wide at one end. The imprint is concave along the short axis (like the print of a cylindrical shape) with a depth of perhaps 2 mm. There are closely-spaced lines running the length of the imprint.

3.5. X-ray diffraction analysis

3.5.1. Introduction

X-ray diffraction was carried out on three occasions using different specimens. First attempt at determining the coprolitic mineralogy was made in the summer 2013 before the material had been sorted in any way. The analysis was done on three randomly selected pieces that were labelled "white", "brown" and "blue" according to colour. The pieces were only a few centimetres large each and may not have been determinable originally but, unfortunately, they were not described prior to sampling. The three specimens were later described based on the fragments that were left after the analysis. However, only little could be made out and the structure is indeterminable for all three specimens.

The second x-ray diffraction analysis was carried out in May 2014 on five described and numbered specimens. The four are identified as coprolites (H026, H096, H199, H228) while the fifth is an assumed fossilized burrow (N4). The coprolites were chosen to represent different features of the material: Structureless with fragments (H096); Irregularly wrapped with fragments (H026); coprolite consisting of pellets (H228). The specimen H199 is a pellety coprolite embedded in a block of sediment (fig. 14). Both coprolite (H199-C) and sediment (H199-S) was sampled for the mineralogical analysis. Care was taken to sample the centre of each specimen in order to avoid the most weathered material.

Fig. 14. Specimen H199 (nodular coprolite imbedded in sediment).
Photo and interpretational sketch.

In August 2014 a third x-ray diffraction analysis was attempted on intact specimens instead of powdered samples. The aim was to determine the mineralogical composition of the fossil food remains within the coprolites. Each specimen was mounted in the x-ray diffractometer so that the food remains in question lay as close to the central measuring area (of about 1 cm^2) as possible. Care was taken to mount the specimens so the measured area was horizontal and at level with the edge of the sample holder. Normal procedure is to rotate a sample during measuring but here a manual program was run to keep the specimens stationary. Four coprolites (H029, H045, H075, H313) were analysed.

3.5.2. Results summer 2013

"White":

The piece appeared to be a broken slice of a cylindrical coprolite. The weathered surface is white to yellowish while the freshly broken surfaces are dark brown. The texture is possibly related to the nodular type described from the material. There are numerous small black fossil inclusions that have been whitened on the weathered surfaces. There is one larger inclusion of yellowish and clear mineral present.

"Brown":

The piece appeared to be part of a cylindrical coprolite. It could possibly have been a damaged end before it was broken for analysis. It had a rather rusty appearance. The broken pieces are brown on the surface and black in the interior. The pieces have an overall grainy appearance, but one slim black fossil inclusion is present.

"Blue":

The piece was somewhat indeterminable even before breakage, but was possibly part of a short bulbous to cylindrical coprolite. The surface is blue while the interior is almost black. There are a few fossil inclusions of about 1 mm present.

The x-ray analysis found fluorapatite, quartz and clinochlore in the samples of all three specimens "white", "brown" and "blue". Fluorapatite is used as representative of apatites and its diffraction pattern is nearly indistinguishable from that of hydroxyapatite. Apatites are important minerals in vertebrate bone, teeth and scales that is often preserved in fossilized bones and in coprolites of carnivorous origin (Kemp 1984). Quartz is a very common mineral in many settings and can be present in coprolites either as sand grains (eaten material or adhesive material) or as a secondary mineral that has in-filled pore spaces. The identification of clinochlore shows that there are clay minerals present in the samples. These can both be minerals of the chlorite group or the smectite group. Clay minerals are not surprising findings in material that have been subjected to high degrees of weathering. In the "white" sample kaolinite was also found, another clay mineral that is also related to the weathering of other minerals. In the "brown" sample, in addition to fluorapatite, quartz and clinochlore, there was found carbonates (in the form of manganesian calcite), feldspars (in the form of albeit and microcline) and micas (in the form of muscovite). Carbonates can very well be related to shell material in a coprolitic sample. Feldspars are the most common minerals in the Earth's crust and can be present in coprolites as sand grains. Micas are common minerals but they are easily weathered and in sedimentary rocks they are mostly found in sands that have not been transported far from the source area (Nesse 2000).

3.5.3. Results May 2014

The samples examined in the second x-ray diffraction analysis had the following characteristics and identified minerals:

H026:

The material acted in splintery way when fragmented using a hammer and the grains had a crispy feeling when powdered using mortar and pestle. Grains sort of 'exploded' when pressure was put on them. The fragments had a flint-like appearance.

Minerals: Fluorapatite, clay minerals (in the form of clinochlore), carbonates (in the form of magnesiumcalcite).

H096:

The material acted in a splintery (or crispy) way under the pestle.

Minerals: Fluorapatite, clay minerals (in the form of clinochlore), carbonates (in the form of magnesiumcalcite), quartz.

<u>H228:</u>

The material acted splintery under the hammer. It had a black and texture-less look. Splintery under the pestle.

Minerals: Fluorapatite, clay minerals (in the form of clinochlore), carbonates (in the form of magnesiumcalcite).

<u>H199-C:</u>

The material acted in a splintery (or crispy) way under the pestle.

Minerals: Fluorapatite, clay minerals (in the form of clinochlore), carbonates (in the form of magnesiumcalcite), quartz.

<u>H199-S:</u>

The material acted more softly under the pestle than the other samples. The grains gave way in a more gradual way when pressure was put on them.

Minerals: Quartz, feldspars (in the form of microcline and albite), clay minerals (in the form of clinochlore), micas (in the form of muscovite).

<u>N4:</u>

The material was very hard and had to be fragmented into very fine pieces by hammer before it could be processed under the pestle. It acted in a crumbling way under the pestle.

Minerals: Quartz, feldspars (in the form of microcline and albite), clay minerals (in the form of clinochlore), micas (in the form of muscovite), lepidocrocite, pyrite.

In all four samples that were taken from specimens identified as coprolites the common minerals are fluorapatite, carbonates and clay minerals. Specimen H096 and H199-C also contain quartz that is likely to be from in-filled pore spaces as these were described from both (see appendix 1).

In the specimen identified as a fossilized burrow there was not found either fluorapatite or carbonates. This correspond well with a non-coprolitic origin. The presence of pyrite can however indicate biological activity as this iron-rich mineral is often associated with organic material when found in sedimentary rocks. Lepidocrocite is an iron hydroxide (rust) that forms when iron-rich minerals are weathered and its presence in association with pyrite is not surprising (Nesse 2000).

Both the suggested burrow and the sampled sediment consist of quartz, feldspars, clay minerals and micas while neither fluorapatite or carbonates are present. It is reasonable to conclude that burrows from the Kap Stewart Formation are generally mineralogically distinct from coprolites.

3.5.4. Results August 2014

H313:

The specimen was polished on one end for the sake of x-ray analysis. It was mounted so measurements could be taken from the polished section. Two attempt were made with slightly different orientations of the specimen to ensure that fossil fragments were included. Both runs gave identical patterns that were identified as that of fluorapatite.

H075:

The specimen was mounted to measure on the fossil fragments exposed in the side. The data collected contained no peaks and no minerals could be identified.

H045:

Measurements were made on the polished section. The resultant pattern was identical to that of H313 and identified as fluorapatite.

H029:

Measurements were made on the polished section. The resultant pattern was similar to that of H313 and H045 but the peaks were lower and wider. It was identified as fluorapatite with a somewhat low crystallinity. A low crystallinity can either be an original structural trait or a result of degradation of the crystalline structure during chemical weathering.

3.6. Data analysis and results

3.6.1. Introduction

There are 328 named specimens described in appendix 1. Of these, 290 specimens had a cross section polished while 38 specimens remain unpolished. When coprolites have not been polished it is either to preserve their shape or their contents. All the specimens named by Milàn et al. (2012) are part of the collection at Geological Museum of Copenhagen and are preserved. A few specimens were not polished due to time constraints. Three specimens, H225, H228 and H309, are weathered to the extent where their diameters, lengths and shapes are obscured. H309 and also H311 have unknown structures. The four specimens are excluded from analyses that concern these traits. The four specimens identified as burrows are excluded from all analyses. The data is examined through column diagrams, pie charts and scatter diagrams which are all described in detail in appendix 2.

Coprolite size:

Coprolites are measured in three planes: length, wide diameter and flattened diameter. The wide diameter is used as a representative of coprolite size. All measurements are made to nearest half millimetre. In this material, coprolites have diameters between 7.5 mm and 48 mm. The amount of specimens of each possible diameter forms a normal distribution (see fig. 15). The most common diameter is 19 mm. 95% of the coprolites have diameters between 12 mm and 30 mm (both values included). If the window is narrowed to 16-26 mm (both values included), 75% of the coprolites are still included. The four burrows that were found in the material have diameters of 19 mm to 20 mm which is why they were easily misinterpreted as coprolites.

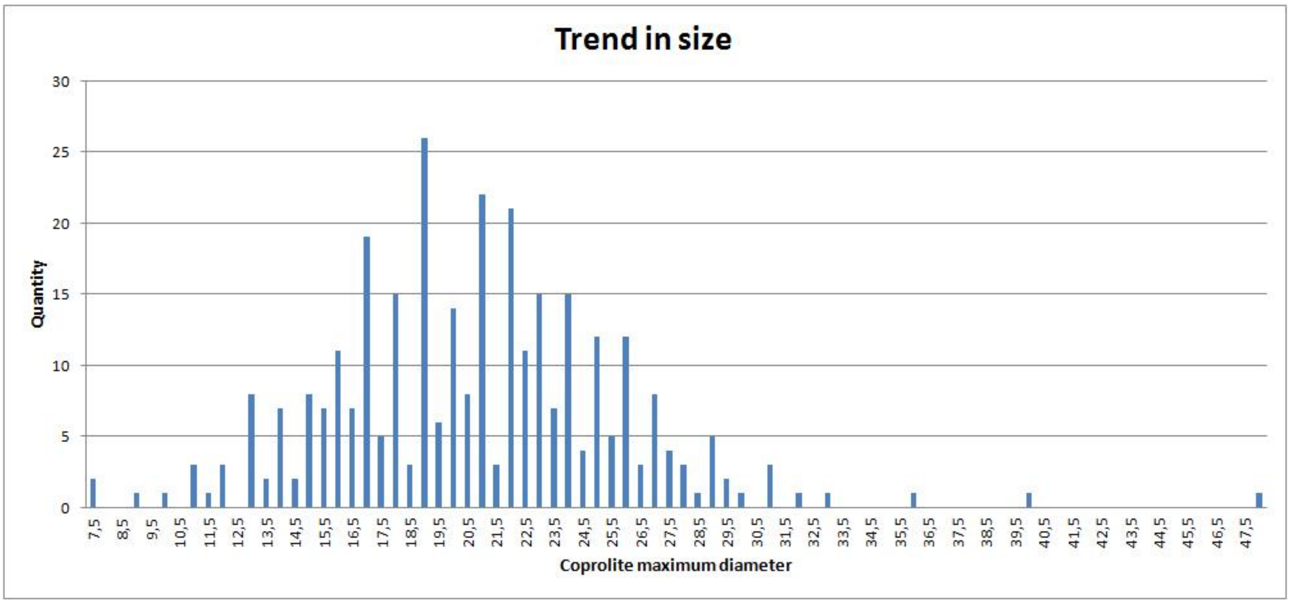

Fig. 15. The distribution of coprolites according to size.

Shape:

Coprolites are sorted according to shape but as most of the material is fragmented the categories are somewhat tentative. Of the 321 specimens that are included more than 80% are considered cylindrical or are thought to have been cylindrical originally. The material is divided into six shapes (number of specimens in brackets):

Bulbous (12), cylindrical (264), cylindrical-bulbous (34), round (4), round-bulbous (4) and round-cylindrical (3).

Structure:

In this material three structures are recognized (number of specimens in brackets):

Irregularly wrapped (179), structureless (124) and spiral/coiled (19).

Texture:

The following ten groups are used to describe the textures found in the material (number of specimens in brackets):

Massive (107), massive-nodular (44), massive-swirly (31), nodular (39), nodular-massive (15), nodular-swirly (14), swirly (10), swirly-massive (13), swirly-nodular (24) and unknown (27).

<u>Fossil fragments:</u>

The fossil food remains found in the coprolites are described in terms of both size and amount. Food fragments can have various sizes within each coprolite but the largest fragment present defines a maximum size that is used to characterize the specimen. Fragments are found in 236 specimens and measure between 0.1 mm and 10 mm. The contents of fragments in each coprolite is somewhat loosely defined as either "none", "few", "some" or "numerous" fragments. In appendix 1 these categories are called "0", "1", "2" and "3", respectively.

<u>Nodules:</u>

The term 'nodules' cover both ordinary nodules and the more intriguing pellety textures found in some specimens of this material. In cross section, nodules and pellets can be quite indistinguishable. As it is not certain what separates ordinary nodules from pellets, they are treated as closely related entities in the analyses. However, large 'nodules' are most often 'pellets'. Nodules are found in 163 specimens and measure between 0.1 mm and 6 mm.

<u>Mineral grains:</u>

Mineral grains are found in 242 specimens and measure between 0.1 mm and 4 mm.

37 specimens with unknown interior are excluded and the dataset consists of 287 specimens.

<u>Preservation:</u>

Various traits are considered when examining the preservation state of the material: The number of preserved ends; the thickness of dark chemical alteration rims and the thickness of light weathering rims. Everything concerning the rims is quite uncertain as these were often difficult to define and measure precisely.

<u>Bend specimens:</u>

20 specimens have a slightly bend shape. The specimens are all cylindrical and have diameters between 13 mm and 24.5 mm. All coprolite structures are represented in the bend specimens. 4 specimens also bear contraction marks (two of these also have pinched ends). Most coprolite textures are represented - exceptions are massive-swirly and swirly-massive.

<u>Flattened specimens:</u>

135 specimens have a flattened shape with short diameters between 8 mm and 33 mm. Most of the specimens are cylindrical but bulbous, cylindrical-bulbous and round-bulbous are also represented. 11 specimens are also bend. All coprolite structures are represented in the flattened specimens. All

coprolite textures are represented, however, the nodular-massive coprolites appear to have been more prone to flattening - 13 out of 15 nodular-massive specimens (87%) are flattened.

Pinched specimens:

12 specimens have pinched ends. They are of cylindrical, cylindrical-bulbous and round-cylindrical shape with diameters between 13 mm and 22 mm. 8 specimens also bear contraction marks (two of these are also bend). Spiral/coiled coprolites are not represented. Textures present: Massive, massive-swirly, nodular-massive, nodular-swirly and unknown (6 specimens).

Specimens with contraction marks:

21 specimens bear contraction marks. They are cylindrical and cylindrical-bulbous with diameters between 11 mm and 22.5 mm. 4 specimens are bend and 8 specimens have pinched ends (two of these are also bend). Spiral/coiled coprolites are not represented. Textures present: Massive, massive-nodular, massive-swirly, nodular-swirly and unknown (7 specimens).

3.6.2. Correlations between coprolite size, shape, structure and texture

Coprolite size and shape:

There is no general correlation between coprolite diameter and shape. However, the four round specimens are restricted to diameters between 15 mm and 20 mm. The three round-cylindrical specimens are restricted to diameters between 16.5 mm and 20 mm.

Coprolite size and structure:

There is no general correlation between the size of coprolites and their structure. The three largest coprolites are significantly larger than the rest of the material. Their structures are, in order, spiral/coiled, irregularly wrapped and spiral/coiled.

Coprolite size and texture:

There is no general correlation between the size coprolites and their texture. The three largest coprolites are, in order, massive-swirly, unknown and massive. Two types of texture have a somewhat limited distribution: Swirly-massive coprolites have diameters between 13.5 mm and 25.5 mm. Swirly-nodular coprolites have diameters between 14 mm and 29 mm.

Shape and structure:

Cylindrical coprolites are the most common in all of the three structures (irregularly wrapped, structureless and spiral/coiled). Round specimens are not found among the spiral/coiled coprolites. Round coprolites are dominated by structureless specimens and round-bulbous coprolites only contain structureless specimens. In the other coprolite shapes (bulbous, cylindrical, cylindrical-bulbous, round-cylindrical), irregularly wrapped specimens are the most common. However, except for cylindrical coprolites, each shape has a very limited distribution and any correlation is uncertain.

Shape and texture:

It is not possible to establish any patterns concerning the distribution of textures within each coprolite shape as only cylindrical coprolites are numerous. Cylindrical coprolites, on the other hand, dominate in all textures. Cylindrical-bulbous coprolites are generally common but absent from nodular-massive and swirly specimens. Massive and unknown coprolites both contain six of the possible seven shapes. Bulbous coprolites are most widespread in nodular coprolites where they comprise more than 15%.

Structure and texture:

The strongest correlation between structure and texture of coprolites is found in spiral/coiled specimens (fig. 16). Spiral/coiled coprolites consists of massive and swirly textures and do not contain any nodular textures. Contrarily, irregularly wrapped specimens are independent of coprolite texture and contain all textures (fig. 17). Structureless specimens appear to be largely independent of texture as well but do not contain any swirly-massive specimens (fig. 18). Irregularly wrapped and structureless coprolites are dominated by the three primary massive textures. The two structures contain similar amounts of nodular specimens.

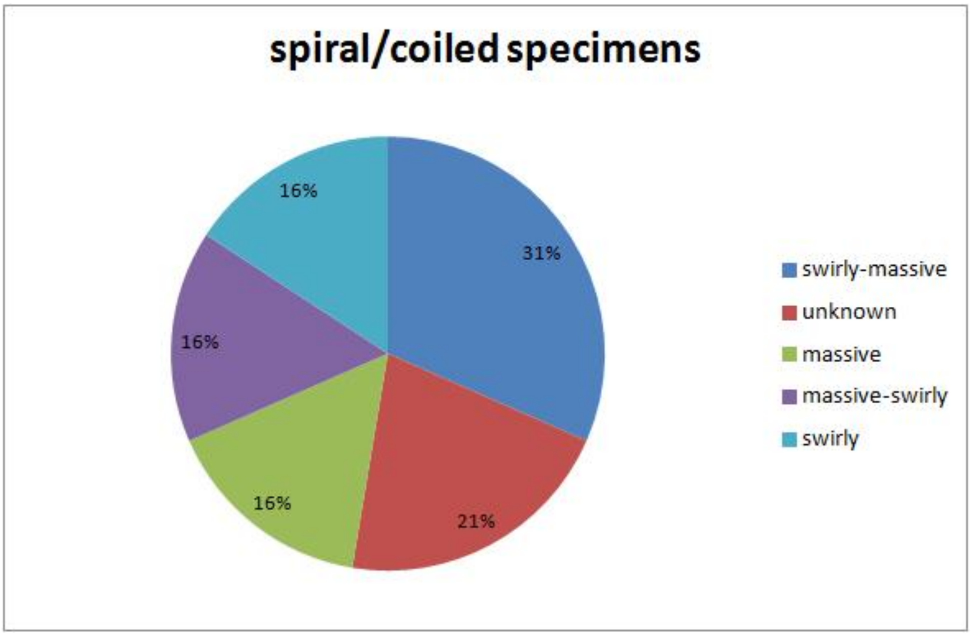

Fig. 16. The distribution of textures within spiral/coiled specimens.

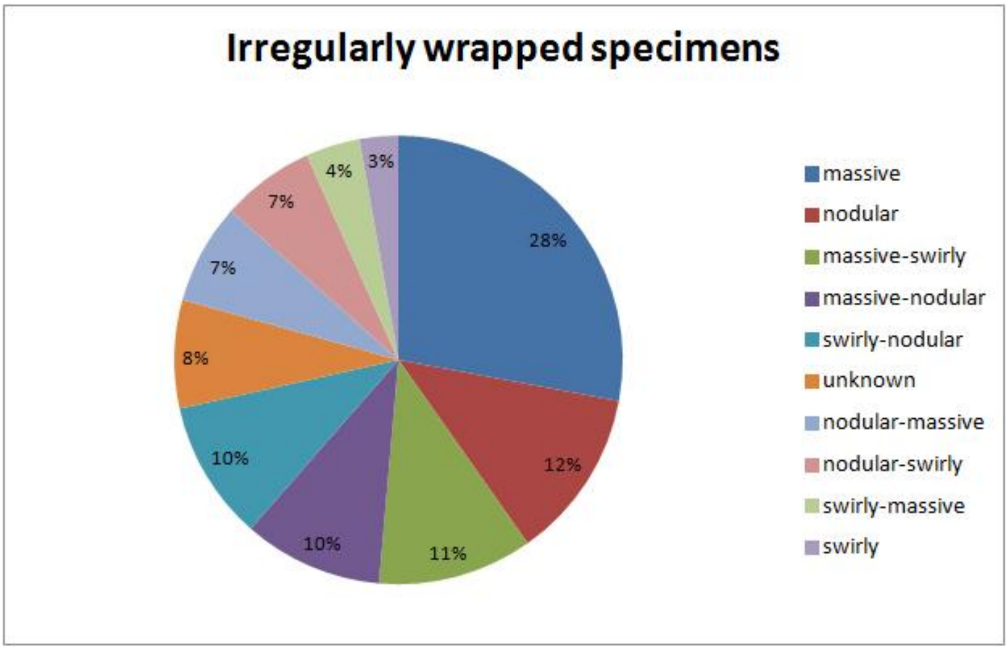

Fig. 17. The distribution of textures within irregularly wrapped specimens.

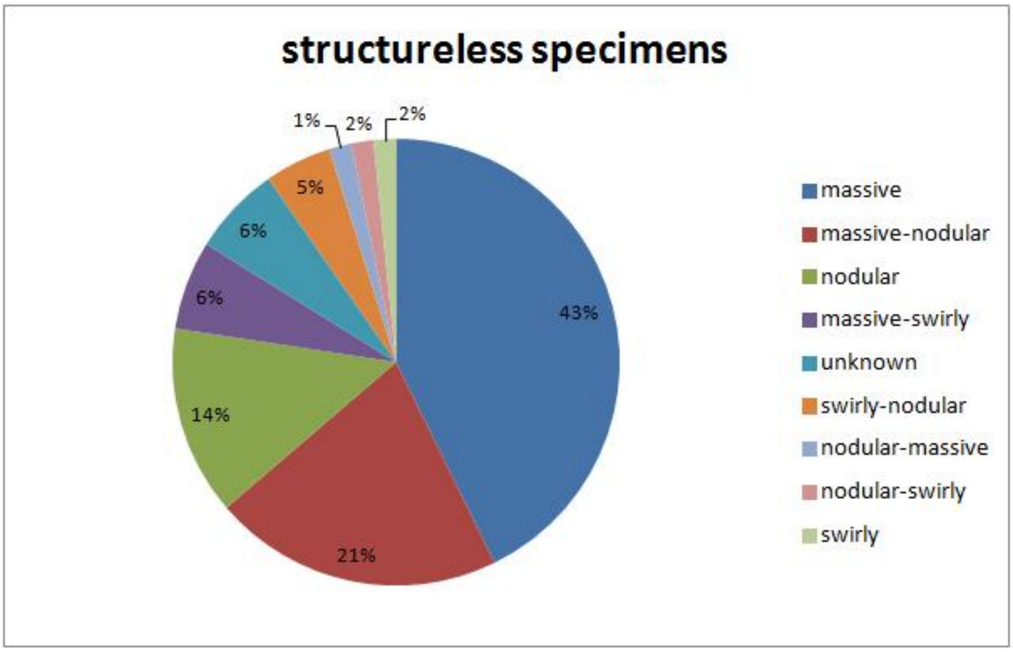

Fig. 18. The distribution of textures within structureless specimens.

3.6.3. Correlations between contents of fragments and coprolite traits

Coprolite size:

There is no general correlation between the size of coprolites and the contents of fragments. If only the interior contents is considered, there is a very slight increase of fragment size to coprolite diameter.

Shape:

Except for cylindrical coprolites, each shape contains too few specimens to interpret any correlations with certainty. Round coprolites are possibly unique in always containing fragments of a considerable size (2-6 mm).

Structure:

There is a general normal distribution of fragment sizes within the three structures. Also, fragment-free coprolites are common within all three structures. This indicates that the structure of coprolites and their contents of fragments do not correlate in any way.

The distribution of fragments categories is similar between structure. Spiral/coiled specimens are so few compared to the other structures that the apparent higher contents of category 3 is uncertain.

Texture:

Nodular coprolites rarely contain fragments and when they do these are never larger than 2.5 mm (fig. 19). The other coprolite textures are difficult to define when it comes to the contents of fragments. They appear to be parts of a spectrum with massive coprolites at one end containing many possible fragment sizes and swirly coprolites at the other containing few fragment size. Nodular-massive and nodular-swirly coprolites contain slightly more nodule-free specimens than the other textures but far less than the purely nodular coprolites.

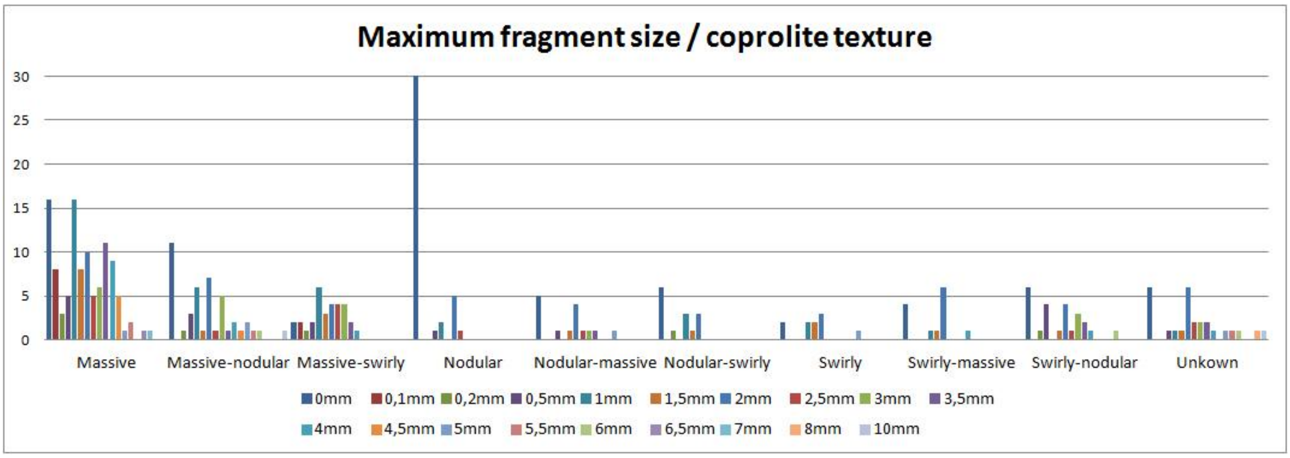

Fig. 19. The distribution of fragment sizes within each texture.

3.6.4. Correlations between contents of nodules and coprolite traits

Coprolite size:

There is no correlation between coprolite size and nodule size except for a restriction of nodules to coprolites with diameters between 9 mm and 31 mm.

Shape:

Except for cylindrical and cylindrical-bulbous coprolites, each shape contains too few specimens to establish any certain correlations. However, the presence of nodules is dependent on the shape of the coprolite to some degree. Nodules are common in cylindrical, bulbous and cylindrical-bulbous coprolites while they are rare in round-bulbous coprolites. Nodules are absent from round and round-cylindrical coprolites.

Structure:

Spiral/coiled coprolites generally do not contain nodules (fig. 20). For the irregularly wrapped and structureless coprolites, the specimens containing nodules are weakly normal distributed according to nodule size. Also, nodule-free specimens are widespread. This indicates that the presence of nodules is dependent on structure but the size of nodules is not.

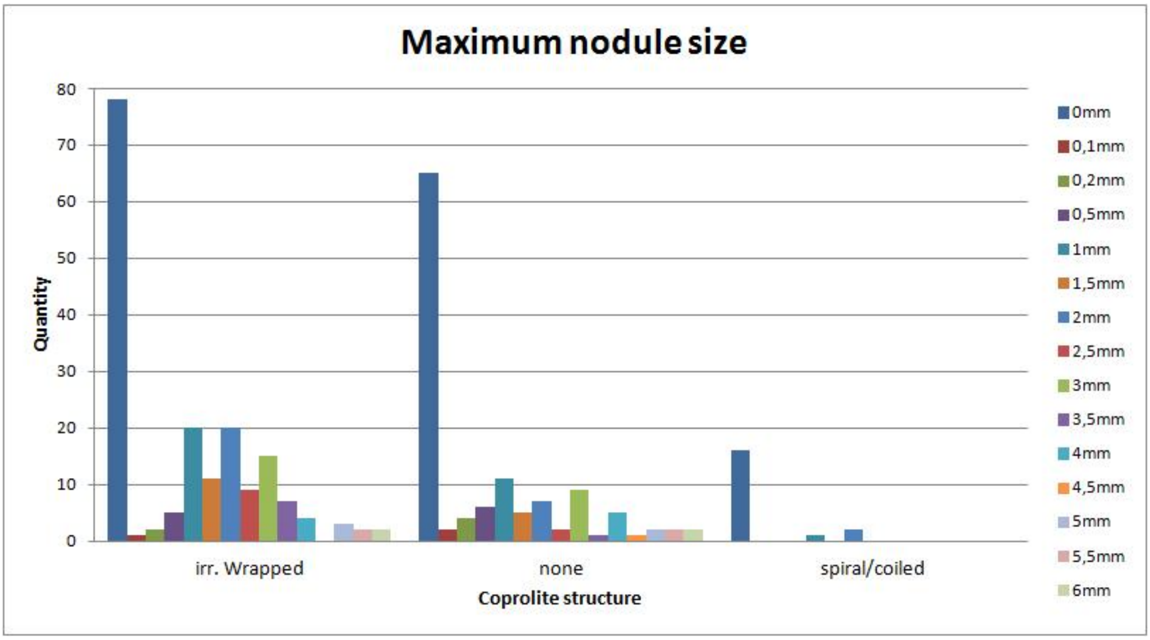

Fig. 20. The distribution of nodule sizes within each structure.

Texture:

Nodules are present in all textures but their size is dependent on the coprolite texture. Nodular and massive-nodular specimens do not only contain the largest nodules but also the widest range of sizes. The shortest range of nodule sizes (except for in unknown coprolites) is seen in swirly and swirly-massive coprolites with only 3 possible sizes found in 3 and 4 specimens respectively.

3.6.5. Correlations between contents of mineral grains and coprolite traits

Coprolite size:

There is a slight tendency for increasing mineral grain size with increasing coprolite size.

Shape:

There is no certain correlation between the contents of mineral grains and the coprolite shape.

Structure:

The contents of mineral grains is partly dependent on coprolite structure as irregularly wrapped and structureless coprolites can contain larger grains than spiral/coiled coprolites. Spiral/coiled specimens always contain mineral grains but they are never larger than 1 mm.

Texture:

There are no certain correlation between the mineral grain size and the coprolite texture.

Fossil fragments:

There is no certain correlation between the contents of fragments and the contents of mineral grains but there might be a tendency for mineral grain size to increase along with fragment size.

Nodules:

Mineral grain size is dependent on nodule size as the largest possible grain size decrease with increasing nodule size.

3.6.6. Correlations between state of preservation and coprolite traits

Coprolite size:

There is a slight tendency for smaller coprolites to be preserved with more ends than large one. There is a slight increase of dark rim thickness with coprolite diameter. There is no correlation between light rim thickness and coprolite diameter.

Shape:

It is not possible to ascertain any trends as most shapes are poorly represented. The number of preserved ends is likely to be independent of coprolite shape. The rim thicknesses for round, round-bulbous and round-cylindrical coprolites are largely unknown. The thickness of dark alteration rims is possibly dependent of coprolite shape as round, round-bulbous and round-cylindrical coprolites never have rims thicker than 1 mm. The thickness of light weathering rims might be somewhat dependent of coprolite shape as round, round-bulbous and round-cylindrical coprolites never have rims thicker than 0.1 mm. However, these specimens are rarely polished.

Structure:

The amount of preserved ends is independent of coprolite structure. The thickness of dark alternation rims is independent of coprolite structure. The general thickness of light weathering rims is similar between irregularly wrapped and structureless coprolites but less in spiral/coiled coprolites.

Texture:

The number of preserved ends and the coprolite texture are independent of each other. There appears to be no correlation between coprolite texture and the thickness of the rims.

Fragment size:

The number of preserved ends and the contents of fragments are independent of each other. There is no correlation between the contents of fragments and the thickness of the rims.

Fragment category:

The number of preserved ends is largely independent of the fragment category but coprolites containing numerous fragments are possibly more likely to preserve both ends. The thickness of dark alteration rims is somewhat dependent on the fragment category as category 3 coprolites appear to contain more specimens with rims. There is generally no correlation between fragment category and light rim thickness.

Nodule size:

There is apparently no correlation between the contents of nodules and the number of preserved ends. There is no correlation between the contents of nodules and the thickness of the rims.

Mineral grains:

There is no certain correlation between the number of preserved ends and the contents of mineral grains. There is a tendency for rim thickness to decrease with the increase of mineral grain size.

3.7. Discussion

3.7.1. Identification of loose fossil fragments

Milan et al. (2012) has reported remains of large temnospondyls, a bone from possibly a pterosaur or theropod and a putative phytosaur scute from the Kap Stewart Formation. Otherwise, there has been done little work on the vertebrate body fossils of the Kap Stewart Formation. The underlying Fleming Fjord Formation has been studied in greater detail by Jenkins et al. (1994). They report the presence of at least these following vertebrates: Labyrithodont amphibians (*Gerrothorax*, *Cyclotosaurus*), aetosaurs (*Aetosaurus ferratus*, *Paratypothorax andressi*), prosauropod (*Plateosaurus*), theropod dinosaurs, pterosaus, turtles (cf. *Proganochelys*), mammals and fishes (including sharks, actinopterygians, coelacanths and lungfish). The association of many of these genera resembles well-known European Norian faunas (Jenkins et al. 1994). The Fleming Fjord

Formation was deposited during most of the Carnian, Norian and Rhaetian while the Kap Stewart Formation was deposited during the last part of the Rhaetian and throughout the Hettangian (Dam & Surlyk 1993). The two formations together span millions of years but they were deposited in a continues lake system and their faunas are unlikely to contain large differences on the higher taxonomic levels.

Dermal bone:

Jenkins et al. (1994) reports that the dermal armour of both the plagiosaur *Gerrothorax* and the cyclotosaur *Cyclotosaurus* are commonly found in especially the Ørsted Dal Member (the youngest member of the Fleming Fjord Formation). Many of the pieces are only identifiable as remains of large temnospondyls (Jenkins et al. 1994). The pieces of dermal bone in the material from the Kap Stewart Formation are most likely from such large amphibians, possibly *Gerrothorax* (pers. comm. Jesper Milán 2014).

Shark tooth:

Jenkins et al. (1994) reports the finding of hybodont teeth and spines in the Fleming Fjord Formation but present no descriptions or figures. The tooth found in the Kap Stewart Formation slightly resembles teeth depicted by Chang and Miao (2004) that are ascribed to the hybodont sharks *Hybodus youngi* (Chang & Miao 2004, fig. 4D) and *Hybodus antingensis* (Chang & Miao 2004, fig. 7B). The teeth are excavated in northern China from freshwater deposits from the Middle Triassic and the Middle Jurassic respectively. Yamagishi (2004) also depicts Asian hybodont teeth and one ascribed to *Hybodus sp.* (Yamagishi 2004, fig. 4.5) has a root quite similar to that of the Kap Stewart tooth. The *Hybodus sp.* tooth comes from marine deposits of Middle Triassic age. It bears weaker ornamentation on the crown than the Kap Stewart one does and the match is not that good. From Europe, Godefroit et al. (1998) depicts a Late Triassic tooth that seems a perfect match to the one from the Kap Stewart Formation (Godefroit et al. 1998, fig. 4.3B). However, this tooth comes from sediments that are interpreted as deposited in a 'restricted costal environment with moderate marine influence (bay, lagoon)'. Teeth of this type are found in several Rhaetic deposits across north-western Europe but they appear to be associated with marine environments (e.g. Storrs 1994). The teeth have traditionally been ascribed to *'Hybodus' minor* but Cuny and Risnes (2005) examined the enameloid construction and showed that the teeth originates from a neoselachian shark. The teeth are now ascribed to *Rhomphaiodon minor*. Based on the morphology and age of the tooth from the Kap Stewart Formation it is here identified as belong to *Rhomphaiodon minor*. This is supported by the fact that the Fleming Fjord Formation fauna resembles European faunas from the same period. As a remark towards the confusion that seems to remain in the classification of hybodont sharks, the presence of these in the Fleming Fjord Formation might need revision.

Shells:

It is not within the scope of this project to identify the shells found together with the coprolitic material to a higher taxonomic level than Bivalvia.

3.7.2. Identification of fossil fragments in coprolites

The coprolites from the Kap Stewart Formation contain fossil fragments of various shapes. Some are flat and rectangular while others are thick and quadratic. The residues of black coating found on some pieces can be either smooth or grooved. The x-ray diffraction analysis showed that the fragments consist of apatite - a group of minerals commonly found in vertebrate bones, teeth and scales. No attempts were made to free the fragments using acid as any acid effective against the coprolite matrix is likely to attack the fragments as well. One coprolite (H313) was mechanically prepared by Werner Schwarzhans and some of the contained fragments were partly uncovered (fig. 9). The fragments of the Kap Stewart coprolites are likely to originate from various Mesozoic fish and the following comparisons are made based on their morphologies.

The thin rectangular scales that are seen in for instance specimens H009 (fig. 7) and H200 resembles scales depicted by Mutter (2004). Mutter reviews the actinopterygian family Colobodontidae that is known from Triassic localities on an almost worldwide scale. He depicts flat scales that resembles those found in the coprolites. The scales (Mutter 2004, fig. 3) have a quadratic to rectangular shape with one large triangular projection on one side and a minor projection displaced of this on the opposite side. Each scale also has shallow depressions on the surface that fit the projections. When the fish was alive, the scales were arranged in a 'peg-and-socket' articulation along its flanks. Mutter 2004 ascribed these scales to *Crenilepis sandbergeri*. The specific affinity of the flat rectangular scales from the Kap Stewart coprolites cannot be determined as they are too damaged. It is a possibility that they belong in the Colobodontidae family or at least in the order Perleidiformes where Colobodontidae sits. However, the group is not properly resolved as it has traditionally been a 'dumping-ground' for many ornament-rich scales (Zuoyu et al. 2008). The thin rectangular scales from the Kap Stewart coprolites appear never to have been covered in thick black coating. Scales in the material that have residues of thick coating are generally thicker themselves and have a wider range of shapes. Both actinopterygian and sarcopterygian fishes have scales consisting mostly of apatite mineral. They are built up of a compact basal bone layer, a spongy bone layer and a dentine-like layer capped by a thin enamel layer. In basal actinopterygian scales, the enamel layer is called ganoid and it is generally much thicker than the corresponding layer of sarcopterygian and modern actinopterygian scales (Kemp 1984). The scales described from the Kap Stewart coprolites are apparently all originating from actinopterygian fishes. It is difficult to determine the true shapes of the scales bearing thick black coating, but minimum two types are present: Thick, quadratic scale with a smooth surface (e.g. H200 (fig. 21)) and rectangular scale with a grooved surface (e.g. H043 (fig. 12), H254 (fig. 11)).

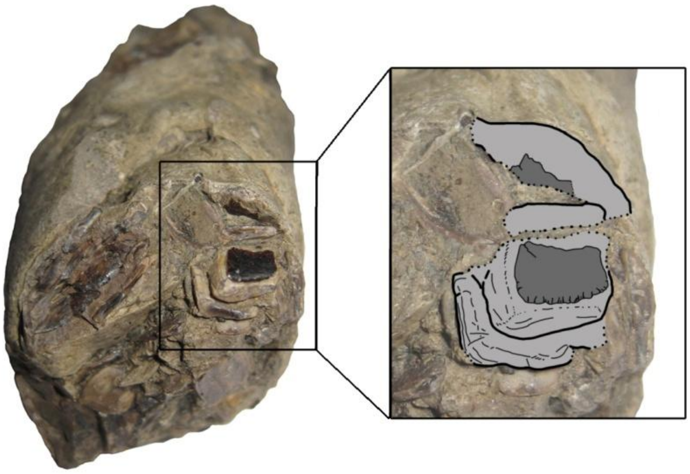

Fig. 21. Specimen H200 with detail of thick scales with smooth coating.

Mutter (2004, fig. 4) depicts a variety of ganoid ornamentation in Colobodontidae scales that resembles that of the grooved type from the Kap Stewart coprolites. The scales all bear parallel ridges that run across the surface in strait or slightly wavy lines. However, the pattern seen in the Kap Stewart scales might not be original features. The pattern could have arisen as the surfaces were eroded as is seen in *Lepidotes maximus* scales depicted by Jain (1984, fig. 6). *Lepidotes* is a genera belonging in the family Semionotidae, a group of neopterygian fish that are found throughout most of the Mesozoic. They are very common in western Gondwanaland but are found in most of the world in both marine and freshwater strata (Gallo & Brito 2004). The group is not thoroughly resolved but the genera *Semionotus* and *Lepidotes* share 'a series of simple, convex scales with moderate to well-developed, posteriorly directed spines along the dorsal midline between the extrascapulars and the origin of the dorsal fin' (McCure 1986). Gallo and Brito (2004) depicts thick Semionotid scales from Brazil that are covered by smooth black ganoin layers. The scales attributed to *'Lepidotes' oliveirai* (Gallo & Brito 2004, fig. 6) are remarkably similar to scales from the Kap Stewart coprolites. They are quadratic to rectangular, have a concentric built-up and one corner is sometimes stretched into a spike. Scales of *'Lepidotes' dixseptiensis* (Gallo & Brito 2004, fig. 10) are more oblong with a slightly rhombohedral outline similar to fragments seen in for instance H029 (fig. 8). Rectangular scales with parallel furrows on part of the surface are also present in *Lepidotes* (Gallo and Brito 2004, fig. 4). It is not possible to conclude which species that are represented in the Kap Stewart Formation on the basis of scales contained in coprolites. However, the scales come from actinopterygian fish and it is plausible that some of the scale are of Semionotid origin and some are of Perleidiform origin.

The scales found in specimen H075 are quite small compared to those just described (fig. 10). The identification of these scales has proven somewhat difficult but it is safe assume that they originate from a fish of smaller size than the other scales do. As there are many sizes of fossil fragments present in the coprolites of the Kap Stewart Formation it appears that a wide range of fish sizes acted as food for the coprolite producers.

The large fossil objects in specimen H313 are somewhat strange as they are nearly round in cross section. It was first speculated that they might be otoliths - fish ear stones. However, this hypothesis was rejected as soon as the x-ray diffraction analysis showed that the objects consist of apatite. Otoliths are always made of aragonite which is a calcium carbonate mineral (Campana 1999).

The fossil fragments in H313 may be fish scales as they could resemble thick, oblong scales with a spike in one corner as the ones of *'Lepidotes' dixseptiensis* (Gallo & Brito 2004, fig. 10).

3.7.3. Coprolite assemblage

The coprolite material from the Kap Stewart Formation was collected on a voluntary basis across an area of perhaps 100 m^2. Care was put into collecting everything that appeared on the surface but coprolites below a certain size are likely to have been overlooked (pers. comm. with Jesper Milàn). The smallest specimen in the material measures 7.5 mm in diameter and 8 mm in length. It is possible for vertebrate coprolites to be smaller than this and the scarcity of small coprolites in the present material is possibly due to sampling bias. However, there are also other possibilities. Very small coprolites could have been rare or absent from the site due to extensive weathering or they may even have been absent originally if the palaeoenvironment did not support the preservation of these specimens. It is unlikely that there were no small faeces present in the original environment but these may have been made by invertebrates rather than vertebrates. If the contents of digested bone and scale material was critical for preservation in the Kap Stewart Formation, the faeces of herbivores, insectivores and detritus feeders (mostly invertebrates) will not be preserved. The present coprolites from The Kap Stewart Formation are interpreted as coming from vertebrates mainly because of their large sizes.

<u>Round to sub-round coprolites:</u>

Shape is generally a useless way to define the Kap Stewart coprolites as they are highly damaged. However, there seem to be a few specimen that can be partly distinguished from their shape. The specimens H074, H075 (fig. 10), H077, H078 and H080 are round to round-bulbous and have smooth surfaces. These round to sub-round specimens have maximum diameters restricted to 15-20 mm and they are structureless. They all appear to be of massive texture and contain fossil fragments of at least 0.5 mm. H081 is possibly in this category too, though it might in fact be an end of a larger cylindrical specimen. H079 is a round specimen but it has irregularly wrapped structure and an uneven surface and is not included with the others. H076 is round-bulbous but consists of nodular texture. H072 is possibly round but it rather appears to be the end of a larger cylindrical specimen with its pinched end.

Spiral and coiled coprolites:

Specimens of spiral to coiled structure are markedly different from other coprolites. They can be as small as 7.5 mm in diameter but are also the coprolites in the material that can be largest (48 mm in diameter). The spiral/coiled coprolites consists of massive and swirly textures and never nodular textures. If nodules are present it is only as single and scattered nodules and not as pellets. Spiral/coiled specimens can contain fossil fragments of all sizes and may have a higher tendency than other types for containing numerous fragments. They always contain mineral grains but these are never larger than 1 mm. The ends, when preserved, are never pinched but can be pointy. Spiral/coiled coprolites appear to have relatively thin light rims as if they are weathered to a shallower depth than other coprolites. The following 19 specimens are included in this type: H001-H013, H017, H249, H310 and MGUH30365-MGUH30367. H017 is possibly an irregularly wrapped specimen that happens to consists of extra thin wraps. The spiral/coiled specimens are quite different from each other and the following sub-groups are described:

- H001, H002 and H003 are similar in diameter (13.5-17.5 mm) and are all flattened (8.5-12 mm in short diameter). They have uneven surfaces and each consists of a simple coil layer. They all contain some or numerous fossil fragments. H310 is slightly larger (20 mm in diameter and 18 mm in flattened diameter) but have the same characteristics.
- H006, H010 and H011 are the smallest spiral coprolites in the material. H006 (14 mm) is preserved as a posterior spire (= initial end) with overlapping layers that gives it a resemblance to a pinecone. Coprolites somewhat similar to this are seen in Buckland (1829, plate 31, fig. 10) and in Williams (1972, plate 1, fig. 8) where they are identify as of heteropolar type. The best match may be to the ichnotaxa group 4 of Laojumpon (2012, fig. 7 A-B). These are Late Triassic spiral

coprolites from Thailand that were found in sediments deposited in brackish water. At the locality was also found a *Hybodus* tooth, bony fish scales and temnospondyl vertebrae as in the Fleming Fjord Formation (Jenkins et al. 1994).

- H010 (15 mm) and H011 (7.5 mm) are poorly preserved but both appear to consist of a tightly wound coil that runs the length of the coprolites.
- MGUH30365 is not just the largest spiral coprolite but the largest coprolite in the entire material. It has a diameter of 48 mm and consists of a thick coil that winds around the center at least four times. The coil is about 5 mm wide at the surface and thins towards the center as seen in cross section. The coprolite is very damaged but ichnotaxa that could resemble it are *Strabelocoprus pollardi* of Hunt et al. (2012c, Fig. 4 A-D) or *Saurocopros bucklandi* of Hunt et al. (2007, fig. 4). The first ichnotaxa is found in Rhaetic to Lower Jurassic deposits in England and is defined as only having very few coils. The other ichnotaxa is found in Late Triassic to Late Cretaceous deposits of Europe and North America and may be a more plausible match.
- MGUH30366 and MGUH30367 are also of large size (28 mm in diameter) but they are very loosely coiled. They could perhaps be similar to *Heteropolacopros texaniensis* depicted by Hunt et al. (2005, fig. 2).
- H004, H005, H007, H013 and H249 have diameters between 23.5 mm and 25.5 mm. They are cylindrical with apparently simple coiled structures that winds around the centre up to three times. H007 was cut in half in the longitudinal plane and a more complex structure was revealed (see fig. 22). The coprolite consists of at least four separate coiled layers (shown in different green colours in the figure) but as they are somewhat folded and displaced they can be difficult to distinguish. The two outer layers do not run the entire length of the coprolite and the specimen is identified as heteropolar.
- H008 is 36 mm in diameter but may have been very large originally as only the posterior spire is preserved. The coprolite is weathered and quite indeterminable.
- H009 is 17.5 mm in diameter. It consists of a simple coil that runs the length of the specimen. It has a smooth surface and is shape like a slightly bend pupae. It might be of scroll type (Hunt & Lucas 2012b).
- H012 has a diameter of 16 mm but is very damaged and indeterminable.

Spiral coprolites originate from fish and other animals with a relatively primitive type of digestive tract that contains a spiral valve. In the Kap Stewart Formation there are various potential producers as both sharks and actinopterygians have been identified in this project and as also coelacanths and lungfish have earlier been identified from the underlying formation (Jenkins et al. 1994). It is not possible to determine which animals that produced which coprolites with any certainty but it is likely that large spiral coprolites were produced by sharks while the smaller ones were produced by a variety of bony fish.

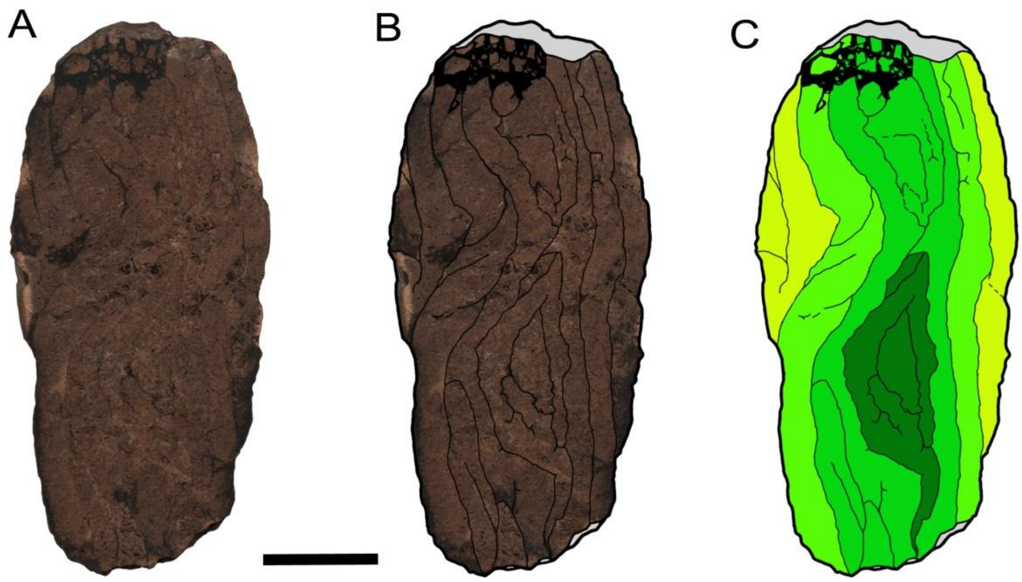

Fig. 22. Specimen H007. A: Photo. B: Interpretational sketch.
C: Proposed layers shown in different green colours. Scale bar: 1 cm.

<u>Irregularly wrapped and structureless coprolites:</u>

Irregularly wrapped specimens and structureless specimens are likely to represent two separate types of coprolite. However, the two types are not distinguishable in other traits than the structure. Both are dominated by the three primary massive textures and purely nodular texture, though structureless coprolites do not contain all textures (swirly-massive is absent). All fragment sizes are found in specimens of the two structures and fossil-free specimens are also common in both. The most common shape is cylindrical and neither the presence of contraction marks or pinched ends support any distinction between the two types. Furthermore, the structureless coprolites may only *appear* structureless because of poor preservation.

Specimens with contraction marks are restricted to diameters between 11 mm and 22.5 mm. This spectrum coincide with the most common diameters in the material in general and does not support the establishment of a separate type. The same argument is valid for bend, flattened and pinched specimens: Bend specimens have diameters between 13 mm and 24.5 mm, flattened specimens between 8 mm and 33 mm and pinched specimens between 13 mm and 22 mm. The number of specimens with a pinched end is not likely to represent an original trend in the material as most ends have been broken during weathering. There could indeed have been a distinct type of faeces with pinched ends in the palaeoenvironment of the Kap Stewart Formation but this is not recognisable in the present material.

Nodular coprolites:

Within the irregularly wrapped and structureless coprolites there is a sub-type of specimens containing nodular textures (136 specimens). Purely nodular coprolites (39 specimens) are usually very distinct as they consists of rounded pellets of up to 6 mm and often have bulbous shapes. These specimens rarely contain fragments (more than 75% are fragment-free) and when they do, the fragments are never larger than 2.5 mm. In specimens that only consists partly of nodular texture the fragments can be larger. Despite the general lack of fossil fragments in nodular specimens there is no reason to assume that they have a herbivorous origin. The x-ray diffraction analyses proved that two completely nodular specimens without fragments (H199 and H228) contained minerals similar to those found in carnivorous coprolites (see e.g. Edwards 1973). Nodular-massive and nodular-swirly coprolites contain slightly more fragment-free specimens than the non-nodular textures but far less than the purely nodular coprolites. Nodular and massive-nodular specimens do not only contain the largest nodules found but also the widest range of sizes. Specimens of entirely nodular texture are quite distinct from other coprolites but even so they appear not to be a completely separated type. For instance, a specimen like H192 (fig. 23) consists of a core of nodular texture covered in wraps of swirly texture. Another specimen, H202 (fig. 24) consist almost completely of pellets but it still has a smooth surface that hardly reveals the nodular contents.

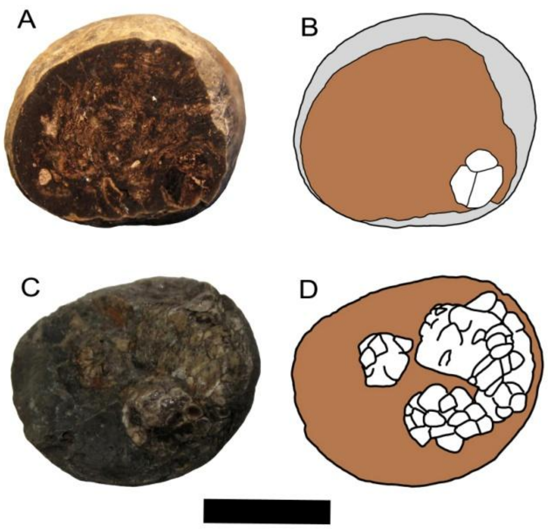

Fig. 23. Specimen H192. Polished section: A: Photo. B: Interpretational sketch.
Broken surface: C: Photo. D: Interpretational sketch.
Scale bar: 1 cm.

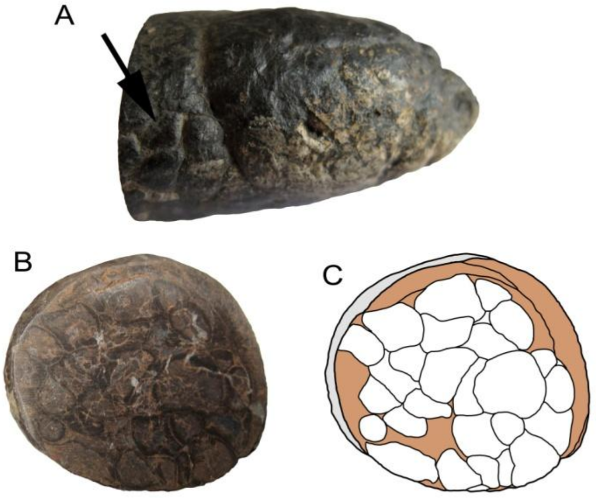

Fig. 24. Specimen H202. A: Lateral view with indication of nodular texture.
Polished section: B: Photo. C: Interpretational sketch.

Apparently, the animal that produced the conspicuous pellety faecal masses also produced faeces of more common textures. Nodular coprolites are therefore not considered a separate type but rather as part of a spectrum of faecal textures produced by a versatile producer. The source of food is likely to be a main influence on the resultant faecal texture especially as nodular coprolites rarely preserve fossil fragments. The nodular specimens are often preserved as quite small fragments and their structure is often difficult to determine as the pellets obscure this. It is therefore possible that all nodular specimens are in fact of irregularly wrapped structure.

3.7.4. Post-depositional characteristics and further analysis

In this project it was not determined if the contents of mineral grains is dependent on the type of coprolite. There is a correlation between nodular texture and mineral grains as specimens containing large nodules never contain large mineral grains. Whether this is could be a result of the nodular chemical composition or perhaps is linked to the fact that fossil fragments are absent is unknown at this point. Mineral grains that were present prior to deposition (i.e. adhesive material) were difficult to recognize in the material but appeared to be rare. The relation of these grains to the coprolite types was not explored in this project though it may potentially highlight the depositional environment in greater detail. If the material should be further analysed with respect to the mineral grains it would be necessary to examine the coprolites again and possibly polish those specimens that were not polished for this project. The data analyses in this project were somewhat questionable as unpolished specimens were assigned a mineral grain size of '0' and should be redone.
The connection between dark chemical alternation rims and coprolite traits is also left largely untouched here. The light rims appear similar between the coprolite types (perhaps with exception

of the spiral coprolites) and are created through the same post-exposure weathering that characterize the entire material. The various rim thicknesses are likely to be a result of differences in how long each specimen has lain exposed on the rock surface.

3.8. Conclusions

A large portion of Late Triassic vertebrate coprolites along with samples of sediment and loose fossil remains were brought back from Jameson Land, East Greenland in the summer 2012. The coprolites were collected from the Kap Stewart Formation which was deposited in an extensive lake with large fluctuations in water depths. The coprolites originate from a sequence of shale that was deposited through a period of high lake level during the Rhaetian stage.

The coprolites are described with respect to size, shape, structure, texture, contents and preservation. A small amount of coprolites were also sampled and mineralogically examined through x-ray diffraction. The coprolites contained apatite, clay minerals, carbonates and occasionally quartz in the form of secondary mineral grains. One sample of sediment and one sample of fossilized burrow that were also examined did not contain either apatite or carbonates but feldspars and micas along with the quartz.

The coprolites can be divided into the following types:

- Round to sub-round coprolites: Specimens of this type have maximum diameters restricted to 15-20 mm. They are structureless and of massive texture. They always contain fossil fragments of at least 0.5 mm.
- Spiral/coiled coprolites: Specimens of spiral or coiled structure have cylindrical to bulbous shapes. They can be as small as 7.5 mm in diameter and as large as 48 mm in diameter. The spiral/coiled coprolites consists of massive and swirly textures. Nodules are only present as single, scattered nodules. Spiral/coiled specimens often contain numerous fossil fragments of various sizes. They always contain mineral grains but these are never larger than 1 mm. The spiral/coiled coprolites can be sub-divided based on size and type of coil. Ichnotaxa that are possibly represented are: *Strabelocoprus pollardi*, *Saurocopros bucklandi* and *Heteropolacopros texaniensis*.
- Irregularly wrapped and structureless coprolites: Many specimens are cylindrical to bulbous and consists of either wrapped or structureless material. Because of the high level of weathering the two structures cannot be distinguished with certainty.
- Nodular coprolites: Within the irregularly wrapped coprolites a sub-type containing nodular texture is found. These coprolites present a spectrum of textures containing more or less nodules. In the end-member that consists entirely of nodules, the nodules are large and shaped like pellets.

These specimens rarely contain fossil fragments. These nodular textures have not earlier been described from coprolites.

The fossil food remains in the coprolites and the loose fossil material where examined. Fragments within coprolites were identified as scales from actinopterygian fish - possibly of Semionotid and Perleidiform origin. Loose fragments of dermal bone were ascribed to large temnospondyls - possibly *Gerrothorax* while a shark tooth was identified as belonging to *Rhomphaiodon minor*.

4. Acknowledgements

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Name	Max. diameter	Flat. diameter	Length	shape	Polished
MGUH30357	19	-	54	cylindrical	
MGUH30358	20	-	43	cylindrical-bulbous	
MGUH30359	24	-	35	cylindrical	x
MGUH30360	40	33	55	cylindrical-bulbous	
MGUH30361	18,5	-	48	cylindrical	
MGUH30362	13	-	28	cylindrical	
MGUH30363	16	-	33	cylindrical	
MGUH30364	14	-	26	cylindrical-bulbous	
MGUH30365	48	-	45	round-bulbous	
MGUH30366	28	19	33	bulbous	
MGUH30367	28	22,5	38,5	cylindrical-bulbous	
H001	17,5	12	31	cylindrical	x
H002	17	12	26,5	cylindrical	
H003	13,5	8,5	22,5	cylindrical	x
H004	24	-	37	cylindrical	x
H005	23,5	-	25	cylindrical	x
H006	14	-	19	cylindrical	x
H007	25,5	-	51	cylindrical-bulbous	x
H008	36	29	42,5	cylindrical	x
H009	17,5	-	36,5	cylindrical	
H010	15	-	25	cylindrical	x
H011	7,5	-	13,5	cylindrical	x
H012	16	11	15	cylindrical	x
H013	20	-	14,5	cylindrical	x
H014	25	21	38	cylindrical	x
H015	19	15	25	cylindrical-bulbous	x
H016	25,5	-	31	cylindrical	x
H017	23	-	20	cylindrical	x
H018	25	-	18	cylindrical	x
H019	19	-	15	cylindrical	x
H020	18	-	17	cylindrical	x
H021	27	19	37	cylindrical	x
H022	23	21	24	bulbous	x
H023	18	-	29	cylindrical	x
H024	19	-	21,5	cylindrical	x
H025	16	-	24	cylindrical	x
H026	19	-	15	cylindrical	x
H027	21	-	29,5	cylindrical	x
H028	19,5	16	23,5	cylindrical-bulbous	x
H029	19	-	33	cylindrical	x
H030	31	20	27	cylindrical	x
H031	17	-	20	cylindrical	x
H032	25	-	15	cylindrical	x
H033	16	13	18	cylindrical-bulbous	x
H034	24	18,5	26	cylindrical	x
H035	24	-	30	cylindrical-bulbous	x
H036	26,5	19	40	cylindrical	x
H037	29	19	48,5	cylindrical	x
H038	19	-	20	cylindrical-bulbous	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H039	19	-	19	round-cylindrical	x
H040	22	17	27	cylindrical	x
H041	17	-	17	cylindrical	x
H042	22	-	21,5	cylindrical	x
H043	19	16	26	cylindrical	x
H044	27	20	26,5	cylindrical	x
H045	19	-	16	cylindrical	x
H046	19	17	17	cylindrical-bulbous	x
H047	20	-	26	cylindrical-bulbous	x
H048	20,5	-	20	cylindrical-bulbous	x
H049	21,5	-	13,5	cylindrical	x
H050	26	20	30	cylindrical	x
H051	24	-	28	cylindrical	x
H052	21	17	28	cylindrical-bulbous	x
H053	24,5	19	22	cylindrical	x
H054	21	-	37	cylindrical	x
H055	26	22	27	cylindrical	x
H056	31	19	18	cylindrical-bulbous	x
H057	20,5	18	41	cylindrical	x
H058	22,5	19,5	31	cylindrical	x
H059	21	18	23	cylindrical	x
H060	19	-	34	cylindrical	x
H061	18	-	27	cylindrical-bulbous	x
H062	17	-	19	cylindrical	x
H063	17	-	16	cylindrical	x
H064	18,5	16	31	cylindrical	x
H065	21	17	26	cylindrical	x
H066	25	-	24	cylindrical	x
H067	22,5	-	28	cylindrical	x
H068	18	-	27	cylindrical	x
H069	20,5	-	40	cylindrical	
H070	21	-	37	cylindrical-bulbous	
H071	12	-	22	cylindrical-bulbous	
H072	20	-	21	round-cylindrical	x
H073	20	-	37,5	cylindrical	x
H074	18,5	-	19,5	round	x
H075	15	-	18	round	
H076	15	-	18,5	round-bulbous	x
H077	17	-	10,5	round	
H078	22	13,5	25	round-bulbous	
H079	20	-	26	round	
H080	17	14	22	round-bulbous	
H081	16,5	-	15	round-cylindrical	
H082	23,5	16,5	33	cylindrical	x
H083	19	13	33	cylindrical	x
H084	24,5	18	46	cylindrical	x
H085	17,5	10	18,5	cylindrical	x
H086	21	14	19,5	cylindrical	x
H087	24,5	-	27,5	cylindrical	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H088	29	25	24	cylindrical	x
H089	29	-	45,5	cylindrical	x
H090	21	15,5	31	cylindrical	x
H091	25,5	22	30	cylindrical	x
H092	23	19	23,5	cylindrical	x
H093	26	-	29	cylindrical	x
H094	22,5	-	37	cylindrical	x
H095	23,5	-	12	cylindrical	x
H096	16,5	-	17	cylindrical	x
H097	33	30	24	cylindrical	x
H098	24	-	29	cylindrical	x
H099	23	17,5	18	cylindrical	x
H100	15,5	12	25	cylindrical	x
H101	24,5	21	35,5	cylindrical	x
H102	16	-	10	cylindrical	x
H103	15	-	21	cylindrical	x
H104	16,5	-	26	cylindrical	x
H105	21	-	28	cylindrical	x
H106	20,5	-	22	cylindrical	x
H107	16	-	27	cylindrical	x
H108	23,5	19,5	42,5	cylindrical	x
H109	26	20,5	33	cylindrical	x
H110	27	17	31	cylindrical	
H111	27,5	-	23	cylindrical	x
H112	29,5	-	36	cylindrical	x
H113	22	15,5	30	cylindrical	x
H114	17	-	23	cylindrical	x
H115	20	-	23	cylindrical	x
H116	29	24,5	19,5	cylindrical	x
H117	22,5	-	23	cylindrical	x
H118	19,5	-	25	cylindrical-bulbous	x
H119	24	-	23	cylindrical	x
H120	24	-	19	cylindrical	x
H121	23	-	26	cylindrical	x
H122	19,5	-	20	cylindrical	x
H123	26	15	10	cylindrical	x
H124	23,5	-	25	cylindrical-bulbous	x
H125	25,5	22,5	21	cylindrical	x
H126	22	19,5	14	cylindrical	x
H127	17	-	16,5	cylindrical	x
H128	21	-	21	cylindrical	x
H129	25	22	36	cylindrical	x
H130	22,5	-	14	cylindrical	x
H131	22,5	20	15	cylindrical	x
H132	19	-	20	cylindrical	x
H133	25	15	22	cylindrical	x
H134	17	-	14	cylindrical	x
H135	17	-	17,5	cylindrical	x
H136	17	-	18	cylindrical	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H137	21	-	16	cylindrical	x
H138	12	-	25	cylindrical	x
H139	25	22	25,5	cylindrical	x
H140	22,5	-	17	cylindrical	x
H141	20	-	16	cylindrical	x
H142	23	18	33	cylindrical-bulbous	x
H143	21,5	-	27	cylindrical	x
H144	28,5	22	20	cylindrical	x
H145	16,5	13	30,5	cylindrical	x
H146	21	17	29	cylindrical	x
H147	25,5	21,5	27	cylindrical-bulbous	x
H148	22,5	18	29	cylindrical	x
H149	26	-	16	cylindrical	x
H150	27	19,5	35,5	cylindrical	x
H151	22	-	19	cylindrical	x
H152	13	10,5	20	cylindrical	x
H153	22	-	33,5	cylindrical	x
H154	14,5	10	21	cylindrical	x
H155	23,5	-	19	cylindrical	x
H156	23	-	16,5	cylindrical	x
H157	22,5	17	31	cylindrical	x
H158	17,5	-	21	cylindrical	x
H159	19	-	18,5	cylindrical	x
H160	22	-	41	cylindrical	x
H161	20,5	-	19	cylindrical	x
H162	26	-	40	cylindrical	x
H163	21	19	24	cylindrical	x
H164	14	12	25	cylindrical	x
H165	20,5	15	29	cylindrical	x
H166	16	-	19,5	cylindrical	x
H167	22	-	19	cylindrical-bulbous	x
H168	23	-	16	cylindrical-bulbous	x
H169	14	12	21	cylindrical	x
H170	19	15	20	cylindrical	x
H171	17	-	22	cylindrical	x
H172	22	17	13	cylindrical	x
H173	15	-	10	cylindrical	x
H174	10	8	11	cylindrical	x
H175	20	17	16	cylindrical	x
H176	23	-	15	cylindrical	x
H177	13	-	14	cylindrical	x
H178	13	-	13	cylindrical	x
H179	21	-	16	cylindrical	x
H180	16	-	25	bulbous	x
H181	15,5	-	33	cylindrical	x
H182	20,5	-	29	cylindrical	x
H183	15,5	13	21	cylindrical	x
H184	22	15,5	34	cylindrical	x
H185	22	18,5	22	bulbous	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H186	14	12	17	cylindrical	x
H187	13	-	22,5	cylindrical-bulbous	
H188	15,5	-	23	cylindrical-bulbous	
H189	14,5	-	16	cylindrical	
H190	12	-	17	cylindrical	
H191	20	-	43	cylindrical	
H192	18	15	17,5	cylindrical	x
H193	19	12	22	cylindrical	
H194	24	18,5	10	cylindrical	x
H195	19	-	29	cylindrical	x
H196	15	-	19	cylindrical	x
H197	22,5	18,5	17,5	cylindrical	x
H198	21	-	16	cylindrical	x
H199	11	-	14,5	bulbous	x
H200	20,5	-	35	cylindrical	
H201	11	9	22	cylindrical-bulbous	
H202	22	20	34	cylindrical-bulbous	x
H203	16	13	27	bulbous	
H204	18	-	23	cylindrical-bulbous	x
H205	22	-	42	cylindrical	x
H206	28	-	46	cylindrical-bulbous	
H207	21	-	13	cylindrical	
H208	20	18	9	cylindrical	x
H209	14	10	10	cylindrical	x
H210	9	8	12	cylindrical	x
H211	18	-	10,5	cylindrical	x
H212	19	-	16	cylindrical	x
H213	15,5	13,5	11	cylindrical	x
H214	16,5	-	8,5	cylindrical	x
H215	13,5	-	10	cylindrical	x
H216	18	15	12,5	cylindrical	x
H217	18	14	19	bulbous	x
H218	13	10	17	cylindrical	x
H219	22	-	15	bulbous	x
H220	7,5	-	8	cylindrical	x
H221	13	11	22	cylindrical	x
H222	15,5	13	17	cylindrical-bulbous	x
H223	13	-	17	cylindrical	x
H224	17	15	24	cylindrical	x
H225	u	u	u	unknown	x
H226	15,5	-	32	cylindrical	x
H227	19,5	16	33	cylindrical	x
H228	u	u	u	unknown	
H229	24	17,5	24	cylindrical-bulbous	x
H230	27,5	20	35,5	cylindrical	x
H231	24	21	27	cylindrical	x
H232	26	21	13	cylindrical	x
H233	25	20,5	24	cylindrical	x
H234	26	23	35	cylindrical	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H235	20	18	21	cylindrical	x
H236	23,5	-	14	cylindrical	x
H237	24	17,5	41	cylindrical	x
H238	23	-	19,5	cylindrical	x
H239	22	-	52	cylindrical	x
H240	27	-	33	cylindrical	x
H241	24	-	27	cylindrical	x
H242	22	-	20	cylindrical	x
H243	22,5	17	36	cylindrical	x
H244	21	-	21	cylindrical	x
H245	22	-	30	cylindrical	x
H246	19	-	30	bulbous	x
H247	23	18	35,5	cylindrical	x
H248	29,5	-	8	cylindrical	x
H249	25	-	9	cylindrical	x
H250	22	-	14	cylindrical	x
H251	26	-	9,5	cylindrical	x
H252	19	-	10	cylindrical	x
H253	21,5	-	20	cylindrical	x
H254	25	19	12	cylindrical	x
H255	27	23	16	cylindrical	x
H256	21	-	22	cylindrical	x
H257	18	-	13	cylindrical	x
H258	19	-	25	cylindrical	x
H259	31	-	29	cylindrical	x
H260	29	24	18	bulbous	x
H261	21	18	18,5	cylindrical	x
H262	24	-	17	cylindrical	x
H263	21	-	7	cylindrical	x
H264	23	-	10	cylindrical	x
H265	21	-	26	cylindrical	x
H266	26,5	-	18	bulbous	x
H267	27	-	21	cylindrical-bulbous	x
H268	18	-	20	cylindrical	x
H269	23	14	8	cylindrical	x
H270	21	-	10	cylindrical	x
H271	16,5	14	24	cylindrical	x
H272	26	-	14	cylindrical	x
H273	23	-	10	cylindrical	x
H274	22	-	16	cylindrical	x
H275	17	-	12	cylindrical	x
H276	16	-	12	cylindrical	x
H277	14	-	10	cylindrical	x
H278	15	11	22	cylindrical	x
H279	22	-	6	cylindrical	x
H280	19	-	8	cylindrical	x
H281	19,5	15	18	cylindrical	x
H282	17	-	14,5	cylindrical	x
H283	19	-	10	cylindrical	x

Name	Max. diameter	Flat. diameter	Length	shape	Polished
H284	11	-	12	cylindrical	x
H285	25	17	11	cylindrical	x
H286	19	11,5	31	cylindrical	x
H287	26	16,5	21,5	cylindrical	x
H288	26,5	22	16	cylindrical	x
H289	32	27	8	cylindrical	x
H290	27	17	16	cylindrical	x
H291	18	-	6,5	cylindrical	x
H292	15	-	7	cylindrical	x
H293	17	13,5	7,5	cylindrical	x
H294	27,5	23	12	cylindrical	x
H295	19	17	6	cylindrical	x
H296	17,5	-	8	cylindrical	x
H297	17	-	3,5	cylindrical	x
H298	27,5	23,5	11	cylindrical	x
H299	25	15,5	5,5	cylindrical	x
H300	30	23	7,5	cylindrical	x
H301	18	-	14	cylindrical	x
H302	18	-	11	cylindrical	x
H303	16,5	-	13	cylindrical	x
H304	23	-	5	cylindrical	x
H305	20	-	6	cylindrical	x
H306	16	-	11	cylindrical	x
H307	18	13	12	cylindrical	x
H308	19,5	15	17	bulbous	x
H309	u	u	u	unknown	x
H310	20	18	29	cylindrical	x
H311	17	-	37	cylindrical	
H312	11,5	9	21	cylindrical-bulbous	
H313	24	22	16,5	cylindrical	
N1	19,5	16	14	cylindrical	x
N3	20	16	22	cylindrical	x
N4	19	16	18	cylindrical	
N2	20	16	23	cylindrical	x

Name	Structure	texture	Nodule size	Dark rims	Light rims
MGUH30357	Irr. wrapped	massive-nodular	2,5	u	u
MGUH30358	Irr. wrapped	unknown	0	u	u
MGUH30359	Irr. wrapped	massive-nodular	0,5	0	2
MGUH30360	Irr. wrapped	unknown	0	u	u
MGUH30361	Strudtureless	unknown	0	u	u
MGUH30362	Strudtureless	unknown	1	u	u
MGUH30363	Strudtureless	unknown	0	u	u
MGUH30364	Irr. wrapped	unknown	0	u	u
MGUH30365	spiral/coiled	massive-swirly	0	u	u
MGUH30366	spiral/coiled	unknown	1	u	u
MGUH30367	spiral/coiled	unknown	0	u	u
H001	spiral/coiled	massive	0	0	0
H002	spiral/coiled	unknown	0	u	u
H003	spiral/coiled	swirly-massive	0	0,1	1
H004	spiral/coiled	swirly-massive	0	0	0
H005	spiral/coiled	massive	0	0,1	0,1
H006	spiral/coiled	swirly-massive	0	0	0,1
H007	spiral/coiled	swirly-massive	0	0,1	0,1
H008	spiral/coiled	massive	0	0,1	1
H009	spiral/coiled	unknown	0	u	u
H010	spiral/coiled	massive-swirly	0	0	0,1
H011	spiral/coiled	swirly	0	0	0,1
H012	spiral/coiled	massive-swirly	0	2	0,5
H013	spiral/coiled	swirly-massive	2	0	0,1
H014	Irr. wrapped	swirly-massive	1,5	0,5	0
H015	Irr. wrapped	massive	0	1,5	0
H016	Irr. wrapped	swirly-massive	2	0,1	0
H017	spiral/coiled	swirly	2	0	0,1
H018	Irr. wrapped	massive	0	0	0,2
H019	Irr. wrapped	massive-swirly	0,5	1	0,1
H020	Irr. wrapped	massive	0	0,1	3
H021	Irr. wrapped	massive	0	0	1
H022	Irr. wrapped	massive	0	0,2	0
H023	Irr. wrapped	nodular-massive	3	0,2	0
H024	Irr. wrapped	massive	0,2	0,5	0,1
H025	Irr. wrapped	massive	0	1	2
H026	Irr. wrapped	massive	0	0	0,1
H027	Irr. wrapped	massive	0	0,5	0,1
H028	Irr. wrapped	massive-swirly	0	0,2	0,5
H029	Irr. wrapped	massive	0	0	0,1
H030	Irr. wrapped	massive-nodular	1	0,1	0,5
H031	Irr. wrapped	massive	0	0,2	0,1
H032	Irr. wrapped	massive-swirly	0	0,2	0,1
H033	Irr. wrapped	massive-nodular	1	0	0,1
H034	Irr. wrapped	massive-swirly	1	0,5	0,1
H035	Irr. wrapped	massive-nodular	1	0,5	0,1
H036	Irr. wrapped	nodular-massive	2	0	0,1
H037	Irr. wrapped	nodular-massive	1,5	0,1	0,1
H038	Irr. wrapped	massive	0	0,1	0,1

Name	Structure	texture	Nodule size	Dark rims	Light rims
H039	Irr. wrapped	swirly-massive	0	0,2	0,1
H040	Irr. wrapped	nodular	5,5	0,2	0,1
H041	Irr. wrapped	massive-swirly	0	0,2	0
H042	Irr. wrapped	massive-swirly	0	0	0,1
H043	Irr. wrapped	massive-nodular	0,2	0	0,1
H044	Irr. wrapped	massive	0	0	2
H045	Irr. wrapped	massive	0	0,1	0,2
H046	Irr. wrapped	nodular	2	0	1
H047	Irr. wrapped	massive	0	0,1	0,1
H048	Irr. wrapped	massive-nodular	1	0	0,1
H049	Irr. wrapped	massive	0	0,2	0,1
H050	Irr. wrapped	swirly-nodular	1	2	0,1
H051	Irr. wrapped	massive	0	0	0,2
H052	Irr. wrapped	massive	0	0,2	0,1
H053	Irr. wrapped	massive	0	0,1	1,5
H054	Irr. wrapped	massive	0	0	1
H055	Irr. wrapped	massive	0	0,2	0,1
H056	Irr. wrapped	nodular-swirly	3	0	0,1
H057	Irr. wrapped	swirly-massive	0	0,5	0,1
H058	Irr. wrapped	massive-swirly	1	0	1
H059	Irr. wrapped	massive	1,5	1	0
H060	Irr. wrapped	massive	0	0	0,1
H061	Irr. wrapped	swirly-nodular	0,5	0,1	0,1
H062	Irr. wrapped	massive	0	0	0,5
H063	Irr. wrapped	massive-nodular	1	0	0,1
H064	Irr. wrapped	massive	0	0,1	0
H065	Irr. wrapped	massive	0	0,1	0,2
H066	Irr. wrapped	massive	0	0,5	0
H067	Irr. wrapped	massive	1	0	0,1
H068	Irr. wrapped	massive-swirly	0	1	1
H069	Irr. wrapped	unknown	0	u	u
H070	Irr. wrapped	unknown	0	u	u
H071	Strudtureless	massive-nodular	3	u	u
H072	Strudtureless	massive	0	1	0
H073	Strudtureless	massive	0	0	0,1
H074	Strudtureless	massive	0	0,2	0,1
H075	Strudtureless	unknown	0	u	u
H076	Strudtureless	nodular	4	0,5	0,1
H077	Strudtureless	unknown	0	u	u
H078	Strudtureless	unknown	0	u	u
H079	Irr. wrapped	unknown	0	u	u
H080	Strudtureless	unknown	0	u	u
H081	Strudtureless	unknown	0	u	u
H082	Strudtureless	massive	0	1	0
H083	Strudtureless	massive	0	0,1	0
H084	Strudtureless	massive	0	0	2
H085	Strudtureless	massive	0	0	0,1
H086	Strudtureless	swirly-nodular	1	0,1	0,2
H087	Strudtureless	massive-nodular	0,5	0	1

Name	Structure	texture	Nodule size	Dark rims	Light rims
H088	Strudtureless	massive	0	0,1	0
H089	Strudtureless	massive	0	1,5	0
H090	Strudtureless	massive	0	0,1	0,5
H091	Strudtureless	massive	0	1	0,5
H092	Strudtureless	massive	0	0	0,5
H093	Strudtureless	massive	0	0,5	0
H094	Strudtureless	massive-nodular	1,5	1,5	0
H095	Strudtureless	massive-nodular	2	1	0,1
H096	Strudtureless	massive	0	0,2	1
H097	Strudtureless	massive	0	0,5	1
H098	Strudtureless	massive-nodular	6	0,5	1
H099	Strudtureless	massive-swirly	0	0,1	1,5
H100	Strudtureless	massive	0	0,2	0,1
H101	Strudtureless	massive-nodular	1,5	0,2	0,1
H102	Strudtureless	massive	0	0,1	0
H103	Strudtureless	massive	0	0,5	0
H104	Strudtureless	swirly-nodular	1	0,2	0,1
H105	Strudtureless	massive-swirly	0	0	0,5
H106	Strudtureless	massive-nodular	0,1	0,2	0,1
H107	Strudtureless	massive-swirly	0,5	0,5	0
H108	Strudtureless	massive	0	3	0
H109	Irr. wrapped	massive	0	1	0
H110	Strudtureless	massive	0	1	0
H111	Strudtureless	massive-swirly	0	1,5	0
H112	Strudtureless	massive-nodular	2	2	0
H113	Strudtureless	swirly-nodular	1	2	0
H114	Strudtureless	massive-nodular	1	1	4
H115	Strudtureless	massive	0	2	0
H116	Strudtureless	massive-nodular	0,5	1	0,1
H117	Strudtureless	massive-nodular	0,2	0,5	0
H118	Strudtureless	massive-nodular	0,1	0	0
H119	Strudtureless	massive-nodular	2	2,5	0,1
H120	Strudtureless	massive-nodular	2	0,5	0,1
H121	Strudtureless	massive-swirly	0	1	0,1
H122	Strudtureless	massive-nodular	1	1	0
H123	Strudtureless	massive	0	1	0
H124	Strudtureless	swirly-nodular	1,5	0,5	0
H125	Strudtureless	massive	0	0,5	0
H126	Strudtureless	massive-swirly	0	0,5	0
H127	Strudtureless	massive	0,2	0,2	0,1
H128	Strudtureless	massive-swirly	0,2	0,5	0
H129	Strudtureless	massive	0	0,1	1,5
H130	Strudtureless	massive	1	0,5	0
H131	Strudtureless	massive	0	1,5	0
H132	Strudtureless	massive-nodular	2,5	0,1	0
H133	Strudtureless	massive	0,5	0,2	1
H134	Strudtureless	massive	0	0,2	0,1
H135	Strudtureless	massive	0	0,5	0,1
H136	Strudtureless	massive	0	0,5	3

Name	Structure	texture	Nodule size	Dark rims	Light rims
H137	Strudtureless	massive	0	0,2	0,1
H138	Strudtureless	massive-swirly	0	1	0,1
H139	Strudtureless	massive	0	0	0
H140	Strudtureless	swirly-nodular	1,5	0,1	2
H141	Strudtureless	massive	0	0	1
H142	Irr. wrapped	massive-swirly	1,5	0,2	0,1
H143	Irr. wrapped	massive	0	1	0,5
H144	Irr. wrapped	massive	0	3,5	0
H145	Irr. wrapped	nodular-swirly	2	0	0,1
H146	Irr. wrapped	swirly-nodular	3	0	0,1
H147	Irr. wrapped	swirly-nodular	1	0,5	0,1
H148	Irr. wrapped	nodular-massive	2	0,1	1,5
H149	Irr. wrapped	nodular	3,5	0	0,1
H150	Irr. wrapped	nodular-swirly	3,5	0	0,1
H151	Irr. wrapped	swirly-nodular	2	0,5	0
H152	Irr. wrapped	nodular	2	1	0,1
H153	Irr. wrapped	massive-nodular	2	2	0,1
H154	Irr. wrapped	nodular-swirly	1	0,1	1
H155	Strudtureless	nodular	3,5	1	0,1
H156	Irr. wrapped	nodular	2,5	0	0,2
H157	Irr. wrapped	nodular-massive	2	0	0,1
H158	Strudtureless	massive-nodular	1	1	0,2
H159	Irr. wrapped	nodular	3	0,2	0,1
H160	Irr. wrapped	swirly-nodular	1	0	0,1
H161	Strudtureless	massive-nodular	1	0	0,1
H162	Irr. wrapped	swirly-nodular	2	0,2	0,1
H163	Irr. wrapped	nodular	3,5	0,1	0,1
H164	Irr. wrapped	swirly-nodular	0,5	0	5
H165	Irr. wrapped	nodular-swirly	4	0,5	0,1
H166	Irr. wrapped	nodular-swirly	2,5	0,2	0
H167	Irr. wrapped	nodular-swirly	2,5	0,5	0
H168	Irr. wrapped	swirly-massive	1	0	0,2
H169	Strudtureless	nodular-massive	2	0	0,5
H170	Strudtureless	nodular-massive	3	0,1	0,1
H171	Strudtureless	swirly-nodular	1	0,5	0,1
H172	Strudtureless	massive-nodular	3	0	0,5
H173	Irr. wrapped	swirly-nodular	3	0	0,1
H174	Strudtureless	massive-nodular	2	0	0,1
H175	Irr. wrapped	nodular-massive	3	0	0,1
H176	Irr. wrapped	massive-nodular	2	0	0,1
H177	Strudtureless	nodular	4	0	0,2
H178	Strudtureless	nodular	5,5	0,1	0,1
H179	Strudtureless	nodular	4	1,5	0
H180	Strudtureless	nodular	3	0	0,1
H181	Irr. wrapped	massive-swirly	1	0	1
H182	Irr. wrapped	nodular	3,5	0,5	0,1
H183	Irr. wrapped	swirly-nodular	2,5	0	0,1
H184	Irr. wrapped	nodular-massive	2,5	0	4
H185	Irr. wrapped	nodular	3	0,1	0,2

Name	Structure	texture	Nodule size	Dark rims	Light rims
H186	Irr. wrapped	nodular	2	0	0,2
H187	Irr. wrapped	nodular	3,5	u	u
H188	Irr. wrapped	nodular	3	u	u
H189	Irr. wrapped	nodular	2,5	u	u
H190	Strudtureless	nodular	3	u	u
H191	Irr. wrapped	massive-nodular	3	u	u
H192	Irr. wrapped	swirly-nodular	2,5	0	0,1
H193	Irr. wrapped	unknown	0	u	u
H194	Irr. wrapped	nodular-swirly	3	0	0,1
H195	Irr. wrapped	nodular-swirly	3	0	0,1
H196	Irr. wrapped	nodular-swirly	3	0	0,2
H197	Irr. wrapped	nodular-swirly	4	1	0
H198	Strudtureless	nodular	5	0,5	0,1
H199	Strudtureless	nodular	4	0,5	0
H200	Irr. wrapped	unknown	0	u	u
H201	Irr. wrapped	unknown	0	u	u
H202	Irr. wrapped	nodular	6	0,1	0
H203	Irr. wrapped	nodular	4	u	u
H204	Irr. wrapped	swirly-nodular	1,5	0,2	0,1
H205	Irr. wrapped	massive-swirly	1	0	0,5
H206	Irr. wrapped	unknown	0	u	u
H207	Irr. wrapped	unknown	0	u	u
H208	Irr. wrapped	nodular-massive	3,5	0	0,1
H209	Irr. wrapped	nodular-massive	3,5	0	0,1
H210	Irr. wrapped	nodular-massive	3	0	0,1
H211	Irr. wrapped	massive-nodular	2	0	0,1
H212	Irr. wrapped	nodular	3	0	0,2
H213	Strudtureless	nodular	3	0	0,2
H214	Irr. wrapped	swirly	1,5	0	0,1
H215	Strudtureless	nodular-swirly	2	0	0,1
H216	Irr. wrapped	massive-nodular	2,5	0	0,1
H217	Strudtureless	nodular	4,5	0	0,1
H218	Strudtureless	swirly	0	0	0,1
H219	Strudtureless	massive	0	0	1
H220	Strudtureless	massive	0	0,1	1
H221	Irr. wrapped	massive-nodular	3	0	0,1
H222	Irr. wrapped	massive	0	0,5	0,1
H223	Irr. wrapped	unknown	0	0	0,1
H224	Irr. wrapped	nodular	4	0	0,1
H225	Irr. wrapped	nodular	6	0,1	0,2
H226	Strudtureless	massive	0	0	1
H227	Irr. wrapped	swirly	1	0	2
H228	Irr. wrapped	nodular	5	u	u
H229	Irr. wrapped	massive	0	0,2	0,5
H230	Irr. wrapped	swirly-nodular	1	0	0,1
H231	Strudtureless	massive	0	0,2	0
H232	Strudtureless	massive-nodular	0,5	0,2	0,1
H233	Strudtureless	swirly	0	2	0
H234	Irr. wrapped	massive-nodular	0,5	0	0,5

Name	Structure	texture	Nodule size	Dark rims	Light rims
H235	Strudtureless	nodular-swirly	1,5	0	0,1
H236	Irr. wrapped	massive-swirly	0	0	0,2
H237	Irr. wrapped	swirly-massive	0	1	0,1
H238	Strudtureless	massive	0	0	4
H239	Irr. wrapped	nodular-swirly	2	0	0,1
H240	Irr. wrapped	massive	0	0	0,1
H241	Irr. wrapped	swirly	0	0,1	4
H242	Irr. wrapped	massive	0	0	0,2
H243	Irr. wrapped	massive	0	0	0,1
H244	Irr. wrapped	massive	0	0	0
H245	Irr. wrapped	massive	0	0	0
H246	Irr. wrapped	massive-swirly	0	0,1	0,1
H247	Strudtureless	massive	0	0,1	0,1
H248	Irr. wrapped	massive	0	0	0
H249	spiral/coiled	swirly	0	0,2	1
H250	Irr. wrapped	massive-swirly	0	0,5	0,1
H251	Strudtureless	massive	0	0,1	0
H252	Strudtureless	massive	0	0	0,1
H253	Irr. wrapped	massive-swirly	1,5	0,1	0,1
H254	Irr. wrapped	swirly	0	2	0
H255	Irr. wrapped	massive	0	0,1	0
H256	Irr. wrapped	massive-swirly	0	0	0,2
H257	Strudtureless	massive	0	0	0,1
H258	Irr. wrapped	swirly	0	0	0,5
H259	Irr. wrapped	nodular	5	0,1	0
H260	Irr. wrapped	swirly-nodular	2	0,2	0,1
H261	Irr. wrapped	massive	0	0,5	0
H262	Irr. wrapped	swirly-nodular	2	0	0
H263	Irr. wrapped	massive-swirly	1,5	0	0
H264	Irr. wrapped	massive	0	0	0
H265	Irr. wrapped	swirly-massive	0	1	0
H266	Irr. wrapped	nodular	5,5	2,5	0
H267	Irr. wrapped	massive-nodular	1,5	0	0,1
H268	Irr. wrapped	massive-swirly	0	0,2	0,1
H269	Strudtureless	massive	0	0	0,5
H270	Strudtureless	massive-nodular	3	0,5	0
H271	Irr. wrapped	nodular-massive	1	0,1	0
H272	Strudtureless	massive	0	0,5	0
H273	Strudtureless	massive	0	2	0
H274	Strudtureless	nodular	4	0,2	0
H275	Irr. wrapped	massive-swirly	0	0,1	0
H276	Strudtureless	massive	0	0	1
H277	Irr. wrapped	massive	0	0	2
H278	Strudtureless	massive	0	0,1	0,2
H279	Strudtureless	massive-nodular	3	0	0,1
H280	Strudtureless	nodular	6	0	0,1
H281	Strudtureless	massive	0	0,1	0,2
H282	Strudtureless	nodular	2,5	0,5	0
H283	Irr. wrapped	massive-nodular	1	1	0

Name	Structure	texture	Nodule size	Dark rims	Light rims
H284	Strudtureless	massive-nodular	1	0	0,2
H285	Irr. wrapped	nodular-massive	1,5	0,1	0,1
H286	Irr. wrapped	massive	2	0	0,1
H287	Strudtureless	nodular	3	0	0,5
H288	Irr. wrapped	massive-swirly	5	0	0,1
H289	Irr. wrapped	massive	0	0	0,1
H290	Strudtureless	massive	0	0,1	0,1
H291	Strudtureless	massive	0	0,2	0
H292	Irr. wrapped	massive	0	0,2	0,1
H293	Strudtureless	nodular	5,5	0	0,1
H294	Irr. wrapped	massive	0	0,5	0,1
H295	Irr. wrapped	massive	0	0,5	0
H296	Strudtureless	massive-nodular	0,2	0	0,1
H297	Irr. wrapped	massive	0	0,1	0
H298	Irr. wrapped	massive-nodular	0,1	0,1	0,1
H299	Irr. wrapped	swirly-nodular	2	0	0,1
H300	Strudtureless	massive	0	0	1
H301	Irr. wrapped	massive	0	0	0,2
H302	Irr. wrapped	nodular-massive	1,5	0	0,5
H303	Strudtureless	nodular	5	0	0,2
H304	Irr. wrapped	swirly-nodular	2	0	0,1
H305	Strudtureless	massive-nodular	0,5	0	0,1
H306	Irr. wrapped	swirly-nodular	1	0	0,1
H307	Strudtureless	massive	0	0	0,1
H308	Irr. wrapped	nodular	2	0,5	0
H309	Unknown	massive	0	3	0
H310	spiral/coiled	swirly-massive	0	1	0
H311	Unknown	unknown	0	u	u
H312	Irr. wrapped	unknown	0	u	u
H313	Irr. wrapped	unknown	0	u	u
N1	Strudtureless	massive	0	0	0,2
N3	Strudtureless	massive	0	0	0
N4	Unknown	unknown	0	u	u
N2	Strudtureless	massive	0	0	0

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
MGUH30357	1	1,5	u	u	1	1,5
MGUH30358	2	2	u	u	2	2
MGUH30359	2	1	u	u	2	1
MGUH30360	3	3,5	u	u	3	3,5
MGUH30361	0	0	u	u	0	0
MGUH30362	3	1	u	u	3	1
MGUH30363	0	0	u	u	0	0
MGUH30364	0	0	u	u	0	0
MGUH30365	0	0	1	0,1	1	0,1
MGUH30366	1	1,5	u	u	1	1,5
MGUH30367	1	2	u	u	1	2
H001	2	2	3	3	3	3
H002	3	3	u	u	3	3
H003	2	1	1	0,5	2	1
H004	0	0	0	0	0	0
H005	1	1	3	3,5	3	3,5
H006	3	1	3	2	3	2
H007	0	0	0	0	0	0
H008	1	1	0	0	1	1
H009	3	4	u	u	3	4
H010	0	0	2	0,5	2	0,5
H011	1	1	3	1,5	3	1,5
H012	0	0	1	0,2	1	0,2
H013	0	0	0	0	0	0
H014	0	0	1	2	1	2
H015	0	0	u	u	0	0
H016	3	1	3	2	3	2
H017	0	0	0	0	0	0
H018	1	2	2	2	2	2
H019	2	2	1	1	2	2
H020	1	1	3	1,5	3	1,5
H021	1	1,5	2	2,5	2	2,5
H022	0	0	2	4	2	4
H023	0	0	0	0	0	0
H024	0	0	2	4	2	4
H025	1	1	1	0,1	1	1
H026	1	1	1	0,5	1	1
H027	1	0,5	2	1,5	2	1,5
H028	0	0	1	1	1	1
H029	1	7	2	6	2	7
H030	0	0	1	0,5	1	0,5
H031	2	0,5	2	1,5	2	1,5
H032	0	0	1	3	1	3
H033	1	1	1	3	1	3
H034	0	0	1	3	1	3
H035	0	0	2	0,5	2	0,5
H036	2	5	1	2	2	5
H037	1	1,5	2	2	2	2
H038	0	0	2	3,5	2	3,5

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H039	2	1,5	3	1,5	3	1,5
H040	0	0	0	0	0	0
H041	0	0	2	2,5	2	2,5
H042	2	2,5	2	2	2	2,5
H043	2	4	2	1,5	2	4
H044	2	2	2	4	2	4
H045	2	2	3	3,5	3	3,5
H046	0	0	0	0	0	0
H047	2	4	2	4,5	2	4,5
H048	1	2,5	2	2,5	2	2,5
H049	1	1	3	4	3	4
H050	0	0	0	0	0	0
H051	1	2	2	3,5	2	3,5
H052	1	1	2	1,5	2	1,5
H053	0	0	1	1	1	1
H054	0	0	1	0,1	1	0,1
H055	0	0	2	4,5	2	4,5
H056	0	0	0	0	0	0
H057	0	0	2	4	2	4
H058	0	0	1	1,5	1	1,5
H059	1	1	1	1	1	1
H060	2	3	1	2	2	3
H061	3	2,5	2	3,5	3	3,5
H062	0	0	1	1,5	1	1,5
H063	0	0	0	0	0	0
H064	0	0	0	0	0	0
H065	0	0	0	0	0	0
H066	1	0,5	2	1,5	2	1,5
H067	0	0	1	1	1	1
H068	0	0	2	3,5	2	3,5
H069	3	5,5	u	u	3	5,5
H070	2	2,5	u	u	2	2,5
H071	1	1	1	1	1	1
H072	0	0	0	0	0	0
H073	0	0	1	1	1	1
H074	0	0	1	2	1	2
H075	2	6	u	u	2	6
H076	0	0	0	0	0	0
H077	1	1	2	2	2	2
H078	1	0,5	u	u	1	0,5
H079	2	3,5	3	2,5	3	3,5
H080	0	0	u	u	0	0
H081	0	0	1	2	1	2
H082	0	0	1	2,5	1	2,5
H083	0	0	0	0	0	0
H084	0	0	1	0,1	1	0,1
H085	2	0,1	0	0	2	0,1
H086	0	0	1	0,5	1	0,5
H087	0	0	1	0,5	1	0,5

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H088	0	0	1	0,1	1	0,1
H089	0	0	0	0	0	0
H090	0	0	0	0	0	0
H091	1	0,2	0	0	1	0,2
H092	1	0,1	2	0,1	2	0,1
H093	0	0	2	0,1	2	0,1
H094	0	0	0	0	0	0
H095	0	0	0	0	0	0
H096	0	0	1	1	1	1
H097	0	0	2	0,1	2	0,1
H098	0	0	0	0	0	0
H099	0	0	0	0	0	0
H100	0	0	2	0,1	2	0,1
H101	1	0,1	1	2	1	2
H102	0	0	2	1	2	1
H103	0	0	2	0,5	2	0,5
H104	1	1	2	2,5	2	2,5
H105	2	1	1	3	2	3
H106	1	3,5	3	6	3	6
H107	0	0	1	1	1	1
H108	1	4	2	4	2	4
H109	0	0	3	4	3	4
H110	0	0	2	3,5	2	3,5
H111	1	1	1	1,5	1	1,5
H112	0	0	2	1	2	1
H113	3	2	2	3	3	3
H114	1	2	2	1	2	2
H115	0	0	2	4,5	2	4,5
H116	0	0	1	3	1	3
H117	0	0	2	4,5	2	4,5
H118	0	0	1	1	1	1
H119	2	2	2	2	2	2
H120	1	2	2	3	2	3
H121	2	1	1	1	2	1
H122	0	0	1	1	1	1
H123	0	0	1	2,5	1	2,5
H124	2	2	2	2	2	2
H125	2	0,5	1	0,5	2	0,5
H126	1	1	1	1	1	1
H127	1	0,5	2	2	2	2
H128	2	1,5	1	2	2	2
H129	1	1	1	2	1	2
H130	0	0	1	1	1	1
H131	0	0	1	3,5	1	3,5
H132	1	3	2	3	2	3
H133	0	0	1	1	1	1
H134	0	0	2	2	2	2
H135	2	3	2	4	2	4
H136	1	1,5	1	2	1	2

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H137	0	0	1	0,5	1	0,5
H138	2	0,5	1	3	2	3
H139	0	0	1	2	1	2
H140	0	0	1	0,5	1	0,5
H141	1	1	1	0,5	1	1
H142	0	0	0	0	0	0
H143	0	0	2	4	2	4
H144	0	0	3	3	3	3
H145	0	0	1	1	1	1
H146	1	2	1	1	1	2
H147	1	0,5	1	0,2	1	0,5
H148	1	1,5	0	0	1	1,5
H149	1	1	0	0	1	1
H150	1	1	0	0	1	1
H151	0	0	0	0	0	0
H152	0	0	0	0	0	0
H153	2	4	2	3	2	4
H154	0	0	1	1,5	1	1,5
H155	0	0	0	0	0	0
H156	0	0	0	0	0	0
H157	0	0	2	2	2	2
H158	1	2	2	1	2	2
H159	1	1	2	2	2	2
H160	2	4	2	4	2	4
H161	2	2,5	2	5	2	5
H162	1	1,5	0	0	1	1,5
H163	0	0	1	2	1	2
H164	0	0	1	0,2	1	0,2
H165	0	0	1	1	1	1
H166	0	0	0	0	0	0
H167	0	0	0	0	0	0
H168	2	1	1	2	2	2
H169	1	2	2	2,5	2	2,5
H170	1	2	1	1	1	2
H171	2	2	2	1,5	2	2
H172	1	1	2	2	2	2
H173	0	0	0	0	0	0
H174	0	0	0	0	0	0
H175	1	1	2	2	2	2
H176	0	0	0	0	0	0
H177	0	0	0	0	0	0
H178	0	0	0	0	0	0
H179	1	1	2	2,5	2	2,5
H180	0	0	0	0	0	0
H181	1	2	1	1	1	2
H182	0	0	0	0	0	0
H183	1	2	1	3,5	1	3,5
H184	0	0	1	0,5	1	0,5
H185	0	0	0	0	0	0

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H186	0	0	0	0	0	0
H187	0	0	u	u	0	0
H188	0	0	u	u	0	0
H189	1	2	u	u	1	2
H190	0	0	u	u	0	0
H191	1	1	u	u	1	1
H192	0	0	0	0	0	0
H193	2	2	u	u	2	2
H194	0	0	0	0	0	0
H195	0	0	1	2	1	2
H196	0	0	0	0	0	0
H197	0	0	0	0	0	0
H198	0	0	0	0	0	0
H199	0	0	0	0	0	0
H200	2	10	3	5	3	10
H201	0	0	u	u	0	0
H202	0	0	0	0	0	0
H203	0	0	0	0	0	0
H204	0	0	1	0,5	1	0,5
H205	0	0	1	0,1	1	0,1
H206	1	2	u	u	1	2
H207	2	2,5	u	u	2	2,5
H208	0	0	0	0	0	0
H209	0	0	0	0	0	0
H210	0	0	0	0	0	0
H211	1	1	2	2	2	2
H212	0	0	0	0	0	0
H213	0	0	0	0	0	0
H214	2	1	2	2	2	2
H215	0	0	2	0,2	2	0,2
H216	0	0	0	0	0	0
H217	0	0	0	0	0	0
H218	0	0	1	1	1	1
H219	1	1	1	1	1	1
H220	0	0	0	0	0	0
H221	0	0	0	0	0	0
H222	0	0	1	2	1	2
H223	0	0	u	u	0	0
H224	1	1,5	2	2	2	2
H225	0	0	0	0	0	0
H226	1	2	1	0,5	1	2
H227	1	1	2	1,5	2	1,5
H228	0	0	u	u	0	0
H229	0	0	2	0,2	2	0,2
H230	1	3	1	0,2	1	3
H231	0	0	0	0	0	0
H232	0	0	1	2	1	2
H233	0	0	2	1	2	1
H234	0	0	1	3	1	3

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H235	2	1	2	2	2	2
H236	0	0	2	4	2	4
H237	1	1	1	2	1	2
H238	0	0	0	0	0	0
H239	1	2	0	0	1	2
H240	1	3,5	2	3,5	2	3,5
H241	1	1	2	2	2	2
H242	0	0	2	5	2	5
H243	2	3,5	3	3	3	3,5
H244	2	3,5	2	3,5	2	3,5
H245	2	5	2	6,5	2	6,5
H246	1	1	2	2,5	2	2,5
H247	3	4	3	5,5	3	5,5
H248	0	0	2	3,5	2	3,5
H249	0	0	0	0	0	0
H250	1	0,5	2	0,5	2	0,5
H251	0	0	2	5,5	2	5,5
H252	0	0	1	2	1	2
H253	0	0	1	1	1	1
H254	1	4	2	5	2	5
H255	0	0	1	0,5	1	0,5
H256	0	0	1	2,5	1	2,5
H257	1	1	2	4,5	2	4,5
H258	2	2	2	2	2	2
H259	1	2	2	2	2	2
H260	0	0	1	6	1	6
H261	1	1	2	4	2	4
H262	0	0	1	2	1	2
H263	1	1,5	2	3,5	2	3,5
H264	0	0	2	3,5	2	3,5
H265	0	0	0	0	0	0
H266	0	0	0	0	0	0
H267	0	0	2	5	2	5
H268	1	1,5	1	0,5	1	1,5
H269	0	0	0	0	0	0
H270	0	0	0	0	0	0
H271	2	3	2	2,5	2	3
H272	0	0	1	0,5	1	0,5
H273	0	0	0	0	0	0
H274	0	0	0	0	0	0
H275	0	0	1	1	1	1
H276	2	0,1	3	1,5	3	1,5
H277	0	0	2	3	2	3
H278	0	0	0	0	0	0
H279	0	0	0	0	0	0
H280	0	0	0	0	0	0
H281	2	1	2	2,5	2	2,5
H282	0	0	0	0	0	0
H283	0	0	2	3,5	2	3,5

Name	Cat. frag. Sur.	Size frag. Sur.	Cat. frag. Int.	Size frag. Int.	Cat. all frag.	Size all frag.
H284	0	0	1	0,2	1	0,2
H285	0	0	0	0	0	0
H286	3	0,2	1	1	3	1
H287	1	0,5	0	0	1	0,5
H288	1	1	2	2	2	2
H289	0	0	1	1,5	1	1,5
H290	2	1	2	2,5	2	2,5
H291	0	0	1	0,2	1	0,2
H292	2	1,5	2	3	2	3
H293	0	0	0	0	0	0
H294	0	0	2	4,5	2	4,5
H295	0	0	1	1	1	1
H296	0	0	2	5,5	2	5,5
H297	0	0	0	0	0	0
H298	0	0	1	10	1	10
H299	0	0	0	0	0	0
H300	0	0	1	1	1	1
H301	0	0	2	3	2	3
H302	1	1	2	3,5	2	3,5
H303	0	0	0	0	0	0
H304	0	0	2	3	2	3
H305	0	0	0	0	0	0
H306	0	0	0	0	0	0
H307	0	0	0	0	0	0
H308	0	0	1	1	1	1
H309	0	0	0	0	0	0
H310	2	3	2	2	2	2
H311	0	0	2	3	2	3
H312	2	5	u	u	2	5
H313	3	7	3	8	3	8
N1	0	0	0	0	0	0
N3	0	0	0	0	0	0
N4	0	0	0	0	0	0
N2	0	0	0	0	0	0

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
MGUH30357				0	0
MGUH30358		x		0	0,1
MGUH30359				0	1
MGUH30360				1	0
MGUH30361		x	x	1	0
MGUH30362	x	x	x	2	0
MGUH30363	x	x	x	1	0
MGUH30364			x	1	0
MGUH30365				0	0,2
MGUH30366				0	0
MGUH30367				1	0
H001				1	0,2
H002				2	0
H003				1	0,1
H004				0	0,2
H005				1	0,5
H006				1	1
H007				2	0
H008				1	1
H009	x			1	0
H010				0	0,2
H011				1	1
H012				0	1
H013				0	0,5
H014				1	0,1
H015		x		1	0,5
H016				1	2
H017				0	0,1
H018				0	0,1
H019				0	0,1
H020		x		0	0,1
H021				0	0
H022				1	2
H023				0	0,5
H024				0	0
H025				0	2
H026		x		0	0,1
H027				0	0
H028				0	4
H029		x	x	1	0
H030				0	0,1
H031				0	1
H032				0	1
H033				0	1
H034				1	0
H035				0	0
H036				0	1
H037				0	3
H038				0	0

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H039				0	0,1
H040				0	0
H041				0	1
H042				0	2
H043				0	0,5
H044				0	0,1
H045				0	0
H046				0	0,5
H047				0	1
H048				0	0,2
H049				0	1,5
H050				0	1
H051				0	1
H052				1	0,1
H053				0	0,1
H054				1	0,1
H055				0	1
H056				0	1
H057				0	0
H058				1	1,5
H059				0	1,5
H060				0	2
H061				0	0,5
H062				0	0,5
H063				0	0,1
H064	x	x		0	1
H065	x			0	0
H066				0	1
H067				0	1
H068		x	x	1	0,1
H069		x	x	2	0
H070		x	x	2	0
H071		x		0	0
H072			x	1	0
H073		x	x	1	1
H074				0	0,2
H075				2	0
H076				1	0,1
H077				1	0
H078				1	0
H079				0	0
H080				2	0
H081				1	0,5
H082				0	0,1
H083	x			0	0,1
H084	x			1	0
H085				1	0,1
H086	x			1	0,1
H087				1	1

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H088				1	3
H089				0	3,5
H090				0	0,2
H091				1	0,1
H092				0	0,2
H093				0	0,1
H094	x	x		0	0,2
H095				0	0,1
H096				0	1,5
H097				0	0,1
H098	x			0	1
H099				0	1
H100				1	0,1
H101				1	0,2
H102				0	0,1
H103				0	0,5
H104	x			0	0,1
H105				1	1
H106				1	0
H107		x		0	0,2
H108				1	0,1
H109				0	1
H110				1	0
H111				0	1
H112				0	0,5
H113				1	0
H114				1	0,1
H115				0	1
H116				0	0
H117		x		0	0,5
H118				1	0,1
H119				0	1,5
H120				0	0,5
H121				1	0,2
H122				0	0
H123				0	0
H124				1	1
H125				0	1
H126				0	1
H127				0	0,1
H128				0	0,1
H129				0	0,2
H130				0	0,2
H131				0	1
H132				0	1
H133				0	0,5
H134				0	0,2
H135				0	3,5
H136				1	1

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H137				0	2
H138				0	0
H139				0	0,5
H140				0	1
H141				1	0
H142				0	0,2
H143				0	1
H144				0	2
H145				0	1
H146				0	0,1
H147				0	2
H148				1	0
H149				0	0
H150				0	0,5
H151				1	1
H152				1	0
H153				0	1,5
H154		x		1	0
H155				1	1
H156				0	0,1
H157				0	0,5
H158				0	0,2
H159				0	1
H160	x			0	0
H161				0	0,1
H162				0	1
H163				1	2
H164	x			0	0
H165				0	0,5
H166				0	0
H167				0	0,5
H168				0	0,5
H169			x	1	0,2
H170				1	0,2
H171				0	1
H172				0	2
H173				0	2,5
H174				1	0
H175				0	2
H176				0	0,1
H177				0	1
H178				0	0,5
H179				0	0,1
H180				0	2,5
H181				1	0,2
H182	x			0	0,5
H183	x			0	0
H184				0	0,5
H185				1	2

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H186				0	1
H187				0	0
H188				1	0
H189				1	0
H190				1	0
H191		x		1	0
H192				0	0,5
H193				1	0
H194				0	1,5
H195	x			0	1
H196				0	0
H197				0	1,5
H198				1	0,2
H199				2	0,2
H200				0	0
H201		x		2	0
H202				1	0,1
H203				1	0
H204				1	0,1
H205				1	0,2
H206				2	0
H207				1	0
H208				0	0
H209				0	0,1
H210				1	0,1
H211				0	0
H212				0	0,5
H213				0	0
H214				0	1
H215				0	0
H216				0	1
H217				0	1
H218	x			0	0,5
H219				0	0
H220				1	0
H221				1	1
H222				1	0
H223				0	0
H224				0	0
H225				0	0,5
H226		x		0	0,5
H227	x			0	0,5
H228				0	0
H229				1	0
H230				0	1
H231				0	0,5
H232				0	0,5
H233				0	0,1
H234				0	4

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H235				0	2
H236				0	1
H237				0	0,1
H238				0	2,5
H239			x	1	1,5
H240				0	0,5
H241				0	0
H242				1	0,2
H243	x			0	0,2
H244				0	0,2
H245				0	0
H246				1	0,5
H247				0	1
H248				0	1
H249				0	1
H250				0	0
H251				0	0,5
H252				0	3
H253				0	2
H254				0	1
H255				0	2
H256				0	0,2
H257				0	3,5
H258				0	2,5
H259				0	0
H260				1	0,5
H261				0	1
H262				0	1,5
H263				0	0,2
H264				0	1
H265				0	1,5
H266				0	1
H267				0	0,1
H268				0	0,5
H269				0	0,2
H270				0	1
H271	x			1	0,5
H272				0	0,1
H273				0	0,1
H274				0	0,1
H275				0	1
H276				0	0,1
H277				0	0,2
H278				0	0
H279				0	0,5
H280				0	0,5
H281				0	0,5
H282				0	1
H283				0	3

Name	Bend	Contrac. marks	pinched end	preserved ends	Mineral grain size
H284				0	0,1
H285				0	1,5
H286				2	0,1
H287				0	0,1
H288				0	2
H289				0	0,2
H290				0	1
H291				0	0,5
H292				0	0,2
H293				0	0
H294				0	1,5
H295				0	0,5
H296				0	0,2
H297				0	0,2
H298				0	1
H299				0	0
H300				0	0,5
H301				0	0,1
H302				0	0,2
H303				1	0,5
H304				0	1
H305				0	0,1
H306				0	1
H307				0	0,2
H308				1	1
H309				0	1
H310				0	1
H311				0	0
H312				1	0
H313				0	0
N1				0	0
N3				0	0
N4				0	0
N2				0	0

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The 4 burrows are excluded from all analyses except for the initial examination of coprolite sizes. Three coprolites (H225, H228, H309) have undefined shapes and are excluded from many analyses. H311 have unknown structure and is also excluded from some analyses. This is why different analyses can contain 324, 322, 321 or 320 specimens.
Analyses involve scatter diagrams, pie charts and column diagrams. When column diagrams are used, data for a trait is often depicted both as separate columns and as one column showing the percent-wise distribution of the trait.

Coprolite size

Coprolite size

Coprolites have diameters measuring between 7.5 mm and 48 mm.
Coprolites are arranged according to size and then plotted as millimetres against sorting number. The plotted values form a sinuous wave where the middle part is fairly linear but the low end drops off suddenly and the high end rises equally suddenly. This shape is created when there are much fewer specimens with the shortest and longest diameters in the dataset. The four burrows fall perfectly within the trend. Only the three coprolites with unknown diameters are seen as 0's in the diagram.
When the 321 specimens with measureable diameters are stacked and depicted in a column diagram, a weak normal distribution is observed. This means that there is an interval within which coprolites are more likely to be found. In this material, 95% of the coprolites have diameters between 12 mm and 30 mm (both included). If the window is narrowed to 16-26 mm (both included) 75% of the coprolites are still included. The most common diameter is 19 mm.
If the specimens are stacked again in one millimeter intervals and depicted in a column diagram, the normal distribution has a more even shape but with maxima both at 19 mm and 22 mm. It would thus appear that the Kap Stewart Formation mostly preserve coprolites with diameters around 19-22 mm. The four burrows that were found in the material have diameters of 19 mm to 20 mm which is why they were easily misinterpreted as coprolites.

Coprolite size and shape

321 Specimens.
Scatter diagram: Specimens are plotted as diameter against specimen number with a colour according to shape. No clear trend is seen so there is no general connection between coprolite size and shape. However, the four round coprolites lie relatively close with diameters between 15 and 20 mm. The three round-cylindrical specimens lie between 16.5 and 20 mm. Bulbous coprolites are never larger than 29 mm.

Coprolite size and structure

321 specimens. H311 has unknown structure but is included.
1) Scatter diagram: Irregularly wrapped, none and spiral/coiled specimens are shown as different colours. The specimens are sorted according to structure and plotted as diameter against specimen number.
2) Diagram: Specimens are sorted according to structure and increasing diameter.
General pattern: structure is not dependent on size. One spiral coprolite is obviously larger than all else but there are also a quite large irregularly wrapped. Spiral/coiled coprolites have diameters between 7.5 mm and 48 mm. Structureless coprolites have diameters between 7.5 mm and 33 mm. Irregularly wrapped coprolites have diameters between 9 mm and 40 mm. The three largest coprolites are significantly larger than the rest of the material. Their structures are, in order, spiral/coiled, irregularly wrapped and spiral/coiled.

Coprolite size and texture

321 specimens.
Column diagram: Each diameter is marked on the x-axis and percent are shown along the y-axis. Each specimen is shown as a column of 100%. The column has one or two colours according to its texture. Either 100% of one texture or 67% and 33% of two textures. Massive, nodular and swirly texture have different colours. There is no clear trend, but there is slightly less nodular texture in the largest third part of the diagram.
Scatter diagram: The specimens within the nine different types of texture (+ unknown texture) are plotted as diameter against specimen number. No clear trend is seen. Three largest coprolites are, in order, massive-swirly, unknown and massive. Only two types of texture seem to have a somewhat limited distribution. Swirly-massive type coprolites all have diameters between 13.5 mm and 25.5 mm. Swirly-nodular type coprolites have diameters between 14 mm and 29 mm.

Coprolite size and fragments

321 specimens.
1) Scatter diagram of specimen diameter and the size of the largest fragment in each specimen. Fragment size is plotted against coprolite diameter. Data from the surface and data from the interior of specimens are different colours. The largest fragments (6-10 mm) are found in coprolites with diameters between 15 mm and 30 mm. Coprolites with no fragments are found in coprolites of all sizes.
2) Scatter diagram of the fragments found on the surface of coprolites: all coprolites with no fragments are removed from the data. Fragments are found in coprolites with diameters between 7.5 mm and 40 mm. Most fossiliferous coprolites have diameters between 11 mm and 30 mm. Linear regression: There is only a minimal increase of fragment size with coprolite size.
Scatter diagram of the fragments found in the interior of coprolites: all coprolites with no fragments are removed from the data. Fragments are found between 7.5 mm and 48 mm. Most fossiliferous coprolites have diameters between 12 mm and 31 mm. Linear regression: There is a *slight* increase in fragments size with diameter.
3) Scatter diagram of coprolite diameter and fragment category: Two diagrams: interior and surface. 'Numerous', 'some', 'few', 'no' and 'unknown' are different colours. Coprolite diameter are sorted and plotted against sorting number.
There is no general trends. On the surface, specimens with 'some' fragments are never larger than 27 mm. In the interior, specimens with 'numerous' fragments are never larger than 28,5 mm and specimens with 'some' fragments are restricted to diameters between 13,5 and 33 mm. All other types contain specimens with shorter diameters.

Coprolite size and nodules

321 specimens.
Scatter diagram: Maximum nodule size of each specimen is plotted against the specimen's diameter. Coprolites with no nodules are found across all possible diameters. Nodules are found in coprolites with diameters between 9 mm and 31 mm. There is no trend between nodule size and coprolite size.

Shape
Bulbous (12), cylindrical (264), cylindrical-bulbous (34), round (4), round-bulbous (4) and round-cylindrical (3). Three specimens of unknown shape (H225, H228, H309) are excluded from the following analyses. 321 specimens.

Shape and coprolite size
Scatter diagram: Each shape is examined separately. The specimens are sorted according to coprolite diameter and plotted against sorting number. No clear trends are seen. Bulbous specimens have diameters between 11m and 29 mm. Cylindrical specimens have diameters between 7,5 mm and 36 mm. The plotted points in the diagram forms a sinuous shape. Cylindrical-bulbous specimens have diameters between 11 mm and 40 mm. A slight sinuous shape is seen in the high end of the cylindrical-bulbous scatter. Round, round-bulbous and round-cylindrical specimens have diameters between 15 mm and 22 mm except for a specimen of 48 mm. There is no connection between coprolite shapes and coprolite size.

Shape and structure
H311 has unknown structure and is excluded. 320 specimens.
Column diagrams and pie charts: Specimens are sorted according to structure and shape. Irregularly wrapped specimens dominate in cylindrical-bulbous (>80%), cylindrical (>50%) and bulbous (>50%) coprolites. Structureless is the most abundant structure in round (>70%) and round-cylindrical (>60%) coprolites which do not contain any spiral/coiled specimens. In round-bulbous coprolites structureless specimens dominate (>70%) while no specimens are irregularly wrapped.

Shape and texture
Column diagram: Specimens are sorted according to texture and shape. Cylindrical coprolites contain all textures and cylindrical-bulbous most textures (8 textures). Round coprolites only contain specimens of massive and unknown texture. Except for cylindrical coprolites, each shape contain too few specimens to interpret any connections.

Shape and fragments
1) Column diagram: Fragment size: Specimens are sorted according to maximum fragment size and shape. It is difficult to talk about trends when most specimens are cylindrical. Within the cylindrical part there is weak normal distribution of the specimens according to fragment size (0,1-10 mm). All the round specimens have fragments of some size (2-6 mm). The round-bulbous and round-cylindrical have no or minor fragments (0-2 mm). This could indicate that the round coprolites are in fact different from the cylindrical ones.
2) Column diagram: Fragment category: Specimens are sorted according to fragment category and shape. Both surface and interior is considered but it is difficult to talk about trends when most specimens are cylindrical. The distribution of categories is similar between cylindrical and cylindrical-bulbous specimens which are the two largest groups in the material. If the over-all categories are considered, the most abundant category is 2 (or 'some' fragments). Category 3 (or 'numerous' fragments) specimens are not found in bulbous coprolites and in round-bulbous coprolites neither 'some' or 'numerous' specimens are found.

Shape and nodules
Column diagram: Specimens are sorted according to shape and nodule size. No nodules are found in round and round-cylindrical specimens. In bulbous specimens, nodules are found in most of the specimens (~75%). Also, the size of nodules present in bulbous specimen is from 1 mm to 5.5 mm. In cylindrical specimens nodules are found in 50% of the specimens and in more than 40% the nodules are between 1 mm and 6 mm. The same is more or less the case with the cylindrical-bulbous specimens. A single round-bulbous specimen has nodules of 4 mm.

Structure
Irregularly wrapped (179), structureless (124) and spiral/coiled (19). Unknown structure (2).

The two specimens with unknown structure (H309, H311) are excluded from the following analysis. 322 specimens.

Structure and coprolite size

Specimens are sorted according to structure and increasing coprolite size. They are plotted as maximum coprolite diameter against sorting number. No general trend is seen. Irregularly wrapped have diameters between 9 mm and 40 mm. Structureless have diameters between 7.5 mm and 33 mm. Spiral/coiled have diameters between 7.5 mm and 48 mm. Largest coprolites are (in order): spiral/coiled, irregularly wrapped and spiral/coiled.

Structure and shape

Pie charts: The different structure data are examined separately.
Irregularly wrapped: Most coprolites are cylindrical (78%). Other significant structures are cylindrical-bulbous (16%) and bulbous (4%). Round, unknown and round-cylindrical coprolites make up the rest with 1% or less each.
Structureless: Most coprolites are cylindrical (88%). Bulbous, cylindrical-bulbous, round, round-cylindrical and round-bulbous coprolites make up the rest with 2-3% each.
Spiral/coiled: Most coprolites are cylindrical (79%). Cylindrical-bulbous coprolites make up 11%. Bulbous and round-bulbous coprolites each make up 5%.
Cylindrical coprolites are the most common in all of the three structures. Round coprolites are not found in the spiral/coiled.

Structure and texture

Pie charts: The three structures are examined separately. The pie charts show the percent-wise distribution of each texture within specimens of each structure.
Irregularly wrapped specimens: Massive coprolites are most widespread (28%). Nodular, massive-swirly, massive-nodular and swirly-nodular coprolites are equally widespread with 10-12% each. Swirly (3%) and swirly-massive (4%) coprolites are the rarest. Coprolites with unknown texture make up 8%. Nodular-massive and nodular-swirly coprolites make up 7% each.
Structureless specimens: Massive coprolites make up nearly half the specimens (43%). Massive-nodular coprolites make up 1/5 (21%). Nodular coprolites make up 14%. Massive-swirly, unknown texture and swirly-nodular coprolites make up 5-6% each. Nodular-massive, nodular-swirly and swirly coprolites make up 1-2% each. There are no specimens with swirly-massive texture.
Spiral/coiled: Swirly-massive coprolites make up the largest part (31%). Unknown texture is abundant (21%). Massive, massive-swirly and swirly coprolites make up 16% each. There are no specimens with massive-nodular, nodular, nodular-massive, nodular-swirly or swirly-nodular texture.
All textures are represented in the irregularly wrapped coprolites which is possibly because these are the most widespread. Both in irregularly wrapped and structureless coprolites, the primary massive textures are the most common along with purely nodular texture. This is contrasted by the spiral/coiled coprolites which do not contain any nodular texture at all but only massive and swirly textures.

Structure and fragments

Data are condensed for the three structures in each 'area' (over-all, surface and interior).
Column diagram 1: Fragment size: Specimens are sorted according to maximum fragments size.
Fragment-free specimens are the most common in all areas and for all structures. The specimens that contain fragments are weakly normal distributed according to the size of the fragments. The bell-shape is most obvious for the irregularly wrapped coprolites which form the largest dataset.
For the over-all content, all structures have most specimens with fragments of maximum 2 mm. On the surface, fragments of maximum 1 mm dominate in all structures. In the interior, irregularly wrapped coprolites have most specimen with 2 mm fragments, while structureless coprolites have slightly more of the specimens with 1 mm fragments. In the spiral/coiled coprolites there are only one or two of each fragment size (4 unknown). In all areas the irregularly wrapped bear the largest fragments found. In the spiral/coiled coprolites fragments are never larger than 4 mm, in the structureless never larger than 6 mm. The largest

fragments found are 10 mm. Percent-wise, there are somewhat similar distributions of sizes within the structures and areas.
Column diagram 2: Fragment category: Specimens are sorted according to fragment category and structure. When the surface is considered, all structures have most specimens with no fragments at all, next comes 'few' fragments and 'some' fragments and fewest specimens have 'numerous' fragments. The spiral/coiled coprolites comprise so little data that the trend is very uncertain. In the interior, the pattern is more uncertain as quite a large amount of coprolites are unpolished and the contents unknown. For the irregularly wrapped, the most specimens have 'some' fragments. The structureless coprolites have a somewhat equal distribution of 'none', 'few' and 'some' specimens. For both irregularly wrapped and structureless there are only few specimen with 'numerous' fragments, while the spiral/coiled coprolites have an equal distribution of ALL categories with 'none' being slightly more common.
When the over-all content is considered, the irregularly wrapped coprolites have most specimens with 'some' fragments (next is 'few' and 'none') and fewest with 'numerous'. The structureless form only a slight trend with fewest specimens having 'numerous' fragments. The spiral/coiled coprolites form no trend at all. The percent-wise distribution of categories is quite similar between irregularly wrapped and structureless in all areas. The spiral/coiled coprolites contain a much larger portion of 'numerous' specimens in all areas (>30% for 'over-all') and also more 'unknown' specimens for 'interior' (>20%).

Structure and nodules

Column diagram: Specimens are sorted according to maximum nodule size. Percent-wise the spiral/coiled coprolites contain most specimens with no nodules (>80%). Next is structureless (>50%) and irregularly wrapped (>40%) coprolites. Nodules have sizes between 0.1 mm and 6 mm. In spiral/coiled coprolites, the nodules that are present are maximum 1 mm and 2 mm. For irregularly wrapped and structureless coprolites, the specimens are weakly normal distributed when sorted according to nodule size. The most common nodules size in the collective data is 1 mm, next is 2 mm and 3 mm. The rarest nodule size is 4,5 mm (1 specimen). Irregularly wrapped and structureless coprolites have a similar number of specimens with the largest nodule sizes.

Texture

Massive (107), massive-nodular (44), massive-swirly (31), nodular (39), nodular-massive (15), nodular-swirly (14), swirly (10), swirly-massive (13), swirly-nodular (24) and unknown (27).

Texture and coprolite size

Three specimens with unknown diameters were excluded (H225 (nodular), H228 (nodular), H309 (massive)). 321 specimens.
Massive have diameters between 7,5 mm and 36 mm.
Massive-nodular have diameters between 10 mm and 31 mm.
Massive-swirly have diameters between 12 mm and 27,5 mm with one specimen of 48 mm.
Nodular have diameters between 11 mm and 31 mm.
Nodular-massive have diameters between 9 mm and 29 mm.
Nodular-swirly have diameters between 13,5 mm and 31 mm.
Swirly mostly have diameters between 7,5 mm and 25 mm.
Swirly-massive have diameters between 13,5 mm and 25,5 mm.
Swirly-nodular have diameters between 14 mm and 29 mm.
Unknown have diameters between 11 mm and 28 mm with one specimen of 40 mm.
There is no connection between coprolite texture and coprolite size.

Texture and shape

Column diagrams: Specimens are sorted according to shape and texture. Cylindrical specimens dominate all textures except unknown where all the indefinable pieces have wound up. Cylindrical-bulbous specimens are also widely found except for in nodular-massive and swirly that only contain cylindrical shapes. Nodular coprolites contain more that 15% bulbous specimens. Massive and unknown coprolites both contain six of the possible seven shapes.

Texture and structure

Two specimens with unknown structure are excluded (H309 (massive), H311 (unknown)). 322 specimens.
Column diagram: Specimens are sorted according to structure and shown as columns within each texture. Irregularly wrapped coprolites are the most abundant and all textures contain 50% or more - except for massive (<50%) and massive-nodular (>40%). Nodular-massive and nodular-swirly coprolites consists almost entirely of irregularly wrapped specimens (>85%). Structureless coprolites are found within all textures except for the swirly-massive that consists of irregularly wrapped (>50%) and spiral/coiled (>40%) specimens. Swirly-massive is the texture containing the largest amount of spiral/coiled coprolites (6 specimens). Irregularly wrapped specimens are independent of coprolite texture. Structureless specimens appear to be largely independent of texture as well. Spiral/coiled specimen are dependent on coprolite texture and are never found in coprolites containing nodular texture.

Texture and fragments

324 specimens.
1) Column diagram: Fragment size: Specimens are sorted according to maximum fragment size within each texture. Massive coprolites contain more possible fragment sizes, but this may be because they are the most abundant type. Among the nodular coprolites more than 75% of the specimens are fragment-free. The other textures have somewhat similar quantities of fragment-free specimens. Nodular-swirly coprolites have the largest amount of fragment-free specimens (>40%) and massive-swirly coprolites have the least (~5%). Nodular, nodular-swirly, massive-swirly and swirly-massive coprolites have fragments no larger than 2,5 mm, 2 mm, 4 mm and 4 mm respectively. The largest fragments are found in massive-nodular (10 mm), unknown (10 mm), massive (7 mm), swirly-nodular (6 mm), swirly (5 mm) and nodular-massive (5 mm) specimens. Massive and massive-swirly are the only textures that contain specimens with a fragment size of 0,1 mm. The most common fragment size is 2 mm. Next is 1 mm.
Nodular appears to be a rather well-defined texture that most often contain no fragments - if fragments are present they are never large. The other textures are not well-defined and they all seem to overlap as parts of a spectrum. Massive texture appears to be closely related to massive-nodular and massive-swirly with fragments up to 10 mm.
2) Column diagram: Category: Specimens are sorted according to category. Surface, interior and over-all contents are considered. The overlap is also examined as the number of specimens that have the same category on the surface and in the interior.
Nodular: Specimen are generally fragment-free. More than 80% have fragment-free surfaces and more than 70% have fragment-free interiors. About 65% of all specimens are completely fragment-free. There are no specimen with 'numerous' fragments.
Nodular-swirly: Almost 80% have fragment-free surfaces and more than 55% have fragment-free interiors. Overlap: Only a bit more than 40% are entirely fragment-free (6 specimens). No nodular-swirly specimens have 'numerous' fragments.
Massive-nodular has about 25% specimens that are completely fragment-free (11 specimens).
Nodular-massive and massive-swirly do not contain any specimens with 'numerous' fragments.
Swirly-massive is special in having a more than 10% overlap of specimens with 'numerous' fragments (~15% on surface and >20% in interior), which however is only 2 specimens.
Unknown specimens only contain one specimen with overlap of categories between surface and interior.
On the surface the most common category, generally speaking, is 'fragment-free' and next is 'few'. In the interior most specimens have 'some' fragments (98), next is 'few' (92) and 'fragment free' (86).
The only certain connection between coprolite texture and the contents of fragments is that nodular coprolites rarely contain fragments and when they do these are never larger than 2.5 mm. All other textures appear to overlap to some extent when it comes to the contents of fragments. They appear to be parts of a spectrum with massive coprolites at one end containing many possible fragment sizes and swirly coprolites at the other containing few fragment size. Nodular-massive and nodular-swirly coprolites contain slightly more nodule-free specimens than the other textures but far less than the purely nodular.

Texture and nodules

Specimens are sorted according to maximum nodules size and texture. Single scattered nodules can be found across all textures. The most abundant nodule sizes are 1 mm (32 specimens), 2 mm (29) and 3 mm (24). Nodules can be up to 6 mm across. Large nodules are present in nodular (6 mm), massive-nodular (6 mm), massive-swirly (5 mm) and nodular-swirly (4 mm) specimens. There is an apparent normal distribution of nodule sizes within each texture but this is difficult to ascertain as the datasets are quite small.
Massive specimens contain nodules between 0.2 mm and 2 mm.
Massive-nodular specimens contain nodules between 0.1 mm and 6 mm.
Massive-swirly specimens contain nodules between 0.2 mm and 1.5 mm.
Nodular specimens contain nodules between 2 mm and 6 mm.
Nodular-massive specimens contain nodules between 1 mm and 3.5 mm.
Nodular-swirly specimens contain nodules between 1 mm and 4 mm.
Swirly specimens contain nodules between 1 mm and 2 mm.
Swirly-massive specimens contain nodules between 1 mm and 2 mm.
Swirly-nodular specimens contain nodules between 0.5 mm and 3 mm.
Unknown specimens only contain nodules of 1 mm. Unknown specimens are unpolished.
Nodular and massive-nodular specimens do not only contain the largest nodules but also the widest range of sizes. The shortest range of nodule sizes (except for in unknown coprolites) is seen in swirly and swirly-massive coprolites with only 3 possible sizes.

Preservation

Each of the following traits are considered: The number of preserved ends; the thickness of dark chemical alteration rims and the thickness of light weathering rims. Everything concerning the rims is quite uncertain as these were often difficult to define and measure precisely.
The data in each analysis is stacked and shown as column diagrams where both the number of specimens and the percent-wise distribution is examined.

Coprolite size

Three specimens (H309, H225, H228) with unknown diameter are excluded and the dataset consists of 321 specimens.
Preserved ends: The four coprolites with shortest diameters are preserved with 1 end. The largest 17 coprolites have 1 or 0 ends. Linear regression: There might be a trend of less preserved ends with increased coprolite diameter.
Dark rims: Rims of 0 mm are found across the coprolite diameters, but there is a slight trend of increasing rim thickness as diameter increases. Thickest rim is found in a specimen of 28.5 mm diameter.
Light rims: Rims of 0.1 mm are found across the coprolite diameters. 0 mm rims are not found in the four smallest coprolites. There is no increase of rim thickness with coprolite diameter.

Shape

Three specimens of unknown shape are excluded (H309, H225, H228) and the dataset consists of 321 specimens.
Preserved ends: It is difficult to say for certain if there are any trends when some shapes are so poorly represented. Cylindrical coprolites have a high percentage of 'no ends' (nearly 80%) because this category is a 'catch all' for all the small slices. Cylindrical-bulbous have more than 10% with 2 intact ends (4 specimens). Round and round-bulbous coprolites each have 25% specimens (1 specimen) with two preserved ends.
Dark rims: Cylindrical coprolites contain all possible rim thicknesses. Bulbous, cylindrical and cylindrical-bulbous coprolites contain somewhat equal amounts of specimens with rims of 0,1 mm (~15%), 0,2 mm (~10-15%) and 0,5 mm (~10-15%). Round, round-bulbous and round-cylindrical coprolites contain rims of 1 mm or less. However, the rim thicknesses for round, round-bulbous and round-cylindrical coprolites are largely unknown.

Light rims: light rims are generally thinner than dark rims within each shape. Bulbous, cylindrical and cylindrical-bulbous coprolites contain 20-30% specimens with rims of 0.1 mm. Round, round-bulbous and round-cylindrical coprolites contain rims of 0.1 mm or less. However, the rim thicknesses for round, round-bulbous and round-cylindrical coprolites are largely unknown.

Structure

Two specimens with unknown structure are excluded (H309, H311) and the dataset consists of 322 specimens.
Preserved ends: The number of preserved ends within each structure shows no clear trends. There seem to be slightly more specimens with two ends preserved among the spiral/coiled coprolites.
Dark rims: Specimens with no rims are most common within all structures. Generally, the amount of specimens decrease as the rim thickness increases (in structureless coprolites there is a peak of specimens with a 0.5 mm rim). Structureless coprolites contain more specimens with a rim (~65%) than irregularly wrapped and spiral/coiled coprolites which both contain about 50% specimens with rims. Spiral/coiled specimens have no rims thicker than 2 mm. This result is somewhat uncertain. The spiral coprolites were often darker on the outside than on the inside but it was difficult to tell if it was due to alteration or if it was an original colour difference.
Light rims: Specimens with rims of 0.1 mm are most common within all structures. Structureless coprolites contain less specimens with rims (~65%) than irregularly wrapped and spiral/coiled which have both about 80% with rims. On the other hand, the amount of specimens with rims thicker than 0,1 mm is equal in all three structures (~30%). Spiral/coiled have rims no thicker than 1 mm.

Texture

324 specimens.
Preserved ends: One specimen with two ends is found in massive (<5%), nodular (<5%) and swirly-massive (<10%) while eight are found in unknown (>25%) coprolites. Specimens with preserved ends obviously have unknown textures. All textures besides the unknown contain at least 60% specimens without ends.
Dark rims: Except for in swirly-massive coprolites (where the various rims are almost equally common), the most common rim thickness is 0 mm. Rims of 0.1 mm are most common in nodular-massive coprolites where they are found in more than 30% of the specimens. In massive and swirly-massive coprolites they are found in about 15-20% of the specimens. Nodular-massive coprolites have no specimens with rims thicker than 0.2 mm. Coprolites of unknown texture mostly have unknown rim thicknesses. Massive coprolites form the largest group and here the number of specimens decrease as the rim thickness increase. The other textures form more messy trends.
Light rims: Except for in massive (where 0 mm is most common thickness) and unknown coprolites, the most common rim thickness is 0.1 mm. Nodular coprolites contain 8 specimens with 0.2 mm rims (about 20 %), massive coprolites contain the same number (<10%). Nodular-massive and swirly-massive coprolites have no specimens with rims thicker than 1 mm. Coprolites of unknown texture mostly have unknown rim thicknesses. It is not possible to ascertain any trends.

Fragment size

324 specimens.
Specimens are sorted according to the over-all maximum fragment sizes.
Preserved ends: The specimens containing fragments form a general bell-shape for 0 ends and 1 end. For 2 ends there are only a few specimens. Fragment-free coprolites are the most common for all three groups.
Rims: There is a general, but somewhat weak, bell-shape within each rim thickness. It is most obvious in the larger datasets but the general trend indicates that there is no connection between preservation and the size of fragments.
Dark rims: The normal distribution is mostly seen for specimens with no rims, rims of 0,1 mm, rims of 0,2 mm, 1 mm and unknown rims. Rims of 0,5 mm form a more 'messy' bell-shape.
Light rims: The normal distribution is mostly seen for specimens with no rims, rims of 0,1 mm, rims of 1 mm and unknown rims.

Fragment category

324 specimens.
Specimens are sorted according to the over-all fragment categories.
Preserved ends: The four fragment categories have somewhat equal distributions of preserved ends. Category 0,1, and 2 contain ~65% to ~80% specimens with no ends, ~20% to ~30% with one end and less than 5% with 2 ends. Category 3 contains slightly more specimens with two intact ends (>15%) than the other categories do. Category 3 contains about 30% specimens with one end preserved and about 50% specimens with no ends preserved at all.
Dark rims: All categories except 3 contain markedly more specimens with no rims than they do of the different types of rims. In category 3 there are equally many specimens without rims as with rims of 0.1 mm (combined, 0 mm and 0,1 mm rims make up about 45%). However, category 3 coprolites contain 30 % specimens with unknown rim thicknesses and the trend is uncertain. Category 0 and 2 coprolites contain most of the possible rim thicknesses. Category 1 coprolites contain rims of no more than 2 mm. Category 3 coprolites contain the specimen with the thickest rim (3.5 mm).
Light rims: Rims of 0.1 mm are the most common in all categories. Category 1 coprolites contain all possible rim thicknesses even though it is not the largest category. Category 1 contains more specimens with 1 mm rims (>10%) than the other categories do. Category 3 coprolites contain 30 % specimens with unknown rim thicknesses.

Nodule size

324 specimens.
Preserved ends: no trend is visible. There is a slight bell shape across specimens with nodules. Specimens with nodules of 0.2 mm (6 specimens), 4.5 mm (1 specimens) and 5.5 mm (4 specimens) have no ends preserved.
Rims: Any trends are impossible to ascertain as the separate datasets are so limited.
Dark rims: Weak normal distribution of specimens with 0 mm rims is seen across the nodule sizes. For coprolites without nodules, the amount of specimens decrease as rim thickness increase.
Light rims: Weak normal distribution of 0,1 mm rims across nodule sizes.

Mineral grains

324 specimens.
Preserved ends: Specimens with two preserved ends are only found among coprolites with mineral grains of maximum 0-0.2 mm. Specimens with one preserved end have mineral grains up to 2 mm across (one specimen has grains of 3 mm). coprolites with mineral grains of 2.5 mm (4 specimens), 3.5 mm (3 specimens) and 4 mm (2 specimens) never have any preserved ends. Coprolites with no ends preserved contain specimen with all the possible mineral grain sizes.
Rims: Specimens with unknown rims are most common (~40%) among coprolites with mineral grains of 0 mm because these are often unpolished (unknown mineral grains are registered with a size of 0 mm in order not to exclude too many specimens).
Dark rims: Generally, there is a tendency for rim thickness to decrease as mineral grain size is increasing. Most common combination (besides unknown rims in specimen with no mineral grains) is rims of 0 mm in specimen with 1 mm large grains (25 specimens).
Light rims: As the mineral grain size increase, the number of rim thicknesses decrease. Generally, there is a tendency for rim thickness to decrease as mineral grain size is increasing. The most common combination (besides unknown rims in specimen with no mineral grains) is rims of 0.1 mm in specimens with 1 mm large grains (28 specimens).

Mineral grains

37 specimens with unknown interior are excluded. The dataset consists of 287 specimens.

Coprolite size
Specimens with unknown diameter are excluded so the dataset consists of 285 specimens.
Scatter diagram: Size of largest mineral grain in each specimen is plotted against coprolite diameter. Linear regression: Mineral grains become slightly larger with increasing coprolite size.

Shape
Specimens with unknown shape are excluded and the dataset consists of 285 specimens.
Scatter diagram: Specimens are sorted according to shape and coprolite size and plotted against sorting number. Cylindrical coprolites (247 specimens) and cylindrical-bulbous coprolites (23 specimens) have specimens with mineral grains of all sizes (0-4 mm). For cylindrical-bulbous coprolites most specimens contain mineral grains of 0.5 mm or less (74%). Bulbous coprolites (10 specimens) have specimens with mineral grains up to 2.5 mm and only one specimen without any. Round (1 specimen), round-bulbous (2 specimens) and round-cylindrical (2 specimens) have mineral grains between 0.1 mm and 0.5 mm.

Structure
Specimens with unknown structure are excluded and the dataset consists of 286 specimens.
Diagram: Specimens are sorted according to structure and coprolite size and plotted against sorting number. Spiral/coiled coprolites (14 specimens) contain grains between 0.1 mm and 1 mm. 8 specimens contain grains of 0.5 mm or less (57%). Structureless coprolites (112 specimens) contain grains up to 3.5 mm across. 78 specimens contain grains of 0.5 mm or less (70%). Irregularly wrapped coprolites (160 specimens) contain grains up to 4 mm across. 93 specimens contain grains of 0.5 mm or less (58%).
Spiral/coiled coprolites are different in always containing mineral grains but these are never larger than 1 mm. In structureless coprolites, most contain none or only small grains. The largest grains are found in irregularly wrapped coprolites.

Texture
Specimens with unknown texture are excluded and the dataset consists of 284 specimens.
Scatter diagram: Specimens are sorted according to texture and plotted as mineral grain size against coprolite diameter. Linear regression: All textures have slightly increasing mineral grain size with coprolite diameter except for nodular and swirly texture that have slightly decreasing mineral grain size.
Massive coprolites (105 specimens) contain mineral grains of up to 3.5 mm. 68 specimens contain grains of 0.5 mm or less (65%).
Massive-nodular coprolites (41 specimens) contain grains of up to 4 mm. 27 specimens contain grains of 0.5 mm or less (66%).
Massive-swirly coprolites (31 specimens) contain grains of up to 4 mm. 17 specimens contain grains of 0.5 mm or less (55%).
Nodular coprolites (33 specimens) contain grains of up to 2.5 mm. 22 specimens contain grains of 0.5 mm or less (67%).
Nodular-massive coprolites (15 specimens) contain grains of up to 3 mm. 11 specimens contain grains of 0.5 mm or less (73%).
Nodular-swirly coprolites (14 specimens) contain grains of up to 2 mm. 7 specimens contain grains of 0.5 mm or less (50%).
Swirly coprolites (10 specimens) contain grains of up to 2.5 mm. 5 specimens contain grains of 0.5 mm or less (50%).
Swirly-massive coprolites (12 specimens) contain grains of up to 2 mm. 8 specimens contain grains of 0.5 mm or less (67%).
Swirly-nodular coprolites (23 specimens) contain grains of up to 2.5 mm. 11 specimens contain grains of 0.5 mm or less (48%).
There are no prominent differences between textures.

Fossil fragments
Column diagram: Category (over-all): Specimens within each category are stacked according to mineral grain size. The distribution of mineral grain sizes is similar between the four categories. Largest grains are

found in category 1 ("few"). In category 3 ("numerous") largest grain is 2 mm. Most sizes are represented in category 2 ("some").
Scatter diagram: Fragment size: Maximum mineral grain size is plotted against maximum fragment size.
Linear regression: There is a very slight increase of mineral grain size with increasing fragment size.

Nodules
Scatter diagram: Mineral grain size is plotted against nodule size. With increasing nodule size there is a significant decrease in the maximum size of mineral grain. Largest mineral grains are seen in specimens with nodules of 0 mm and 0.5 mm. For specimens with nodules of 5.5 mm and 6 mm the mineral grains are never larger than 1 mm. Many specimens have neither mineral grains nor nodules (20 specimens).

Bend specimens
20 specimens with diameters between 13 mm and 24.5 mm.
Shape: All specimens are cylindrical (~7.5% of all cylindrical specimens are bend).
Contraction marks: 4 specimens (19% of all specimens with contraction marks) with diameters between 13 mm and 22.5 mm.
Pinched end: 2 specimens of 13 mm and 16 mm in diameter. These two also bears contraction marks.
Structure:
Irregularly wrapped: 10 specimens (6% of all irregularly wrapped specimens).
Structureless: 9 specimens (7% of all structureless specimens).
Spiral/coiled: 1 specimen (5% of all spiral/coiled specimens).
Texture:
Massive: 5 specimens (5% of all massive specimens).
Massive-nodular: 2 specimens (4,5% of all massive-nodular specimens).
Massive-swirly: none
Nodular: 1 specimen (2,5% of all nodular specimens).
Nodular-massive: 1 specimen (<7% of all nodular-massive specimens).
Nodular-swirly: 1 specimen (7% of all nodular-swirly specimens).
Swirly: 2 specimens (20% of all swirly specimens).
Swirly-massive: none
Swirly-nodular: 5 specimens (21% of all swirly-massive specimens).
Unknown: 3 specimens (11% of all unknown specimens).
Fragments: Category: over-all:
"0": 7 specimens (8% of all "0").
"1": 6 specimens (6% of all "1").
"2": 4 specimens (3,5% of all "2").
"3": 3 specimens (17% of all "3").
Fragments: Over-all: fragments of 0 mm to 4 mm are represented.
Nodules: Nodules of 0 mm to 6 mm are represented.
Ends preserved:
0 ends: 14 specimens
1 end: 5 specimens
2 ends: 1 specimen
Rims: 3 specimens are unknown.
Dark rims: 0-1.5 mm are represented.
Light rims: All thicknesses (0-5 mm) are represented.
Mineral grains: 3 specimens are unknown. Grains of 0 mm to 1 mm across are represented.

Flattened specimens
135 specimens with flattened diameters between 8 mm and 33 mm.

Shape and size: 7 bulbous (13-24 mm), 110 cylindrical (8-30 mm), 14 cylindrical-bulbous (9-33 mm), 2 round-bulbous (13.5-14 mm).
Bend specimens: 11 specimens. Diameters between 13 mm and 24.5 mm; flattened diameters between 10 mm and 18 mm.
Contraction marks: 4 specimens (19% of all specimens with contraction marks) with diameters between 11 mm and 19 mm. Flattened diameter: 9-16 mm.
Pinched end: 1 specimen of 12 mm in flattened diameter.
Structure:
Irregularly wrapped: 80 specimens (45% of all irregularly wrapped). Fl. diameter: 8-33 mm.
Structureless: 46 specimens (37% of all structureless). Fl. diameter: 8-30 mm.
Spiral/coiled: 8 specimens (42% of all spiral/coiled). Fl. diameter: 8.5-29 mm.
Texture:
Massive: 49 specimens (46% of all massive). Fl. diameter: 10-30 mm.
Massive-nodular: 12 specimens (27% of all massive-nodular). Fl. diameter: 8-24.5 mm.
Massive-swirly: 8 specimens (26% of all massive-swirly). Fl. diameter: 11-22 mm.
Nodular: 14 specimens (36% of all nodular). Fl. diameter: 10.5-20 mm.
Nodular-massive: 13 specimens (87% of all nodular-massive). Fl. diameter: 8-19 mm.
Nodular-swirly: 8 specimens (57% of all nodular-swirly). Fl. diameter: 10-19.5 mm.
Swirly: 4 specimens (40% of all swirly). Fl. diameter: 10-20.5 mm.
Swirly-massive: 5 specimens (38% of all swirly-massive). Fl. diameter: 8.2-21 mm.
Swirly-nodular: 11 specimens (46% of all swirly-nodular). Fl. diameter: 12-24 mm.
Unknown: 10 specimens (37% of all unknown). Fl. diameter: 9-33 mm.
Fragments: Category: Over-all:
"0": 37 specimens (42% of all "0"). Fl. diameter: 8-21 mm.
"1": 52 specimens (54% of all "1"). Fl. diameter: 10-29 mm.
"2": 35 specimens (31% of all "2"). Fl. diameter: 9-30 mm.
"3": 10 specimens (38% of all "3"). Fl. diameter: 11.5-33 mm.
Fragments: Over-all: Fragments of 0-10 mm are represented.
Nodules: Nodules of 0-6 mm are represented.
Ends preserved:
0 ends: 90 specimens (39% of all with 0 ends). Fl. diameter: 8.5-30 mm.
1 end: 40 specimens (49% of all with 1 end). Fl. diameter: 8-33 mm.
2 ends: 4 specimens (36% of all with 2 ends). Fl. diameter: 9-14 mm.
Rims: 11 are unknown.
Dark rims: All thicknesses (0-3.5 mm) are represented.
Light rims: All thicknesses (0-5 mm) are represented.
Mineral grains: 11 are unknown. All sizes (0-4 mm) are represented.

Pinched specimens

12 specimens with diameters between 13 mm and 22 mm.
Shape: Cylindrical: 9 specimens (3% of all cylindrical specimens)
Cylindrical-bulbous: 2 specimens (6% of all cylindrical-bulbous specimens).
Round-cylindrical: 1 specimen (33% of all round-cylindrical specimens).
Bend specimens: 2 specimens.
Contraction marks: 8 specimens - 2 are also bend.
Structure:
Irregularly wrapped: 6 specimens (3% of all irregularly wrapped specimens).
Structureless: 6 specimens (5% of all structureless specimens).
Spiral/coiled: none
Texture:
Massive: 3 specimens (3% of all massive specimens).

Massive-nodular: none.
Massive-swirly: 1 (3% of all massive-swirly specimens).
Nodular: none.
Nodular-massive: 1 specimen (<7% of all nodular-massive specimens).
Nodular-swirly: 1 specimen (7% of all nodular-swirly specimens).
Swirly: none.
Swirly-massive: none
Swirly-nodular: none.
Unknown: 6 specimens (22% of all unknown specimens).
Contents: Category: Over-all:
"0": 4 specimens (4.5% of all "0").
"1": 2 specimens (2% of all "1").
"2": 4 specimens (3.5% of all "2").
"3": 2 specimens (8% of all "3").
Fragments: Over-all: fragments of 0 mm to 7 mm are represented.
Nodules: nodules of 0 mm to 2 mm are represented.
Ends preserved:
0 ends: none.
1 end: 9 specimens.
2 ends: 3 specimens.
Rims: 6 specimens are unknown.
Dark rims: thicknesses of 0 mm and 1 mm are represented.
Light rims: thicknesses of 0-1 mm are represented.
Mineral grains: 6 specimens are unknown. Grains of 0 mm to 1.5 mm are represented.

Contraction marks

21 specimens with diameters between 11 mm and 22.5 mm.
Shape: Cylindrical: 16 specimens (6% of all cylindrical specimens).
Cylindrical-bulbous: 5 specimens (15% of all cylindrical-bulbous specimens).
Bend specimens: 4 specimens.
Pinched end: 8 specimens - 2 are also bend.
Structure:
Irregularly wrapped: 12 specimens (7% of all irregularly wrapped specimens).
Structureless: 9 specimens (7% of all structureless specimens).
Spiral/coiled: none
Texture:
Massive: 7 specimens (6.5% of all specimens).
Massive-nodular: 4 specimens (9% of all specimens).
Massive-swirly: 2 specimens (6.5% of all specimens).
Nodular: none
Nodular-massive: none
Nodular-swirly: 1 specimens (7% of all specimens).
Swirly: none
Swirly-massive: none
Swirly-nodular: none
Unknown: 7 specimens (26% of all specimens).
Contents: Category: Over-all:
"0": 6 specimens (7% of all "0").
"1": 7 specimens (7% of all "1").
"2": 5 specimens (4% of all "2").
"3": 3 specimens (11.5% of all "3").

APPENDIX 2

Fragments: Over-all: fragments of 0 mm to 7 mm are represented.
Nodules: nodules of 0 mm to 3 mm are represented.
Ends preserved:
0 ends: 9 specimens.
1 end: 8 specimens.
2 ends: 4 specimens.
Rims: 9 specimens are unknown.
Dark rims: thicknesses of 0-1.5 mm are represented.
Light rims: thicknesses of 0-3 mm are represented.
Mineral grains: 8 specimens are unknown. Grains of 0 mm to 1 mm are represented.