A magnesium budget for serpentinisation of abyssal peridotite during the Cenozoic

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Snow and Dick (1995) suggested that the depletion in MgO in serpentinised peridotites (Fig. 1) could deliver large fluxes (up to 80% of the riverine flux) of Mg to oceans.

Many subsequent studies invoke this hypothesis to explain Mg depletion, but few have quantitatively explored it, either petrologically, geochemically or tectonically.

We present a preliminary tectonic model to determine:

(i) Whether this flux could be a potential significant source of Mg to oceans.

(ii) If so, what possible impact this flux could have on ocean chemistry.

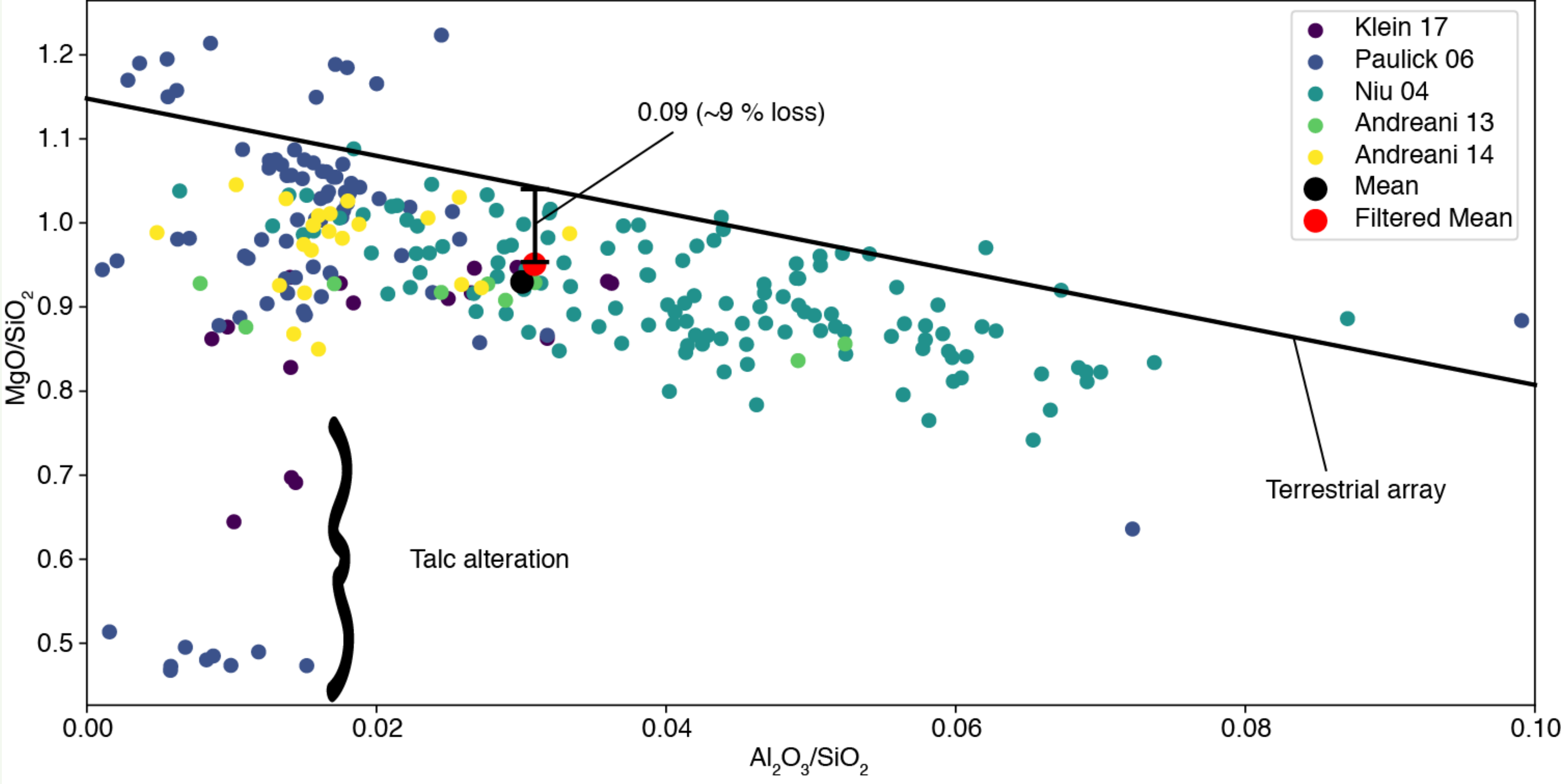

Figure 1

Scatter plot from studies on whole rock oxide data from abyssal serpentinised peridotites. Talc alteration has occurred and been identified in some samples in some studies, but has not been invoked in other studies (either unmentioned, explicitly not observed, or not identifiable in thin section images provided in publications). There is mean ~9 % loss in MgO from the terrestrial array.

Recent work has developed parameterised models of possible serpentinite thickness at mid-ocean ridges, and then traced their kinematic motion away from the ridge as the system continues to evolve (Merdith et al., 2019; 2020; Fig. 2a).

This (along with age grids of seafloor) provides a time-sensitive approach for interrogating an estimate of the volumetric distribution of abyssal serpentinite (and then MgO wt%) in ocean basins.

We assume (as a first step) for this analysis that only ~20% of available serpentinised peridotite is available for off-axis hydrothermal fluids (i.e. max seafloor weathering depth is ~500–600 m below seafloor).

Figure 2 shows the data at present-day. For this analysis we use the appropriate grids for each timestep back to 100 Ma.

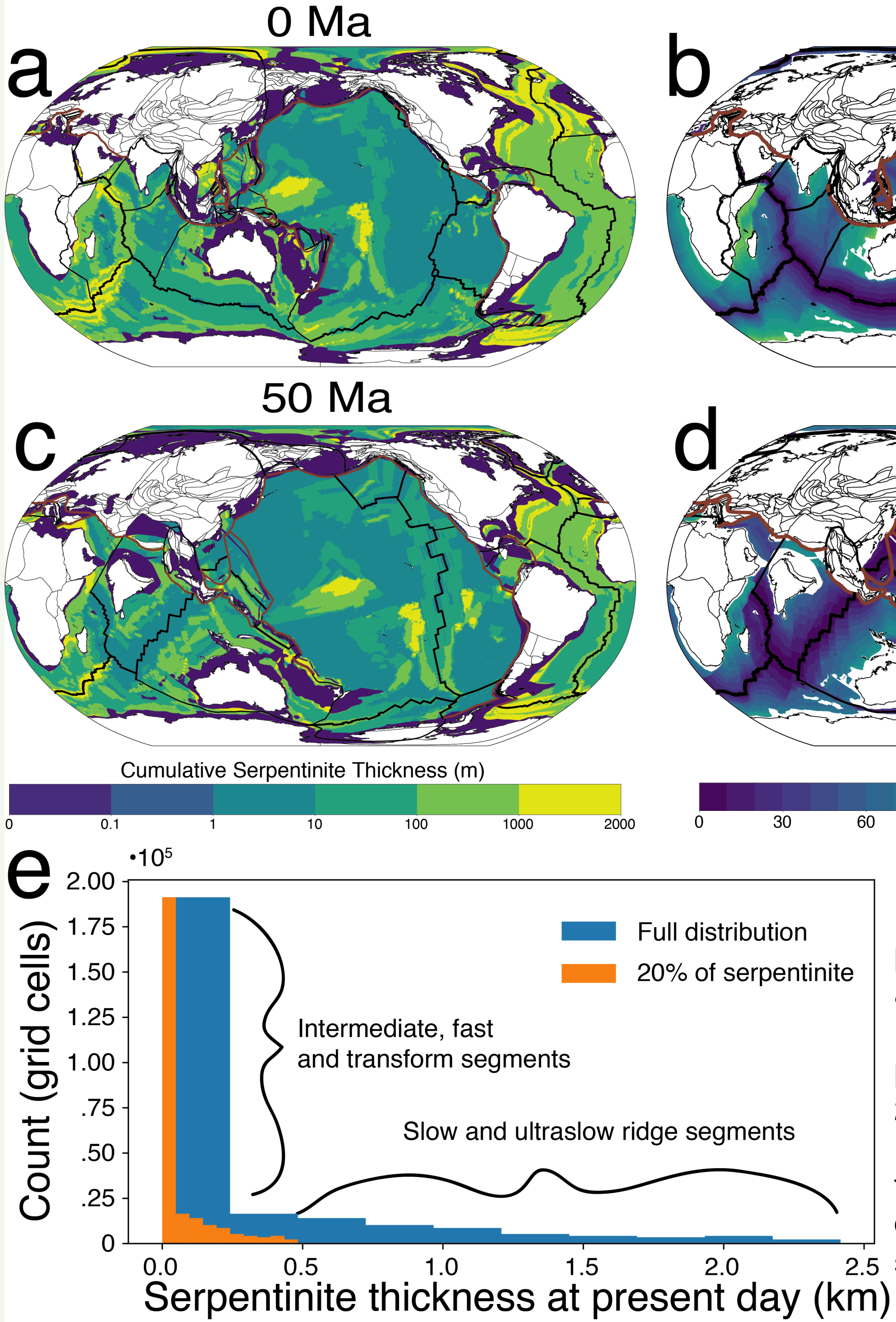

Figure 2
(a, c) Serpentinite thickness at present-day and 50 Ma (Merdith et al. 2019).
(b, d) Age grids of ocean basins at present-day and 50 Ma (Müller et al. 2016).
(e) Distribution of serpentinite thickness from (a). Orange distribution assumes only 20% of serpentinite is available for Mg loss.

At each time step (starting at t=100 Ma) of our analysis we:

1) Define our ages of weathering in terms of seafloor age at time, t (weathering ages = 1,2,…21)
2) Use age grids (e.g. Fig. 2b) to define area of seafloor at each weathering age for each time t
3) Use corresponding serpentinite grid (e.g. Fig. 2a) to extract serpentinite thickness of each weathering age
4) Calculate volume of serpentinite at each weathering age (using age area of seafloor and thickness of serpentinite of seafloor at that age)
5) Calculate available serpentinite volume (Fig. 2c, orange) → serpentinite mass → MgO mass (using 37 wt% MgO) → MgO loss (10% and 5% incrementally over 20 Ma) → Mg moles → sum results per timestep (Fig. 3)

The peak at ca. 80–50 Ma is due to the opening of the ultraslow–slow spreading North Atlantic and Labrador Sea (e.g. Seton et al. 2012).

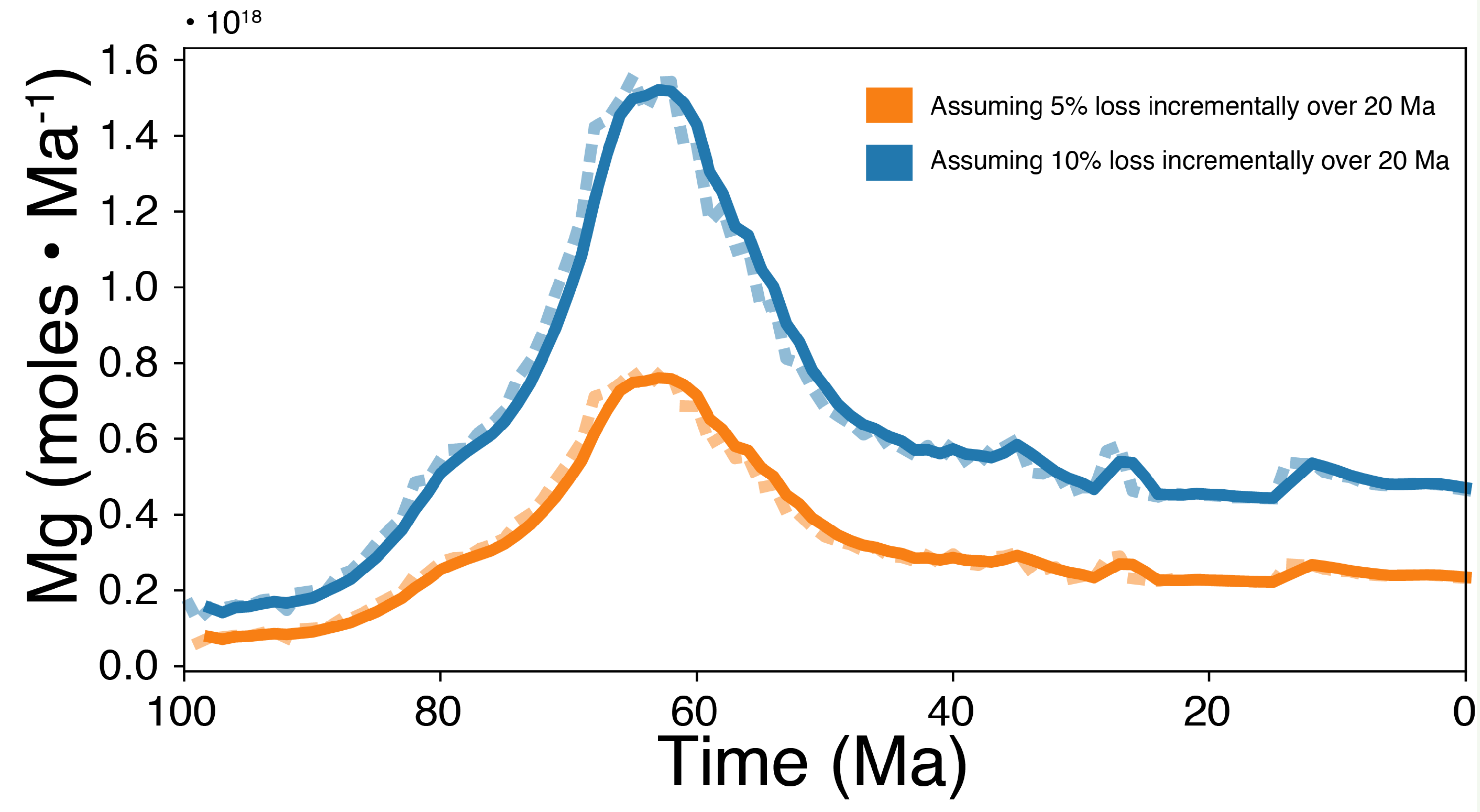

Figure 3

Possible Mg loss from serpentinised peridotite since 100 Ma assuming 5% and 10% loss incrementally over 20 Ma (i.e. 0.25% and 0.50% loss from serpentinite per 1 Ma \respectively). Solid lines are a running mean (window 3 Ma), dashed lines are raw results. Riverine flux is 5–6 • $10^{12(18)}$ mol/a(Ma). Uncertainty on serpentinite thickness is not yet considered (future steps).

Next steps:

We have a gross tectonic estimate of what Mg could be lost from seafloor weathering. We now want to supplement and compare it with (some combination) of fluid and rock data collected from ocean basins.

We calculate the fluid flux of seawater circulating through off-axis oceanic crust per seafloor age step (Fig. 4a–d).

We would like to combine Fig. 4d with Figs. 2a, c. This would give us fluid flux through serpentinite and then use geological and fluid vent data to better constrain possible motion of some elements (Mg, Ca etc.).

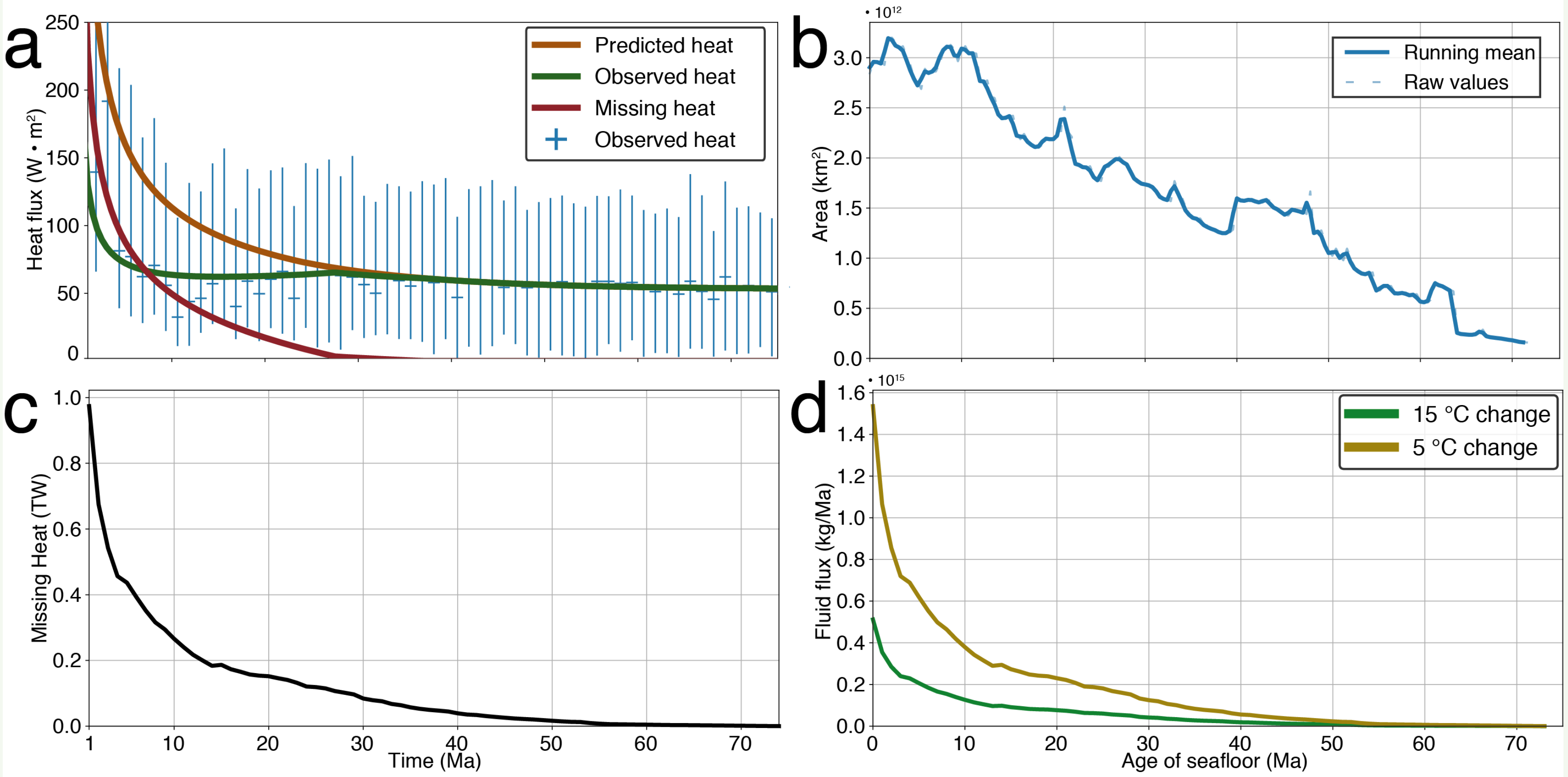

Figure 4

Calculating fluid flux through ocean crust based on age. These four figures are based on work done by Hasterok (2013a; b) and Coogan and Gillis (2018). (a) Heat flux in ocean basins (observed, predicted and missing). (b) seafloor age distribution at present day. (c) Total missing heat per age of seafloor (i.e. combine (a) and (b)). (d) Necessary seawater flux cycling through ocean crust to balance missing heat, assuming either 5 or 15 °C warming.

References

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