

Interactive comment on “Clay mineralogy, strontium and neodymium isotope ratios in the sediments of two High Arctic catchments (Svalbard)” by Ruth S. Hindshaw et al.

Anonymous Referee #1

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Review of the manuscript entitled “Clay mineralogy, strontium and neodymium isotope ratios in the sediments of the two High Arctic catchments (Svalbard)” by Hindshaw et al.

The study reported in this manuscript investigates the sources of sediments and sedimentary rocks collected in two small catchment areas (one is glaciated, the other is not) in Svalbard (Arctic region) using clay mineralogy and Sr-Nd isotopic compositions.

The manuscript is well written, the figures are clear and the methods used to analyze the samples are adapted and seem of good quality. Based on previous published studies, the authors have envisaged several scenarios to explain their data, which

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reflects a good knowledge of the existing bibliography on the subject. In general, I think that the isotopic variability and the clay mineralogy well support the idea of mixing between two proto-sources (a young basaltic terrane and an Archena one) discussed by the authors all through the manuscript. However, I have several concerns regarding the interpretations of the weathering and grain-size effects, and on the fact that the formations exposed in the two catchment areas do have distinct isotopic signatures. I explain these concerns in more details below (see specific comments).

Beyond that, I think one of the main issues of the study is the sampling strategy. First, I do not understand why the authors decided to focus on such small catchment areas (a few km² at most) when the aim of the study is to better constrain the composition of river sediment inputs from Svalbard to the oceans (cf. page 2, lines 32-35 and page 3, lines 1-10). What is special about this area? Are the lithologies exposed in these two catchment areas representative of what can be found elsewhere on Svalbard? Then, I found that there was a general confusion on what is considered a sediment source, a sedimentary rock or a sediment all through the manuscript. After several readings, I think I finally understood that the authors had collected random pieces of sedimentary rocks (not in place) in the catchment areas together with river, and supra-glacial sediments and that they were trying to determine the nature of the sedimentary formations randomly sampled, the sources of the river and supra-glacial sediments, and the sources of the sedimentary formations exposed in the catchment area. Again, if the aim is to constrain the composition of sediments exported from Svalbard to the Arctic ocean, I do not understand the sampling strategy of the authors. Why didn't they sample the drained formations in place to know the isotopic compositions of the sources? How did they choose the pieces of bulk rock to analyze? There is a significant isotopic bias between samples from the Fardalen and Dryadreen catchment areas (see specific comment below), how can the authors be sure that it is not a sampling bias? The information given in Table 1 and 2 are also not very clear: Which samples are assumed to be the sources and which ones are the sediments for which the sources are unknown? Why are the stream sediments from Fardalen and Dryadreen (samples

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L and O) and the sediment collected at the surface of a glacier (sample D) grouped together with bulk rocks collected in the catchment areas? This needs to be clarified. I would suggest that the authors clearly divide their samples into two groups: river sediments and potential sources; or first-cycle sediments and second-cycle sediments; or sedimentary rocks (old consolidated sediments exposed in the catchment area) and sediments (modern river, stream, glacial sediments). The notation F and D (Fardalen and Dryadbreen) is also unclear in Table 1 since D is the name of a sample. I would simply add an additional column to mention clearly the name of the catchment area from which the samples were taken in Table 1.

Specific comments

1. What controls the isotopic variability of the samples (grey trend in Fig. 3)?

As I said above, I generally agree with the idea that the Nd-Sr isotopic compositions of the sedimentary rocks and the sediments are controlled by variable contributions of two main proto-sources ("East" and "West" as called in the text). The question is why are the contributions so variable from one sediment/sedimentary rock to another? Page 9, it is explained that each sedimentary formation may have a distinct isotopic signature. Why not, but I don't think the arguments are convincing enough. Knowing the composition of a rock sampled in place from each formation would easily solve the problem but since this data is not available I think the authors should develop a little bit more this part of the discussion. Maybe they should add a figure to clearly compare the clay mineralogy and the major and trace element concentrations of each of the formations (published data) to the composition of their sedimentary rocks. A striking feature of the author's dataset is that the Dryadbreen and Fardalen suspended AND catchment rocks form two very distinct groups in the Nd-Sr isotopic space (see red and blue circles in Figure 3 in the attached pdf). This difference is discussed for the suspended sediments only (end of page 8 and page 9) but this actually also concerns ALL the other collected rocks. How do the authors explain this difference given that the same formations are present in the two catchment areas? Did they

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unexpectedly sample only one formation in each catchment area? Is it a sampling bias? I was wondering whether it could be related to the fact that one catchment is glaciated and not the other. Assuming each rock-type (shale, siltstone, sandstone), not each formation, has its own isotopic signature, would it be possible that sandstones, enriched in Archean erosion products, be more eroded by the glacier in Dryadbreen than they are in the unglaciated catchment? Knowing the sampling locations of all the studied catchment rocks might help to understand this feature. Alternatively, assuming that the different formations exposed in the catchment area do have distinct Sr-Nd isotopic signatures, why would the presence of the glacier in Dryadbreen favors the erosion of the upper part compared to Fardalen? Is it directly related to the steepness of the eroded area and the location of the glacier? I think more explanations are needed here.

2. Effect of grain-size/mineral sorting

Page 9, lines 17-20: the authors argue that the isotopic difference observed between the clay fractions and the bulk rocks in Figure 3 (black and whites triangles) could be explained by a process similar to the one that creates the general trend (grey lines, Fig.3) in Sr-Nd isotopic space. However, when you link the bulk rocks to their respective clay fractions (see the red arrows in Figure 3 in the attached pdf), the variations point towards different endmembers (much steeper slope than the general trend). To me, this indicates that the intra-sample variability (clay-bulk) cannot be explained with the same processes or the same sources than the inter-sample variability. Initially, I thought that the steeper trend was due to the ingrowth of radiogenic Nd since the formation of the Eocene sedimentary rocks but the difference of Sm/Nd ratios between the clay and the bulk fractions is too small to generate such a large variability in ϵ_{Nd} in 50 Ma (only 0.1 to 0.4 ϵ_{Nd} units according to a quick calculation). One would need to do a mass balance calculation for Nd and Sr but the low ϵ_{Nd} value of sample R03 (the only coarse-grained sediment, presumably enriched in REE-rich accessory minerals) suggest that another mineral phase controls the Nd isotopic composition of the sedimentary rocks,

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probably heavy minerals (monazite, apatite, allanite; see Garzanti et al, EPSL, 2010; 2011 and Garçon et al, Chemical Geology, 2014). This mineral phase would plot below the grey trend. Anyway, my point is that the intra-sample and inter-sample variability are not easily comparable. Trying to understand why bulk and clay are different may be interesting in the scope of the study.

3. Effect of weathering/leaching

At page 10, the authors speculate on the nature the leached mineral phases based on the REE element pattern of the bulk and residual fractions after leaching (Fig. 7b). My first point is that Sr and Nd are likely not hosted by the same mineral phases, so the authors should address the problem separately for Nd and Sr. Using REE patterns to investigate the carrier phases of leached Nd is OK but this is certainly not a good way for Sr. Secondly, the authors should take advantage of the major and trace element data (Table 1) they measured in the bulk and residual fractions. There, one can see that the residues contain much less CaO and Mn than the bulk phases. The loss of Ca could be linked to apatite or carbonate leaching but Mn is more difficult to explain, maybe more in favor of a leaching of Mn-oxides? The leaching experiment and the weathering effects are closely related together. I would discuss these two things in the same part of the discussion for more clarity. The section discussing weathering effect at page 7 is not clear and needs to be re-written anyway so maybe it would be better to merge it with the leaching section to explain that weathering, in particular the formation of secondary minerals, is responsible for some isotopic variability but cannot account for the large range of isotopic compositions measured in this study.

4. Seasonal variability

I would be more careful with the effects of seasonality. There are only two samples taken at different times of the year and they do not show a significant variability. For Nd, 20120618F and 20120726F could be slightly different but the difference is barely resolvable if an uncertainty of $\pm 0.6 \text{ } \epsilon\text{Nd}$ (2s) is considered, as suggested by the re-

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peated measurements of JNdi and the shale SCo-1. For Sr, the effect of seasonality seems to be bigger though.

4. Implications for Nd as a sediment source tracer (pages 11-12)

I generally agree with this section and I think it is a great idea to discuss the potential consequences of the re-organization of glaciers in catchment areas on short-time (annual) scales. However, the authors need to keep in mind that their studied area is pretty small and the bigger is the drained area, the more homogenous will be the composition of the exported sediments. Therefore, the global river exports from Svalbard to the oceans could be much more homogenous in composition than what they analyzed in this study. Also, this part of the discussion is a bit short and should be more developed/elaborated to strengthen the argument being made. Maybe the authors can try to model the worst-case scenario based on the Nd isotopic variability measured in this study, for example by quantifying by how much such a seasonal variability will change the relative source proportions in the study of Tütken et al. (2002)?

Technical comments

I found that Figure 1 was not enough detailed. I think you should add more information to help the lecturers understand the context of the study. First, I would enlarge the small map of Svalbard to show the different areas you mention in the text on Svalbard but also around (Central basin, Spritsbergen, Ny Friesland, Longyearbyen, Greenland, Arctic ocean, Uralides, Siberia, etc.). I'm not a specialist of the Arctic region and Svalbard and had to download several maps to be able to follow your discussion on the sources and the seawater composition, so a general map at the beginning would definitively help. Then, you should show the sampling locations of ALL samples in Figure 1. As it is now, it's unclear to me which ones are shown and why. Since the suspended sediments were taken from rivers, maybe you can also show the rivers on the figure.

More technical comments in the attached pdf version.

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Please also note the supplement to this comment:
<https://www.earth-surf-dynam-discuss.net/esurf-2017-55/esurf-2017-55-RC1-supplement.pdf>

Interactive comment on Earth Surf. Dynam. Discuss., <https://doi.org/10.5194/esurf-2017-55>, 2017.