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THE USE OF BENTHIC FORAMINIFERA AS INDICATORS OF ENVIRONMENTAL AND HUMAN INFLUENCES IN THE AURLANDSFJORD

ENVIRONMENTAL CHANGE IN THE AURLANDSFJORD

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Introduction

In October 2014, a flood happened in western Norway. Also Flåm was affected strongly. The water from the river Flåmselvi, that flooded a big area, transported a lot of material into the Aurlandsfjord (Bender, Bordne, & Klopsch, 2016). The Aurlandsfjord is the invested area of a science project in autumn 2016 and in 2017.

This project, about mainly benthic foraminifera, consists of practical work in the laboratory and a report about it. The work in the laboratory was done voluntary and out of own interest. The report is written to get approved as an interdisciplinary project at the environmental campus Birkenfeld, Hochschule Trier.

The project is based on samples and results obtained during the 'From Mountain to Fjord' science project "Effects of human impact on the Aurlandsfjord" in autumn 2016 at Høgskulen på Vestlandet in Sogndal in Norway. The science project in 2016 was part for the course 'Fjord Processes'. For that I worked in a group that analyzed the depth distribution of benthic foraminifera and other organisms in sediment cores sampled from three stations in the inner part of the Aurlandsfjord, near the outlet of the river Flåmselvi.

With the present project, I started in May 2017. I investigated parts of a fine grained fraction of the sediment core that were taken from the station Kistadypet to confirm or disprove the interpretation, based on the graphs of the coarse and medium grained fraction analyzed in the 'From Mountain to Fjord'-project, autumn 2016. The laboratory work I did was the same as in the semester before. I searched manly for foraminifera, but also for other eye-catching species that appeared more often, for example Tintinnids. Foraminifera react quickly to environmental changes due to natural and/or anthropogenic causes. Benthic foraminifera take place numerously in almost every marine benthic aquatic habitat. Species vary in ecological niches, and ecological profiles of most species are known. The fossil assemblages can be used as a proxy for environmental conditions and compared with chemical studies it can illustrate the environmental change in former times (Scott, Medioli, & Schafer, 2001).

Methods

In this project the already prepared samples from the project before were used (Science project, From Mountain to Fjord course 2016). In the given time, three samples off the core MF 2016-4 from the place Kistadypet could be investigated.

For a good understanding of the project and its results an explanation of the whole process is advantageous. The sediment cores were taken from the soft bottom of a fjord close to a place called Flåm in the Aurlandsfjord, part of the Sognefjord. The core was a Niemistö core and the diameter of the sediment cores were 7.1 cm (inner diameter) (Niemistö, 1974). Each three cores were taken in three different places, the Harbor (ca. 37 m), Stampa (ca. 60 m), and Kistadypet (ca. 60 m) (Figure 1). The investigated core in this present project is MF 2016-4 from the station Kistadypet, marked with a red circle.

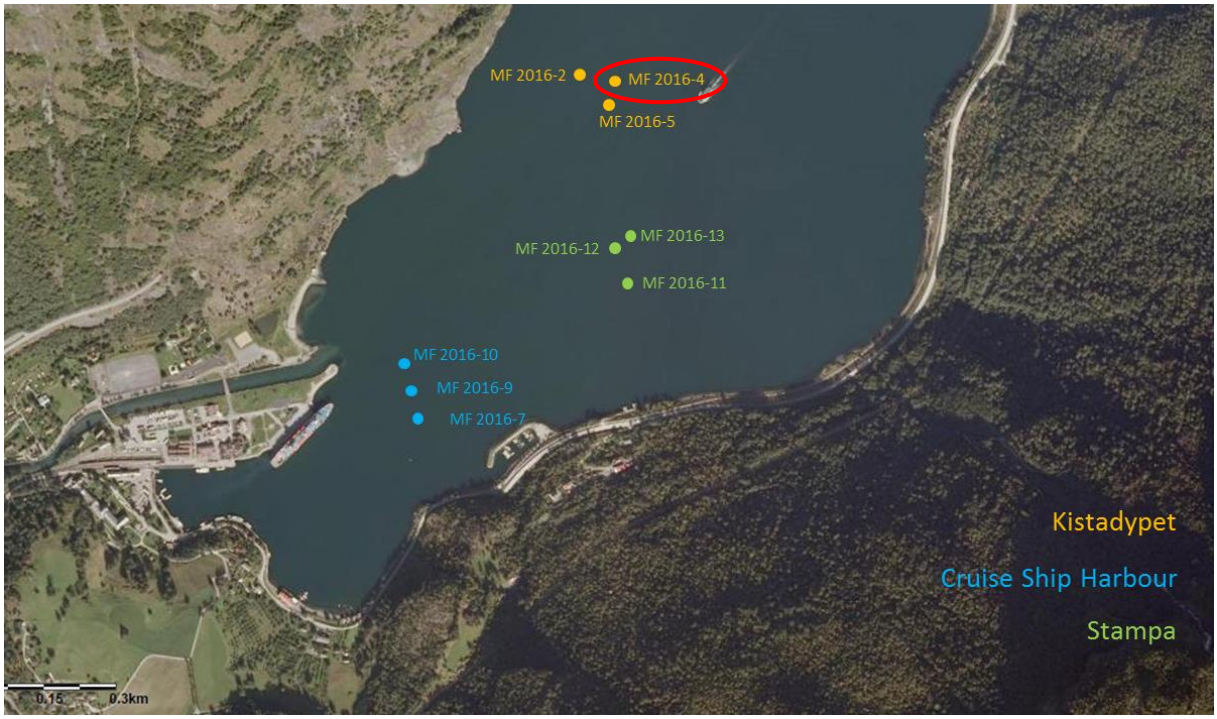

Figure 1 *Location of taken samples (source: http://norgeibilder.no/ edited Paula Schatte and Vivian Sinnen). The outlet of the river Flåmselvi can be seen in the left part of the picture.*

In the laboratory, the cores were spit in sections of 1 cm. To extract the samples, the sediment was scooped out with a spoon. Every removed sediment section was mixed with 20 ml ethanol to estimate the volume of the sediment (Figure 2a). The volume of the sediment for each section of core MF 2016-4 is given in Table 1.

After the volume was determined, the sediment was sieved through four sizes. The mesh-sizes were 2 mm, 250 µm, 125 µm, and 63 µm (Figure 2b). To keep the sediment, with the size categories 2 mm – 250 µm (coarse grained fraction), 250 – 125 µm (medium grained fraction), and 125 – 63 µm (fine grained fraction), it was stored in three different cups with 75 % alcohol for each centimetre.

Figure 2a *In the front is a measurement cylinder for the volume measurement. Behind is a core and in the very back are some cups to store the sediment in.*

Figure 2b *The four sieve sizes with the remaining sediments for each size fraction*

After this, the inspection could start. One sample was placed into a container, that has two open chambers on one side, to divide it in half (Figure 3a). Depending on how much of the sample needed to be inspected, this process can be repeated several times. After the first splitting, the sample is 50 %, after the second it is 25 %, after the third it is 12,5 %, and so on. The part, that should be checked, was transferred into a modified petri dish to look for benthic foraminifera with the binocular microscope (Wild M5) (Figure 3b). For the coarse and medium grained fraction x12 and x25 times magnification was used and x50 times magnification only to improve identifications. Though, for the fine grained fraction only the highest (x50 times) magnification was used. Every foraminifera was counted and as many as possible were identified to species or genus. Also, the pelagic diatoms *Coscinodiscus* sp. and the pelagic tintinnids *Parafavella* sp. and *Tintinnopsis* sp. were counted, as well as the sporangium of fern (Wójcicki, 2015).

Figure 3a *Process of dividing the sample*

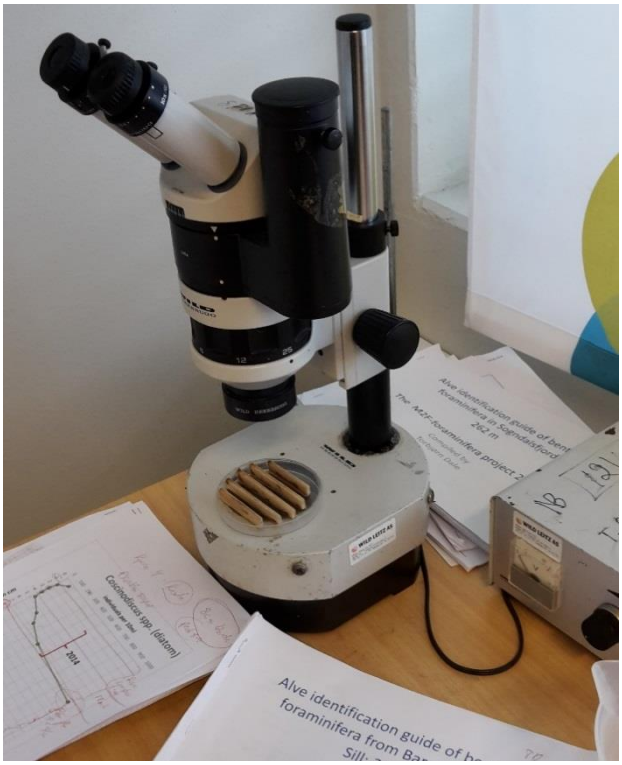

Figure 3b *Microscope (Wild M5) and the modified petri dish*

In this project three fine-grained samples (125 – 63 µm) of the core MF 2016-4 from Kistadypet were investigated for foraminifera, diatoms and sporangia. Also, two species of unidentified Tintinnids were found on numerous occasions and were noted down. The sample 0 – 1 cm was divided in 50 %. But the fine-grained fraction took much more time as expected. Due to that, only about 6 % out of the 50 % was examined. To find out about how much of the sample was investigated, the whole sample got divided so often that is was assessable (Figure 4a, Figure 4b). The amount was about half of 12,5 %, so around 6 % has been examined.

Figure 4a *Core MF 2016-4, fine grained fraction, 0 – 1 cm, investigated sediment, approx. 6 % of the sample*

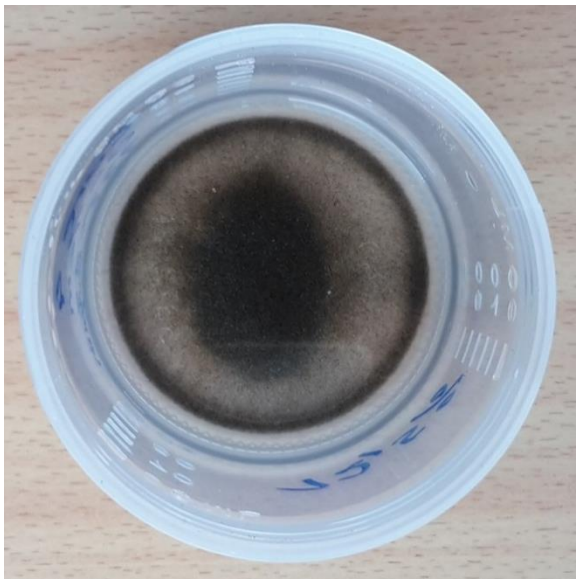

Figure 4b *Core MF 2016-4, fine grained fraction, 0 – 1 cm; 12,5 % of the sample*

The other two samples, 3 – 4 cm and 8 – 9 cm, have been divided to approximately 1,5 %, so that there was a possibility to get some results from some more samples in the given time. To calculate the three samples of the fine-grained fraction correctly, the amount of 6 % and 1,5 % were standardized to 100 %. This number was divide with the corresponding volume (ml) and multiplicated by 10, to get the amount for 10 ml. The concentration of organisms have been expressed as individual/10 ml wet sediment following Grønning (Grønning, 1983). This is necessary to compare the samples with each other and, as the case may be, with other chemical studies like organic matter, oxygen, nutrients, etc. A way to demonstrate and compare the numbers is to create graphs. After that step the results can be compared and interpreted. So, the graphs of the fine fraction, investigated in this project, got compared with the graphs from the coarse and medium fraction. Those are taken from the presentation of the results of the science project at the public seminar in December 2016 (Baßler, Bucher, Grohs, & Klamer, 2016).

During the laboratory work pictures of the work and the organisms were taken with my smartphone (Samsung Galaxy S5 mini). Because of this, the sizes of the organisms were not identified, but most of this pictures are from the medium fraction. This means they have a size between 250 – 125 µm.

Results

In the samples of the investigated core MF 2016-4 from Kistadypet, most of the dominating species have agglutinated shells, like *Adercotryma glomeratum* (Figure 5b), *Leptohalysis gracilis* (Figure 5c), and *Textularia* sp. (Figure 5d). All of them are found in all sizes, coarse to fine grained. Some calcareous species, for example *Bulimina marginata* (Figure 5a), have been found as well.

Figure 5a *Bulimina marginata, medium fraction*

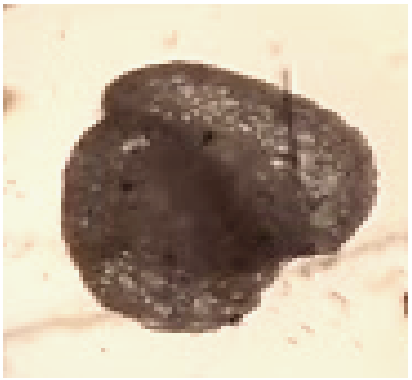

Figure 5b *Adercotryma glomeratum, medium fraction*

Figure 5c *Leptohalysis gracilis, medium fraction*

Figure 5d *Textularia sp., medium fraction*

The other eye-catching organisms that have been found and counted is *Coscinodiscus*, a genus of diatoms (Figure 6a); *Parafavella*, species of Tintinnid (Figure 6c); another species of Tintinnid, probably a *Tintinnopsis* sp. (Figure 6d); and fern sporangium (Figure 6b).

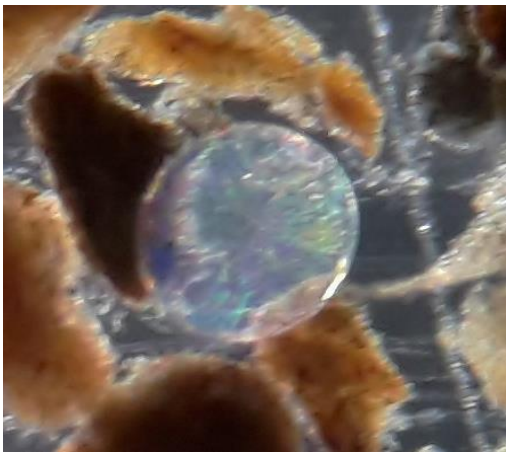

Figure 6a *Diatom Coscinodiscus, medium fraction*

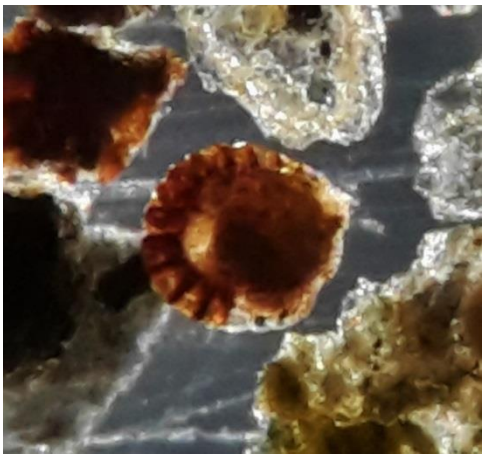

Figure 6b *Fern sporangium, medium fraction*

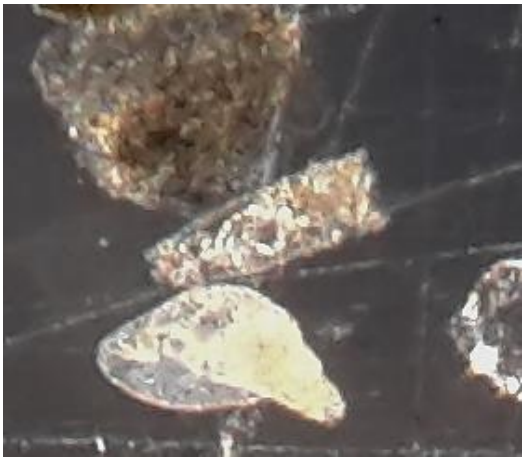

Figure 6c *Remains of Parafavella, a species of Tintinnid (central object), fine fraction (between 125 – 63 µm)*

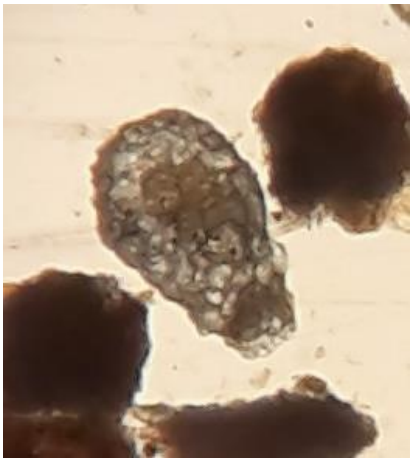

Figure 6d *A species of Tintinnid, probably a Tintinnopsis sp., medium fraction*

The concentration of found foraminifera in core MF 2016-4 of Kistadypet is shown in Figure 7. The graph on the left side shows how many individuals of a size between 2 mm and 125 µm (coarse and medium) where found per centimeter depth in the sediment sample. The concentration in the 0 – 1 cm and 1 – 2 cm layer is approx. 350 – 400 foram./10 ml. 2 – 3 cm to 7 – 8 cm is approx. 150 – 275 and at 8 – 9 cm is approx. 525 foram./10 ml. So, from the top layer to the lowest layer, a clear decrease and a following increase is visible. The most dominant species in the coarse/medium fraction is *Bulimina marginata*. There are also some unidentified species. The numbers are visible in Table 6.

In the graph shown on the right side, there are only three investigated depth, 1 – 2 cm, 3 – 4 cm, and 8 – 9 cm. The size of these foraminifera is between 125 µm and 63 µm (fine fraction). The trend again is at first a clear decrease with a following increase. At the top sediment layer (1 – 2 cm) is approx. 4000 foram./10 ml, in the middle (3 – 4 cm) is approx. 100 foram./10 ml and at the deepest sediment layer (8 – 9 cm) is 2750 foram./10 ml. The most dominant species in the fine fraction is *Textularia* sp. The exact numbers are given in Table 4.

The results also indicate that the concentration in the fine fraction is much higher at the upper and the lowest layer as in the combined coarse and medium fraction.

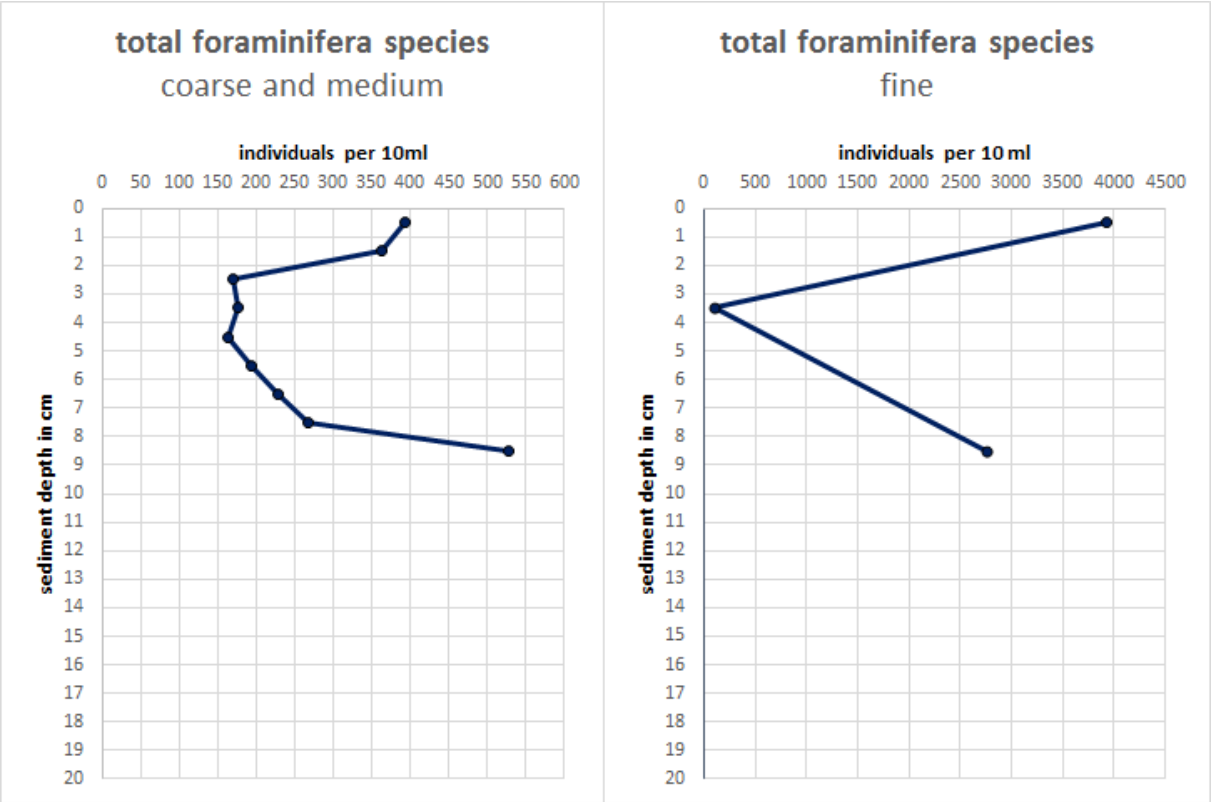

Figure 7 *The concentration of all foraminifera species together in the coarse grained and medium grained fraction (left graph), as well as in the fine grained fraction (graph to the right). (Kistadypet)*

All the found diatom species *Coscinodiscus* sp. in core MF 2016-4 of Kistadypet are shown in Figure 8. The left graph shows *Coscinodiscus* with the coarse and medium size. In the 0 – 1 cm to 4 – 5 cm layer the concentration is below. 75 Cosci./10 ml, in the 5 – 6 cm to 7 – 8 cm layer it is rising from approx. 150 to 410 Cosci./10 ml and at the lowest layer (8 – 9 cm) it is approx. 950 Cosci./10 ml. The exact numbers are given in Table 6.

In the graph to the right, the fine size, are again only the three investigated depth. The concentration found in the fine fraction is similar to that in the coarse and medium fraction together. At the top sediment layer (1 – 2 cm) is 600 Cosci./10 ml, in the middle (3 – 4 cm) is no *Coscinodiscus* and at the deepest sediment layer (8 – 9 cm) is 750 Cosci./10 ml. The numbers are also given in Table 4.

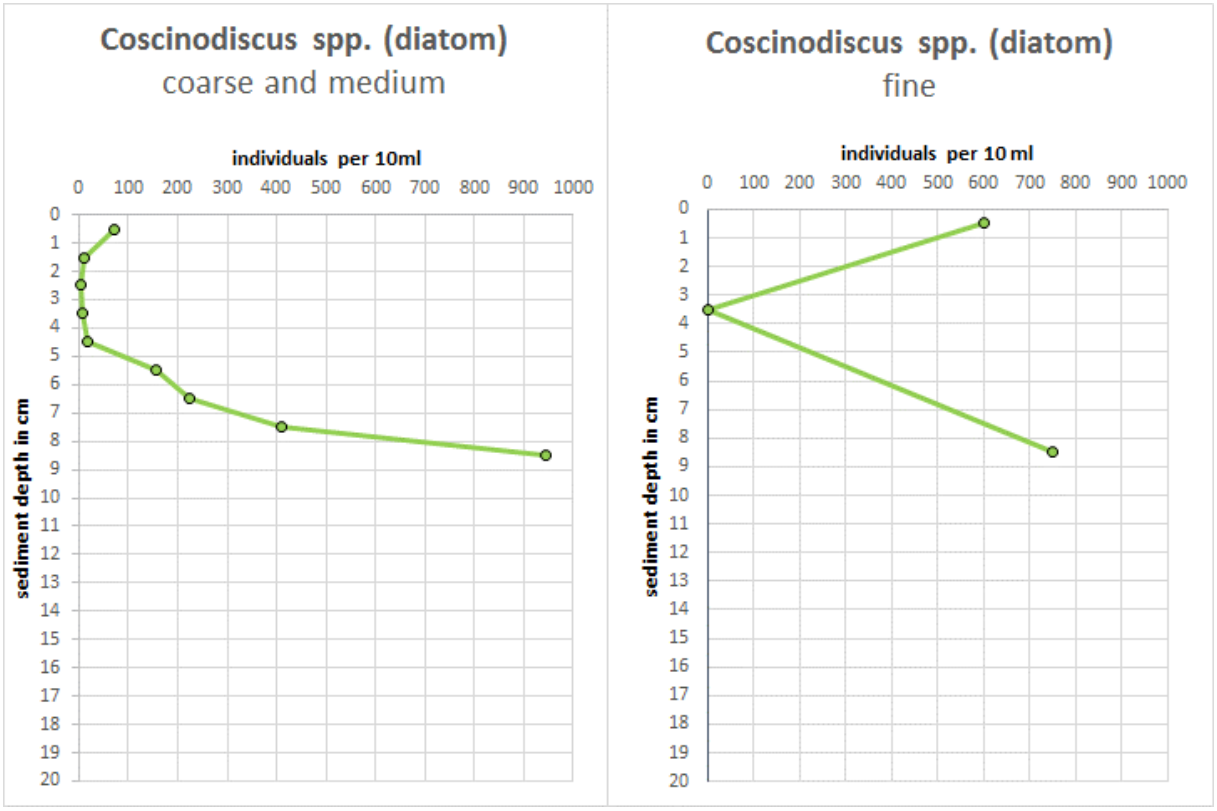

Figure 8 *The amount of the diatom Coscinodiscus in the coarse grained and medium grained fraction (left graph), as well as in the fine grained fraction (right graph). (Kistadypet)*

Two species of tintinnid, found in the fine fraction of the sample, have this kind of trend, too (Figure 9). It is not that clearly visible in the depth distribution of the Tintinnid spp., but still recognizable. At the station Kistadypet these species were only observe in the fine fraction.

At both of this graphs only the three investigated depth, 1 – 2 cm, 3 – 4 cm, and 8 – 9 cm are given. The concentration per 10 ml of *Parafavella* at 1 – 2 cm is approx. 16000, at 3 – 4 cm approx. 300 and at 8 – 9 cm approx. 17000. The concentration per 10 ml of Tintinnopsis spp. is with approx. 230 at the 1 – 2 cm layer, approx. 100 at the 3 – 4 cm layer and 1000 at the 8 – 9 cm layer much lower. The exact numbers are given in Table 4.

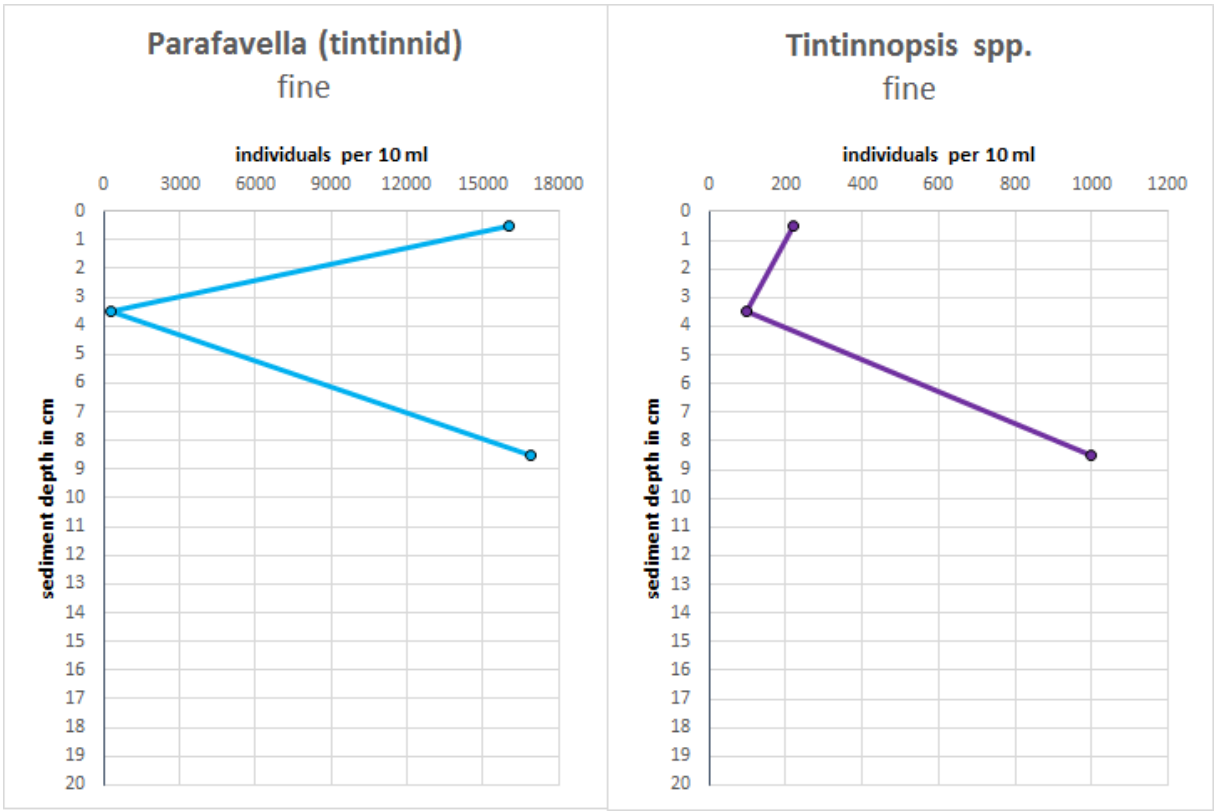

Figure 9 *The amount of Parafavella (left graph) and a probably other species of Tintinnid (right graph) in the fine grained fraction. (Kistadypet)*

In the coarse and medium grained fraction variable numbers of fern sporangium were found along the depth profile (Figure 10). The depth distribution is fairly even in the upper 5 cm, but shows 4 minima. The minimum with the lowest concentration is at 5 – 6 cm with 5 individuals/10 ml. From the 4 maxima, the one with the highest concentration is 30 individuals/10 ml. This numbers are also given in Table 6. The sporangium is too large to be found in the fine fraction.

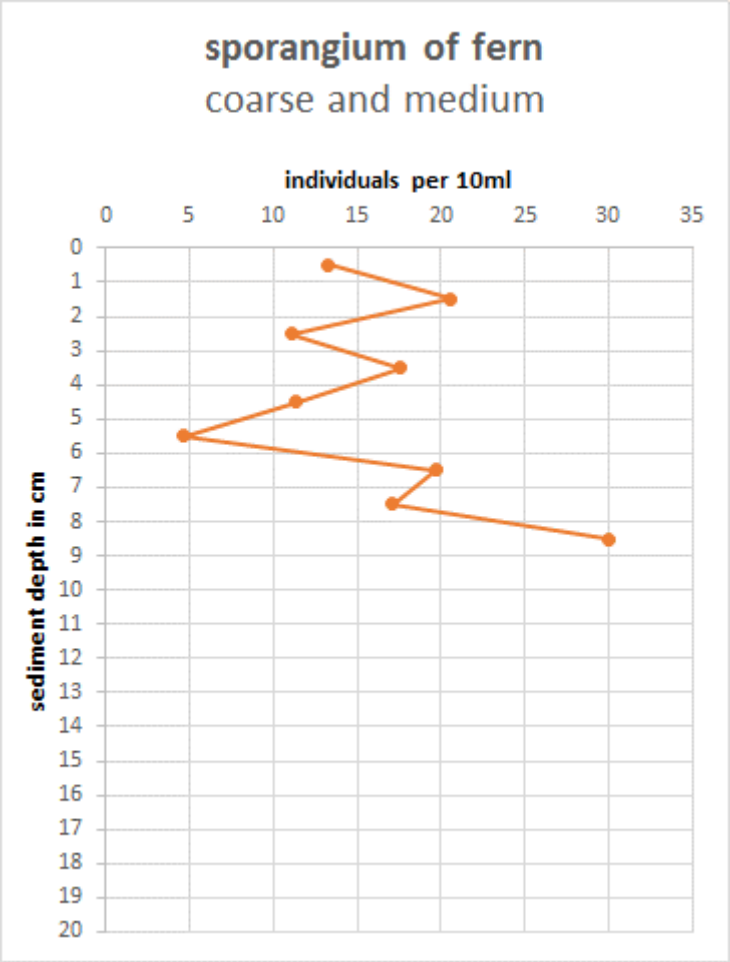

Figure 10 *The amount of fern sporangium in the coarse grained and medium grained fraction. (Kistadypet)*

Discussion

The main point of this project was to figure out whether the depth distribution of foraminifera and other organism found in the fine grained fraction is confirming the depth distribution observed in the medium and coarse grained fraction; and so if the conclusion, that the flood event 2014 is seen in the sediment cores, is right.

In the science project of the 'From Mountain to Fjord' course in autumn 2016 the graphs of the foraminifera and the *Coscinodiscus* from the coarse and medium fraction got compared with the graphs of chemical studies from other groups to get a better overview of what could have happen in the Aurlandsfjord. Thereby, the conclusion that the flood event is visible in the sediment core developed.

The depth distribution of foraminifera in the fine fraction is confirming the trend of the medium and coarse fraction (Figure 7). Both depth distributions indicate a high concentration in the sediments before the flood, low in the sediments deposited during the flood and increasing again in the top. Foraminifera reproduce in the sediment. Due to there was so much new sediment deposited in a short time, the foraminifera were not able to reproduce much. Though, they can crawl up and down in the sediment to find more food. This could explain the decreasing concentration from 7.5 cm to 4.5 cm and from 1.5 cm to 4.5 cm in the medium and coarse fraction (T. Dale, personal communication).

Due to foraminifera can move in the sediment, the measured concentration per cm is not perfectly exact. Also, the laboratory work might be not exact and so the data are always a bit inaccurate. They are still exact enough to get a basic trend of the depth distribution that can be interpreted.

The depth distribution of the pelagic diatom *Coscinodiscus* gives the same picture as the foraminifera. Both, coarse/medium and fine grained fraction of the sample show the same trend. The concentration decreases from the deepest layer to the middle layer and increases again in the top layer (Figure 8).

Diatoms are mostly phototrophic organism, so they need light to survive. *Coscinodiscus* sp. (Figure 6a) lives and reproduce in the euphotic zone of the water masses. The euphotic zone in the Aurlandsfjord is usually between 10-20 m. The *Coscinodiscus* specimens found in the sediments have therefore been sinking down

from the euphotic zone. The tintinnids are heterotrophic planktonic organisms that also reproduce and live in the water mass (T. Dale, personal communication). The low concentrations of both the pelagic diatoms and tintinnids in the middle part of the sediment core supports the interpretation that the sediment must have been deposited rapidly as would happen during a massive sedimentation following the flood. If more sediment deposited as usual, it's understandable that not that much diatoms, and also not that much tintinnids, sink down. This means the concentration decreased in the time of the flood event. That explains also the depth distribution of the tintinnids shown in Figure 9.

Parafavella (Figure 6c), of which numbers are shown in Figure 9, is not very well investigated yet. A small report is written about the sedimentation of Tintinnids (Dale, 1989). *Parafavella* sp., as well as the diatom Coscinodiscus, are usually found in the euphotic zone, where they feed on phytoplankton (T. Dale, personal communication). The other observed Tintinnid species, shown in Figure 6d, could be also a species of the thecamoebian indicators. They look very similar. It's hard to be sure about what it is, without confirmation of an expert. However, they show the same trend as the foraminifera and *Coscinodiscus* and is thus supporting the assumption of the flood event.

This results and graphs, of some other groups of the science project in 2016, as well as the graphs of the coarse and medium grained fractions and the fine fraction show a change in the middle of the cores from the station Kistadypet. Thus, the conjecture is that this part of the core is the sediment that deposited during and after the flood.

In general it's hard to find the real reason why there is sometimes a high number and sometimes a small number for a special kind of foraminifera without the help of an expert. Thought, some reasons that cause changes are known. Most species life in salt water, some species can live in brackish water. Only a few species prefer fresh water. The fjord water is saline to brackish water. Good conditions for most of the foraminifera species. How high the salinity in the Aurlandsfjord is, is hard to say with only checking the foraminifera. Some can tolerate low salinity, some high, some both. The hydrography group of the science project in autumn 2016 showed "normal" sea water salinity of ca 33 per mille at the depth of about 60 m. Foraminifera also get influenced by the oxygen level in the water. Some species can tolerate a high oxygen

level as well as a low level, some prefer a lower or higher level. According to the hydrography group the oxygen level at the depth of 60 m is 5ml/L.

Foraminifera build shells usually out of calcium carbonate ($CaCO_3$) or have agglutinated shells out of sand grains or other particles. If the water contains more calcium carbonate, more species with a $CaCO_3$-shell are found, otherwise agglutinated shells are predominantly found. Generally, as higher the temperature and the salinity become, the more $CaCO_3$ secreting foraminifera replace agglutinated species. Agglutinated foraminifera like low pH-value by either low oxygen or high organic matter concentrations (Scott, Medioli, & Schafer, 2001).

At the place Kistadypet only a few species with a $CaCO_3$-shell are found, but some more with agglutinated shells. This means that there is not a lot of carbonate in the water but still enough for the calcareous foraminifera to live there.

Summary

In 2016, sediment core samples were collected during the science project of the course “From Mountain to Fjord” at the station Kistadypet outside the river Flåmselvi in the Aurlandsfjord. These samples were examined with respect to depth distribution of foraminifera, diatoms and fern sporangia in the sediment. The investigation of the coarse and medium size fraction of the samples led to an indication of a massive addition of sediments following the large flood in 2014, seen in the sediment between circa 2 – 8 cm.

The present inspection of the fine fraction off some of the same samples was done to support this earlier hypothesis. The depth distribution of the foraminifera, diatoms, and tintinnids in this fine fraction of the course confirm this hypothesis. The graphs of the depth distributions show the probable flood layer of ca. 5 cm thickness between 2.5 – 7.5 cm in the investigated sediment cores.

The general depth distribution of benthic foraminifera, ferns, diatoms (*Coscinodiscus*) and tintinnids in the sediment of Kistadypet showed a marked minimum between 2 – 7 cm in the coarse and medium fraction combined. This was interpreted as a result of the huge flood in 2014. The depth distribution of foraminifera and *Coscinodiscus* in the fine fraction supports this explanation.

Acknowledgment

I thank especial Torbjørn Dale, but also Matthias Paetzel for their support, help and interested in this project. I also thank my group (Achim Bucher, Lucas Grohs, Thomas Klamer) from the science project of the ‘From Mountain to Fjord‘-course 2016 for a good working together to get some results and interpretations.

Literature

Baßler, I., Bucher, A., Grohs, L., & Klamer, T. (12. December 2016). Presentation: Foraminifera in the Aurlandsfjord. Høgskulen på Vestlandet, Sogndal, Norway.

Bender, A.-M., Bordne, K., & Klopsch, C. (2016). *Presentation: Environmental history of Flåm.*

Dale, T. (1989). *Sedimentation of Loricas of Tintinnids (Ciliata, Protozoa) and Shells of Bivalve Larvae in the Landlocked Fjord, Lindåspollene, Norway.* Institute of Marine Biology, Blomsterdalen, Norway: VEB Gustav Fischer Verlag Jena.

Grønning, H. (1983). Sogndalsfjordområdet: maringeologisk og benthonisk foraminifer utbredelse. Hoved fagsoppgave Geologisk Ynststutt, Universitetet i Bergen.

Niemistö, L. (1974). A gravity corer for studies of soft sediments. Finland: Meretutkimuslait, Julk. / Havforskningsinst. Skr.

Scott, D. B., Medioli, F. S., & Schafer, C. T. (2001). Monitoring in Coastal Environments Using Foraminifera and Thecamoebian Indicators. United Kingdom: Cambridge University Press.

Wójcicki, K. J. (2015). Authigenic and allogenic organic remains as an indicator of geomorphological process activity within the floodplain environment: two case studies from Racibórz Basin, southern Poland. In K. J. Wójcicki, *Bulletin of Geography. Physical Geography Series* (S. 81 - 93). University of Silesia in Katowice, 40-007 Katowice, Poland: De Gruyter Open.

Appendix

Table 1 *Volume in ml of the sediment at every cm of the sample (Kistadypet).*

Kistadypet	0 - 1 cm	1 - 2 cm	2 - 3 cm	3 - 4 cm	4 - 5 cm	5 - 6 cm	6 - 7 cm	7-8cm	8-9cm
Volume in ml	7,5	6,8	9	6,8	7	8,5	7,1	7	8

Table 2 *Counted numbers of Foraminifera, Coscinodiscus and Tintinnids (fine fraction - Kistadypet).*

Species	0 - 1 cm	3 - 4 cm	8 - 9 cm
Adercotryma glomeatum	7	1	1
Bulimina marginata	1	0	0
Cribrostommoides sp.	4	0	0
Leptohalysis gracilis	29	0	0
Liebusiella göesi	1	0	0
Saccamina	1	0	0
Textularia sp.	125	0	5
Stainforthia fusiformis	5	0	23
Unidentified	4	0	4
Coscinodiscus (Diatom)	27	0	9
Parafavella	723	3	203
Tintinnopsis spp (Species of Tintinnid I)	10	1	12
Species of Tintinnid II	3	0	1

Table 3 *Calculated amount of Foraminifera, Coscinodiscus and Tintinnids (fine fraction - Kistadypet). Individuals per 10 ml sediment.*

Species	0 - 1 cm	3 - 4 cm	8 - 9 cm
Adercotryma glomeatum	156	98	83
Bulimina marginata	22	0	0
Cribrostommoides sp.	89	0	0
Leptohalysis gracilis	644	0	0
Liebusiella göesi	22	0	0
Saccamina	22	0	0
Textularia sp.	2778	0	417
Stainforthia fusiformis	111	0	1917
Unidentified	89	0	333
Coscinodiscus (Diatom)	600	0	750
Parafavella	16067	294	16917
Tintinnopsis spp (Species of Tintinnid I)	222	98	1000
Species of Tintinnid II	67	0	83

Table 4 *Summed up amount of Foraminifera, Coscinodiscus and Tintinnids in (fine fraction - Kistadypet). Individuals per 10 ml sediment.*

	0 - 1 cm	3 - 4 cm	8 - 9 cm
total number of foraminifera	3933	98	2750
Cosinodiscus	600	0	750
Parafavella	16067	294	16917
Tintinnopsis spp	222	98	1000

Table 5 *Procentage and volume of counted sample (fine fraction - Kistadypet)*

	0 - 1 cm	3 - 4 cm	8 - 9 cm
procentage of counted sample	10	1,5	1,5
Volume in ml	7,5	6,8	8

Table 6 *Calculated amount of Foraminifera, Coscinodiscus and fern sporangium (coarse and medium fraction - Kistadypet). Individuals per 10 ml sediment. The two samples, 0 – 1 cm and 1 – 2 cm, were counted to 100 %. The other samples were counted to 50 % and standardized to 100 %.*

Species	0 - 1 cm	1 - 2 cm	2 - 3 cm	3 - 4 cm	4 - 5 cm	5 - 6 cm	6 - 7 cm	7 - 8 cm	8 - 9 cm
Leptohalysis sp.	5	9	0	0	3	7	6	0	5
Hippocripinella hir.	3	4	2	0	6	0	0	0	0
Eggerelloides scaber	19	28	11	15	9	19	20	11	40
Liebusiella göesi	23	7	4	6	3	0	9	11	15
Reophax sp.	23	24	11	21	6	7	14	9	5
Saccamina	87	89	31	35	29	35	34	14	20
Globobulimina auriculata	28	21	11	12	14	17	51	66	70
Bulimina marginata	81	59	18	18	9	40	42	43	158
Leptohalysis gracilis	15	3	2	0	6	19	3	11	28
Cribrostommoides sp.	12	13	7	15	23	5	17	17	23
Nonionella labr.	4	3	0	3	0	9	3	14	50
Uvigerina peregerina	0	4	2	0	6	0	6	17	13
Textularia earlandi	0	38	0	9	0	0	0	9	0
Ammodiscus gullmarensis	0	0	0	0	0	2	0	0	5
Spiroplectammina bif.	43	0	36	3	0	9	3	0	3
Hyalinea balthica	3	0	0	0	3	2	0	3	3
Stainforthia fusiformis	3	6	2	0	3	0	0	6	18
unidentified	48	56	33	41	46	21	23	37	75
sporangium of fern	13	21	11	18	11	5	20	17	30
Coscinodiscus (Diatom)	71	12	2	6	17	155	225	409	945