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Climate of the Past Discussions

Interactive comment on "Trace elements and cathodoluminescence of detrital quartz in Arctic marine sediments – a new ice-rafted debris provenance proxy" *by* A. Müller and J. Knies

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Reply to discussion: Müller and Knies CPD 9, 4145-4189: "Trace element and cathodoluminescence . . ..ice-rafted debris provenance proxy"

Reviewer #1

Reviewer comment: "In terms of my own "expertise" I would claim both an interest and knowledge of ice-rafting processes, but I have had very little to no experience in the tracers used in this study. One small point before I discuss some major issues—my colleague at the University of Colorado is Lang Farmer, i.e. his 1st name is Lang (see referencesâĂŤthey should be Farmer, L.). I certainly support the publication of this

paper as it has the potential to address a critical issue in many IRD studies, and that is trying to better identify source(s) for that the ubiquitous mineral—quartz. Because this is all about quartz then I suggest they should reference Kolla, V., Biscaye, P.E., Hanley, A.F., 1979. Distribution of quartz in Late Quaternary sediments in relation to climate. Quaternary Research 11, 261-277 and also Bond's efforts to identify source(s) based on the hematite stains on sand-size quartz grains. Nevertheless, their assertion that characterizing the provenance of quartz in Quaternary sediments is an important objective for IRD studies is totally correct."

Reply: We corrected the reference "Farmer et al." and added the references.

Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I., Bonani, G. 1997. A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climates. Science, 278, 1257-1266.

Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M.N., Showers, W., Hoffmann, S., Lotti-Bond, R., H., Hajdas, I., Bonani, G. 2001. Persistent solar influence on north Atlantic climate during the Holocene. Science, 294, 2130-2136.

Reviewer comment: "I think the authors might say a little at the beginning about the grain-size spectra of their sediments. I think many researchers have the mistaken belief that when "we" talk about IRD that the sediments contain a great wt% of coarse sand. In my experience this is not the case and even in this study it appears that quartz grains were not all that plentiful. What was the fraction of quartz versus other minerals in this size range?"

Reply: An additional paragraph was added at the end of chapter 3.1: "The grain-size spectra in Setting B samples consist of sand-bearing clayey silts, with sand contents varying between 0 and 6 wt. % (Winkelmann, 2003). The sand content in Setting A samples of Setting A may reach up to 30 wt.% of the total fraction. In the >500 μm fraction, the fraction of quartz relative to other minerals was between 10 and 20 %."

Winkelmann, D., 2003. Reconstruction of recent and late Holocene sedimentation processes on the continental shelf west off Spitsbergen, Diploma Thesis, Freiberg University of Mining and Technology. pp. 156.

As an example for the grain size spectra of setting B, the grain size distribution for three stations in the Storfjorden, southern Spitsbergen, is shown in Figure 1.

Reviewer comment: “However, when considering any laboratory method and its research application there are two vital issues that need to be discussed “up front” (at least in my mind)âĂŤthey are the time taken to process samples, and then what is the cost. I do not think more than a paragraph is needed but with a new method then I suggest that these are important questions. For example, how long did it take to garner the 198 quartz grains etc etc. These issues become critical if someone was thinking of using this method in order to obtain multi-decadal records over a 1-2 cal ka interval. This is where the potential costs will also come in—what would be the cost for example of processing say 100 samples?”

Reply: An additional paragraph was added at the end of chapter 1: "Processing and analyzing the offshore (9) and onshore (18) samples with our new quantitative approach are relatively fast. For the LA-ICP-MS analyses (133 offshore quartz grains; 53 quartz grains in onshore samples), we used 20 working days including data processing. Initial handpicking of 198 quartz grains, preparation of thick sections, investigations by optical microscopy and SEM and SEM-CL work lasted another ca. 30 working days. The analysis of ca. 100 samples to obtain information on the origin of IRD-derived quartz grains in a millennial-centennial record outside Svalbard will last ca. 7 months with this new approach."

A general comment to the raised questions above: The handpicking of 198 grains out from the 500 μm took about two days. After hand picking the sand grains were embedded in epoxy resin and polished down half size as we described in our paper. The mounting of the sand grains was carried out at the thin section laboratory at the

Geological Survey of Norway (NGU). 18 petrological polished thick ($\sim$300 mm) sections were prepared from the onshore samples. The sample preparation took two months and the cost per mount was ca. 64 Euro (25 mounts and 18 sections were prepared with a total cost of 2752 Euro). Five working days were spent for optical microscopy and 20 working days for SEM and SEM-CL investigations at NGU. For the LA-ICP-MS analyses – 133 analyses of offshore quartz grains and 53 analyses on onshore samples - we used 20 working days including data processing. Summarizing we used about 2 months for the preparation and analyses of 9 offshore sand samples and 18 onshore hard rock samples. To answer your question: The preparation and analyses of 100 samples would require 7 months working time applying the preparation costs of NGU and the working efficiency of the authors.

The costs for applying the analytical methods are different for different laboratories and prices change with time. NGU has access to all facilities in its own laboratory, and costs are therefore rather moderate. Furthermore, people work in different ways and with different efficiency and, thus, the time needed will be different for different people. For that reasons, we cannot estimate the exact working time and costs for each individual project applying this approach, and we are not aware of any scientific paper in which prices and time estimation for sample preparation and analyses are provided.

Reviewer comment: Another major concern I had was with the identification of the quartz groups (p. 4152) i.e. “....offshore samples were classified into five major types....” It is not clear to me 1) how these groups were initially defined, and 2) are they indeed “unique”, i.e. what is the probability of assigning a grain to only one group? The criteria for placing a quartz grain in one of the 5 groups, A to E, are complex and not necessarily numeric but when I look at the plots on Fig. 6 my first question is: how distinct are the designated groups? This could be tested by Discriminant Function Analysis (DFA) under the null hypothesis that there are no differences between the groups based on the element analysis. However, in Table 3 (p. 4169) the distinction

between groups A, B and C re primary and secondary rock types appears marginal at best—or do I misunderstand?

Reply: We wrote in our paper: “The quartz grains of offshore samples were classified into five major types, A to E, based on mineral micro inclusions, CL intensity, intragranular structures visualized by SEM-CL imaging and trace element content.” which answers your point (1). This statement implies that classification was developed on the base of the observed, most significant features of the investigated offshore grains. Thus, the classification application is restricted to the offshore sample area of this study. In a number of onshore rock samples we found quartz grains with features which were not observed in offshore grains. For these grains a classification was not necessary because they could immediately be excluded as the source of offshore grains. We choose the features distinguishing the groups in that way that each offshore grain could assigned to one group only. With the applied classification we identified successfully the source area of most of the onshore grains and, therefore, the classification is distinctive enough for this study. To make us more clearly we did a number of changes at the beginning of the chapters 5.1 and 5.2.

Reviewer comment: “The authors demonstrate the power of the method in terms of a relatively small (i.e. small in the context of the NH ocean which would today or in the past be subject to IRD) region. The underlying question that I pose to them is this: does your characterization of the quartz grains carry enough information that we are likely (probably?) to be able to discriminate between quartz grains of similar origins (e.g. Table 3) from say NE Greenland versus SW Spitsbergen? They might legitimately answer that this is the next step, but. . ...they probably know enough of the regional geology of these areas as to hazard a guess or a best case scenario because after-all, for this method to have widespread utility then it needs to be able to differentiate, if possible, between rocks of similar ages and origins (the Old Red Sandstone) but which are now disjunct. I am certainly not advocating that this needs to be done for this paper, but this is the larger and more important issue that this paper, and methods, raise. “

Reply: An additional paragraph was added to chapter 7: "The next steps will be (1) collecting and analysing further onshore samples from Svalbard to expand the database for further IRD provenance studies in this climate-sensitive region, and (2) start analysing down-core records from the Yermak Plateau, an area influenced by former paleo ice streams (e.g. Gebhardt, et al., 2011) and variable sea ice conditions (Fig. 2). On a longer term perspective, onshore samples from Greenland, Scandinavia and Iceland will be added to the database delineating major IRD provinces in the circum North Atlantic - Arctic Ocean further."

Gebhardt, A.C., Jokat, W., Niessen, F., Matthiessen, J., Geissler, W.H., and Schenke, H.W., 2011. Ice sheet grounding and iceberg plow marks on the northern and central Yermak Plateau revealed by geophysical data. Quaternary Science Reviews, v. 30, p. 1726-1738.

A general comment to the raised issue: The quartz grains of the studied area carry enough information to identify the source area. Taking our results in consideration: yes, it is probably possible to discriminate between quartz grains from NE Greenland and SW Spitsbergen, but we simply do not know, because - to our knowledge - there are no data of CL structures and trace element contents of quartz in onshore rocks from NE Greenland available. On a longer perspective, we need to build up this database for the circum Atlantic-Arctic IRD provinces to improve this knowledge. We currently have only a sufficient overview about potential quartz grains being derived from Svalbard and western Scandinavia.

Interactive comment on Clim. Past Discuss., 9, 4145, 2013.

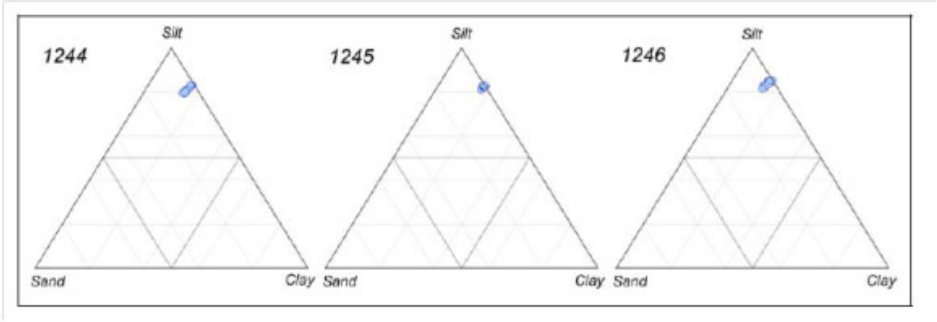

Fig. 1.