Response to the reviewers

We thank both reviewers for their positive and constructive remarks. Below we address each of the points of reviewer 1 and show how we adapted the manuscript accordingly. These and other small changes to the manuscript are also indicated in red in the updated version of the manuscript.

Host rocks are indeed more widespread than source rock in all simulations (compare host rock over time plots below in Fig. R1 with the plots in Fig. 5). That said, the majority of host rocks are found in the wide continental margins without active faults that formed by rift migration in narrow asymmetric and wide rifts, and there are basins with source rock without host rocks. The latter mostly occurs 1) when marine sediments which were previously cold enough to act as host rocks are heated up upon burial in the border basin, which closes the mineralization window, 2) after rift migration has stopped and, thus, faults in the border basin have become inactive, which also closes the mineralization window, or 3) during active faulting in the rift

centre. These cases are exemplified by the smaller amount of orange than red bars in Fig. 6 (although these bars do not necessarily represent the same timestep). Therefore, suitable host rock does act as a limiting factor. The focus of Fig. 5 lies on source rock area as it is less widespread and determines the size of the potential deposit, and the size of the host rock area is less important than its presence, as you also recognize in your next point.

We think adding the count of basins with host rock only will make it harder to get the message of Fig. 6 across, as it will require increasing the upper limit of the y-axis. We have however added the following statement to the main text (starting line 422):

Note that there are also basins with host rocks and active faults but no source rocks (e.g., Figure 5a at 15 My) and basins with only host rocks and inactive faults (e.g., border basin in Figure 3i and in all wide margins). These cases are however not represented in Figure 7, as they do not have a potential metal source and can therefore not be a site of mineralization.
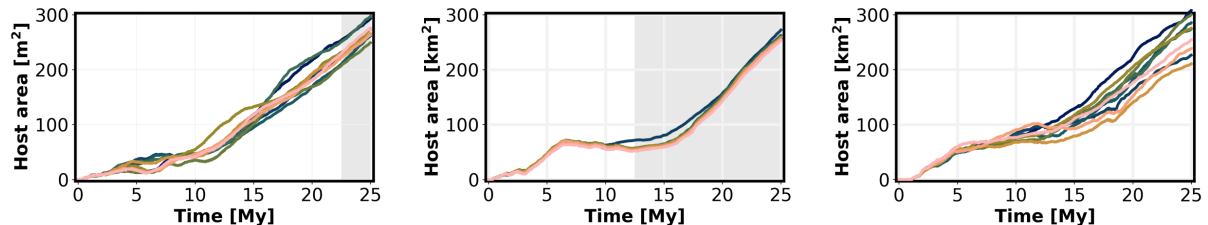

Figure R1 Host rock area over time for narrow asymmetric, narrow symmetric and wide rift simulations. Grey shading indicates the start of oceanic spreading.

Related to this point, do we actually want widespread host rocks? Local ones that are in the vicinity of the brine conduits are probably all we need to concentrate metals into a viable deposit. Having them widespread has the potential to result in metals precipitating in lower concentrations over larger areas, depending on the particular hydrothermal circulation pathways.

The host rocks provide a key ingredient for ore formation, i.e., an abundant source of reduced sulfur. We agree that *widespread* host rocks are not required. However, in the geological record it is clear that mudstones are ubiquitous in most basins worldwide, and yet large Zn deposits are rare. This points to the importance of a focussing mechanism of the fluids towards the host rock. We regard fluid focusing through active or inactive fault structures as one of the key parameters in our analysis, because it may help avoid widespread disseminated mineralization at low grades within the abundant host rock units.

We would also like to note that with increased marine sedimentation rate, not only does the modelled amount of host rock become more widespread, but the amount of source rock also increases (see Section 3.4.1), in turn increasing the potential for metallogenesis.

We have added the following to the Methods section 2.4 (line 206) to highlight the focussing effect of faults:

*Fault activity (e.g., seismic pumping and pulsing and fault valving) and passive upward flow then bring the fluids to the surface (Walsh et al., 2018), **mechanisms that focus the fluids and concentrate the metals in the host rock.***

In the Abstract (line 23) and PLS (line 31-32), we added:

*… and 4) the generation of smaller faults that cut the major basin created by the border fault and provide additional pathways **for focussed fluid flow** from source to host rock.*

*We use computer simulations of rifting and the associated erosion and deposition of sediments to understand why they formed in some basins, but not in others. **In particular, we look for basins that combine metal source rocks, faults that focus fluid flow and rocks that can host deposits.***

I realise that these models do not include melting and it is therefore prudent to not overly speculate on this aspect, but I wonder if they might also provide insights on the potential for generating mafic volcanism? These rocks often act as a source of Zn and particularly Cu, such as the Eastern Creek Volcanics at Mount Isa. Given that the locations and strength of mantle upwelling is modelled, we can infer where in the model domain the solidus is most likely to be crossed. It strikes me that the narrow asymmetric margin more often has a focused mantle upwelling in its vicinity than other margins in the various models? They may therefore be more susceptible to generating volcanic rocks, which would be another potential strength of this particular geodynamic setting.

Indeed, our simulations do not include melting and represent magma-poor rifts. As you suggested, we computed the degree of melting in a narrow asymmetric rift simulation based on a linear interpolation of the melt fraction between a solidus and liquidus of Katz et al. (2003). As shown in Fig. R2 at 20 My, the melt fraction is highest in the asthenosphere underneath the narrow asymmetric margin during rift migration. If we vertically integrate the melt fraction, we estimate melts could generate a magmatic layer of up to 1.5 km thickness (e.g., Brune et al., 2014). Only some part of this melt would intrude the basement or sedimentary sequence.
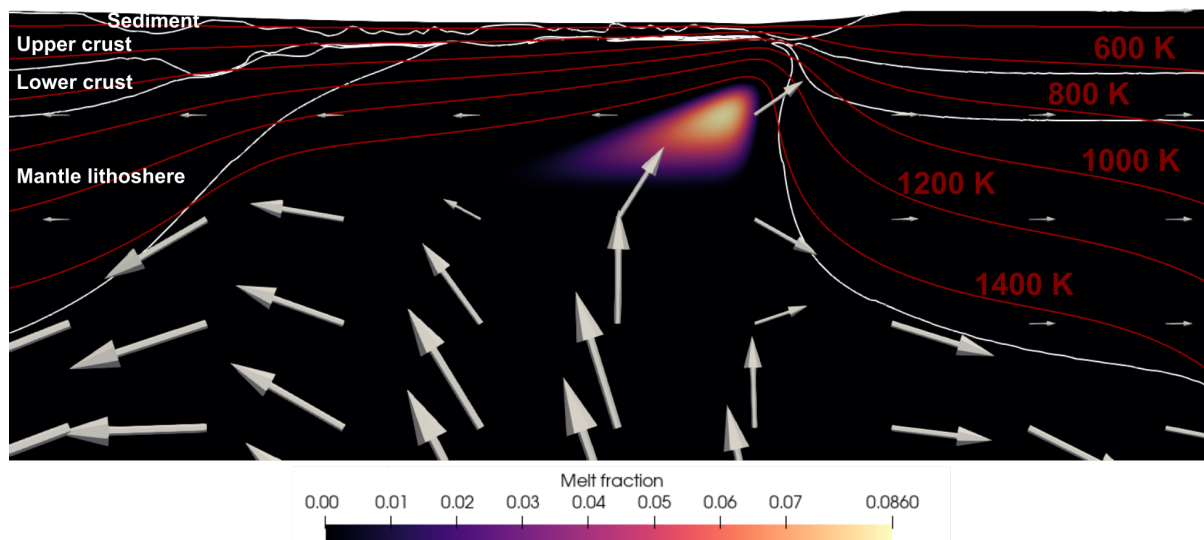
Figure R2 Melt fraction at the time of ore formation mechanism 1 (20 My) for whole model domain (bottom) and zoom-in (top) for narrow-asymmetric rifting simulation NA-4.

A further potential benefit of the narrow-margin setting would be proximity of source and host rocks to the adjacent continental platform. This architecture would seem to be ideal for the "brine factory" ideas of Manning & Emsbo (2018) and others – i.e. potential for a nearby evaporative platform to generate brines and a hydrological head to drive them down into the basin.

Thank you for this suggestion. We have added the brine reflux flow system hypothesis of Manning and Emsbo (2018) to the Discussion where we discuss other evidence for metallogenesis close to shore in Section 4.2 (line 588):

For example, high salinity fluids derived from seawater evaporation along the basin margin are preserved in fluid inclusions in some locations (Banks et al., 2002; Leach et al., 2004), ***inspiring the hypothesis of a platform "brine factory" (e.g., Leach et al., 2010).***

…

Line 598 onwards:

Modelling of the brine reflux system by Manning and Emsbo (2018) shows that evaporated seawater generated on a carbonate platform (the brine factory) can form ore fluids of the required salinity and temperature that sink into the platform, flow oceanward and discharge along faults to the nearby ocean floor.

Please forgive the personal bias, but one of the interpretations we made in Hoggard et al. (2020) was that large clastic-dominated base metal deposits are all located in basins that occur on cratonic margins. The models in this study are all run using regular, Phanerozoic-style (ie. thin) lithosphere as the starting template. It may be that you don't agree with the craton story, but I'd be interested to hear your take on

which aspects of the narrow-margin fertility might translate well to a potential extensional setting on the edge of thick lithosphere? In addition, which aspects of your model results might change if they were run using thicker, potentially depleted lithosphere? For example, I would guess that the basal heat flow would be lower and it would be trickier to get the source rocks into your desired temperature window? At the same time, the solubility of Zn and Pb in brines is still high at lower temperatures, as long as they are oxidised, so I don't think it would matter much.

We were actually very intrigued by your 2020 study. Our approach has been to investigate the controls on mineralization with models of continental rifting of normal continental lithosphere and then to run a second suite of simulations in the presence of a craton, to fully explore the possible craton effects. The latter results warrant a separate publication, but we can say that a craton very close to the initial rift centre determines the direction of rift migration (conform Raghuram et al., 2023) and, therefore, affects the potential of the border basins for metallogenesis.

We have added the following sentence to the Discussion (section 4.2) to point out this important direction of future research (line 579):

Future modelling should also investigate the role of thick, cold cratonic lithosphere (e.g., Raghuram et al., 2023; Gouiza and Naliboff, 2021) in promoting the formation and/or preservation of CD-type deposits, as Hoggard et al. (2020) *(and Groves and Santosh, 2021; Lawley et al., 2022; Huston et al., 2022) found a correlation between deposit location and the edges of thick and/or cratonic lithosphere.*

Some specific comments:

The Plain Language Summary makes mention of the 3 Myr maximum extent for mineralisation, but this fact is not listed in the abstract. It seems potentially important enough to mention somewhere in there too?

Good point. We have added it to the abstract as follows (line 15):

We show that the largest potential metal endowment can be expected in narrow asymmetric rifts, **where the mineralization window spans about 1-3 My in the upper ~4 km of the sedimentary infill close to shore**.

Mccuaig should be McCuaig throughout.

Thank you, we have fixed the capitalization throughout.

Just checking - is the sand and silt porosity set to zero, as suggested in Table 1? I only ask because I think that renders the e-folding depths redundant.

That is correct, the sand and silt porosity are set to zero and therefore the e-folding depth has no effect. I have removed the mention of e-folding depth from line 183 of section 2.3 and from Table 1.

Lines 294-295: Qualify that the "geotherm and adiabat *temperatures* match".

We have changed the line to

*... such that at the LAB the geotherm and adiabat **temperatures** match **(at 1350 °C)**.*

Line 326: Typo "inhered" → "inherited"?

Thank you for spotting this typo.

Figs 3, 7 and 8: Add a simple label above panels stating the model type (e.g. "Narrow Asymmetric Rift") to ease quick comparison.

We have labelled the figures with their respective rift type.

Figure 4: I found the panels for ore formation mechanisms 2 and 3 a bit small – the first one is better. I also wonder if you could potentially reverse the domain for model NA-9 to make comparison and contrast to NA-4 easier (i.e. have all the rifts migrating in the same direction)?

We agree. I have split Figure 4 into two separate figures, one for mechanism 1 and one for mechanism 2 and 3. I have also mirrored the figures for model NA-9 so that the narrow margin also occurs on the right-hand-side of the model domain.

Figure and text order: Potentially move Figures 7 and 8 ahead of 5 and 6, so a reader sees all the model results prior to the scenario comparison figures. Lines 410-415, Figures 5 and 6 would then naturally fall under a separate subsection after 3.3 called something like "Optimal characteristics for mineralisation" or similar.

Thank you for the suggestion; we have however refrained from reordering the figures and text to keep the flow of the text and to pique the reader's interest earlier on.

There currently is no Section 3.4.

Thank you, we have corrected the numbering.

Line 455: typo "at in".

We have fixed it to "in".

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