Poeppelmeier et al biogeosciences June 2021

In view of the resurgence of interest in the marine Cr cycle in recent years, this is a timely study which highlights crucial gaps in knowledge and provides an important framework to guide further research. I recommend publication after considering the minor points I am raising below.

General comment:

One of the main conclusions derived from this study is that sediments are the most important source of Cr to the ocean. Since this source was previously considered to be minor, this is a very important finding. I think, however, that the significance of this finding could be further discussed.

First, it would be interesting to contrast the Cr mass balance and residence time obtained from this study and previous estimates. I note that while the residence estimated by the authors is in the lower range of previous estimates, it is still within this range. How come? Since a major new source has been identified in this study, shouldn't the resulting residence time be lower than the previously estimated range?

Second, when reporting residence times in a reservoir, we must define and justify the boundaries of this reservoir, and I think this is particularly important here. The residence time calculated in this study is based on the assumption that pore waters are a source of "new" Cr, similar to that added by rivers and dust. However, it is possible (likely?) that much of the pore water Cr diffusing to bottom water was scavenged from the water column and is being recycled. In which case it may be more appropriate to calculate residence time based on river/dust input only, which would match the burial rate of Cr in sediments. On the other hand, if much of the pore water Cr is derived from dissolution of lithogenics in sediments, then pore waters would be a source of new Cr, and the residence time calculated in this study would be unambiguously correct. At this point, we know little about the source of Cr in pore water, so this distinction is still difficult to make. However, I think it is important to bring this up in the discussion, considering that there has been a slow paradigm shift in recent years regarding the importance of lithogenic dissolution in sediments as a source of elements to the ocean (in particular for Nd (e.g. Abbott et al., GCA 154, 186, 2015) but also other elements (e.g. Jeandel and Oelkers, Chem Geol 395, 50, 2015)). Whether pore water Cr is "new" or "recycled" can be assessed from the shape of the pore water profiles. Pore water Cr concentration would gradually increase with depth in the sediment if the Cr is "new". Recycled Cr would produce a surficial or subsurface pore water Cr maximum. Clearly, the pore water profile reported by Janssen et al (2021) is of the latter type, and so are the pore water profiles from the California Borderland reported by Shaw et al (1990) [which I think should also be brought in the discussion; GCA, 54, 1233]. However, these pore water profiles generate fluxes that are much higher than needed to match model results with the existing water column profiles, and therefore cannot be representative of the whole ocean, as indicated by the authors. Whether the needed lower Cr fluxes reflect the slow dissolution of lithogenics producing pore water profile of the former type (i.e. gradually increasing with depth) over large area of the ocean floor (presumably in low productivity regions) is an open question, which could be asked explicitly in this paper.

Detailed comments

Line 44: "Cr(III) accounts for the majority of total dissolved Cr in OMZ.." vs line 47-48 "subsurface Cr(III) concentrations are substantially lower than Cr(VI) concentrations typically ranging 0 and 0.3 nM".

These two statement are not consistent

Line 110: "..rivers showing strong anthropogenic contamination were removed (supplementary data 1)"

It is not clear how the selection was done from this spreadsheet.

Line 120/130; equation (5)/(7): What is V(θ,ϕ)/ V(θ,ϕ, z)? Is this the volume of the grid in the model receiving the river inflow and pore water efflux? (also, for the sake of non-modelers like me, indicate somewhere that (θ,ϕ) simply represents latitude and longitude)

Table 1 Caption: Indicate that references/justifications for the values given to these variables are discussed (mostly) in the text. Make sure that you justify or reference all of them. Also, adding references in this table would help.

Line 240; Fig. 2: It would help the reader if you use a different color to highlight the runs with the best fit, which are associated with benthic fluxes of 0.1 – 0.2 nmol/cm2.y and residence times of 5 – 8 kyrs. It must be obvious to the authors but it took me a while to figure out what I was supposed to look at in Fig. 2.

Line 293: It is probably a simple wording issue, but what "deficit" are we talking about here? The model overestimates Cr concentration in the Arctic.

First reference in the text to Fig. 6 is on line 426, after Fig. 7 and 8 have been referred to.

Line 345: the actual Cr sink is the sediment in contact with the OMZ, right? Not the OMZ in the water column. CrIII produced in the OMZ could be scavenged and re-oxidized deeper in the water column.

Line 347: Probably another wording issue. "below the OMZ" to me means in water deeper than the OMZ, but I think the authors mean Cr removal happens in the sediment in contact with ("below") the OMZ.

Line 348: "Cr(III) concentration are partly in disagreement with observed Cr(III)" How is the reader supposed to see this? Can you add a figure or provide the concentrations in the model vs observations? I find this entire paragraph difficult to follow.

Line 371: Again, give the value or range of values observed.