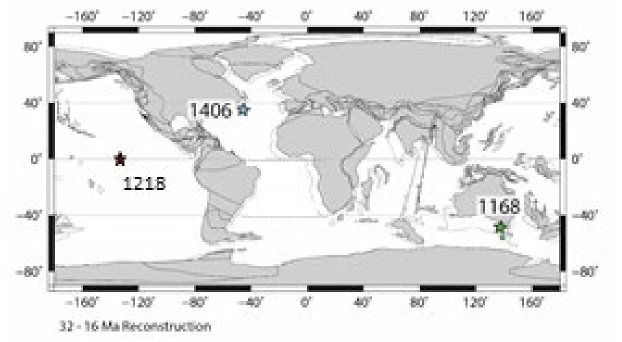
We thank Prof. Derry for the attentive reading and many constructive suggestions to clarify the paper including a deeper representation of the contrasting ocean response times of Sr isotopes and oxygen isotopes. Author response to community comment by L. Derry. Reviewer comments in black, response in violet and quotations from revised text in blue.

CC

This ms presents new 87Sr/86Sr data from the period of rapid rise in in the isotopic composition of Sr dung the late Oligocene to early Miocene. The innovation is using a common orbitally tuned age model (CENOGRID) for the ODP core samples. The improved precision of the CENOGRID age model allows the authors to recognize additional “fine” structure in the overall increasing 87Sr/86S6 signal through interval from about 32 to 19 Ma. The apparently higher sedimentation rate at Site 1218 allows more detail to emerge that at sites U1406 and 1168. Nevertheless correlation with the Sr isotope data improves the age model for those sites as well. It also provides an improved correlation between the Sr and benthic oxygen isotope records. All this seems to be well documented and straightforward, and is a useful refinement. It should be possible to extend this approach to the high resolution data in Oslick 1994, for example.

It would be helpful to have lat-lon-depth at minimum for the three sites. Most of us don’t have a ODP site map in our head.

We appreciate the suggestion to provide a site map also made by reviewer 1 and will add this to the revision. The latitude-longitude coordinates and depths for the three ODP sites were provided in the methods subsection titled Sediments.



Location of sites investigated in this study. Reconstructions using the plate tectonic reconstruction service ODSN (www.odsn.de).

There is a sedimentation rate curve for U1406 and 1168 – why not also 1218?

We have provided sedimentation rate plots for the sites in which a new age model is provided here via Sr isotope stratigraphy (U1406 and 1168). We do not illustrate the sedimentation rate for the site for which we employ a previously published age model based on astrochronology (ODP 1218). The sedimentation rate from ODP 1218 was published in Supplementary Figure S2 in Palike et al., 2006.

While not necessary here, the uncertainties on 87Sr/86Sr could be improved by up to a factor of 2 by using modern TIMS in place of ICPMS.

We thank the Prof. Derry for pointing out the higher precision of TIMS which may be useful to consider in future studies.

There is some discussion of the potential link between Antarctic glaciation and variations in SW 87Sr/86Sr based on the observation that changes in the rate of 87Sr/86Sr are related to climate events recorded in d18O. It's much harder to constrain the drivers of 87Sr/86Sr in this interval as there are multiple potential drives. The apparent correlation with benthic d18O signal could reflect glacial influence on weathering in Antarctic as they propose, and they also note that climate shifts could influence the position of the ITCZ and this impact rainfall pattern in areas that could change the Sr flux or its isotope composition. Changes in precipitation (and glaciation in high altitude zones) could also occur the beyond the polar and ITCZ-impacted regions. A further potential player is the unroofing of highly radiogenic sources rocks in the Himalaya at this time (Galy et al 1999 *Tectonophysics*). The detailed timing and impact of this unroofing is not known with sufficient accuracy to assign to particular changes in slope occurring in < 1 Myr reported here, but may well be playing a major role on the overall rapid increase (Myrow et al 2016 *EPSL*). There are also known changes in the 87/86 ratio of rivers draing NE Tibet in this interval (Yang et al. 2022 *GSAB*). The combined range of potential climate and tectonic/geologic factors makes it difficult to move beyond a somewhat speculative statement here. While there is nothing "wrong" about the discussion of possible contributions from radiogenic rocks in Antarctica, or changes in weathering of the Deccan flood basalts, or other mechanisms, there is nothing particularly convincing about any of this either.

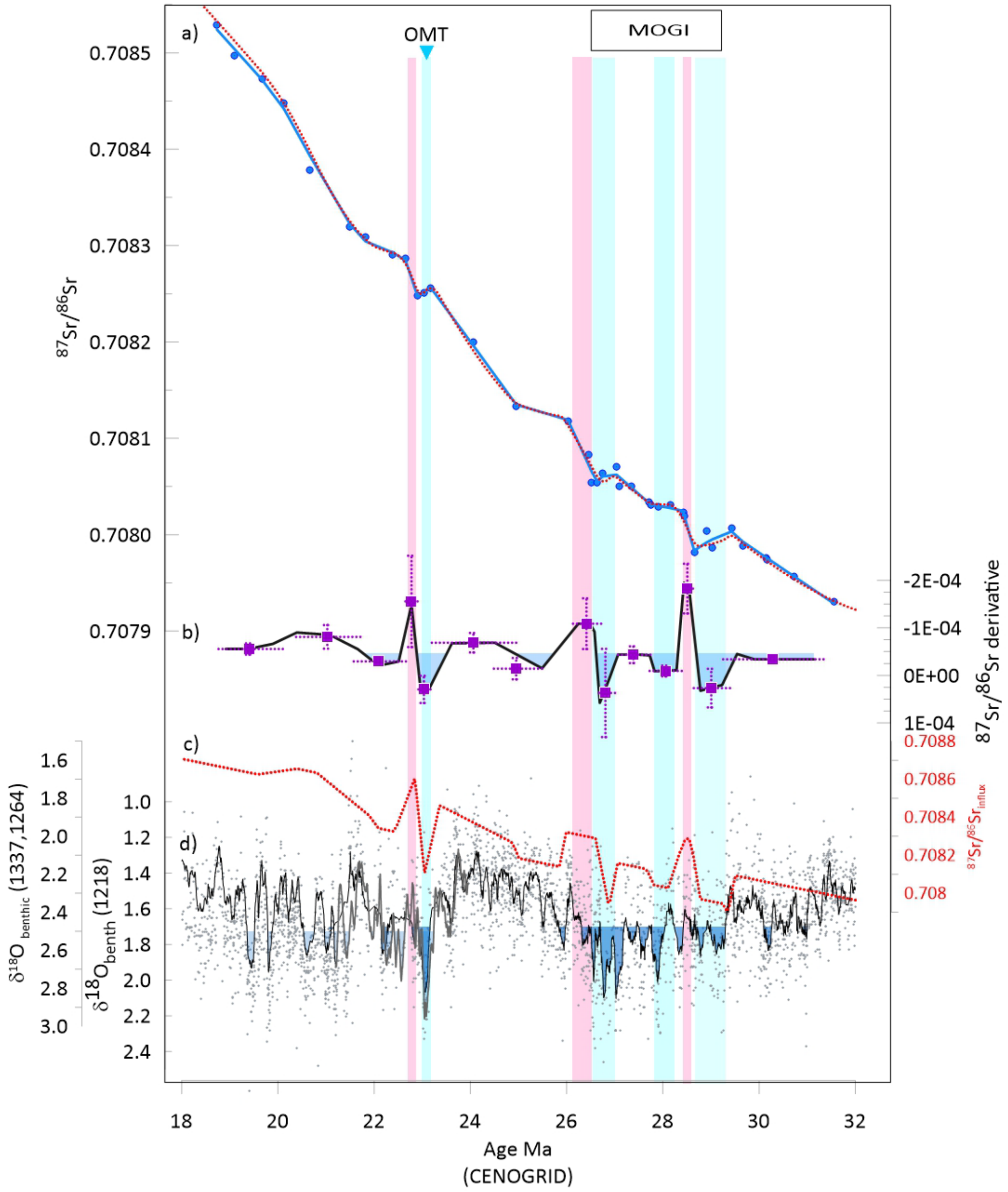
We appreciate the suggestion of additional references relating to the tectonic processes affecting the exposure of highly radiogenic bedrocks which may contribute to the overall rapid increase in the 87Sr/86Sr ratio of the Oligocene, and propose to include these in the introduction.

It's worth keeping in mind that the oceanic residence time of Sr is ≈ 3 Myr, much longer than for O, so the response time scales are quite different (e.g. Richter and Turekian, 1993). If d18O is responding to a climate driver the 87Sr/86Sr response will be lagged and damped significantly. It's not that easy to get d(87/86)/dt rates up to 2x10^{-4} per Myr as they propose for an interval just after 29 Ma, that would require large and rapid fluctuations in the input of Sr and it's isotopic composition. Before taking these short term variations as gospel it would be worth doing a calculation to see what kind of weathering input variations are necessary to drive such sharp changes.

We appreciate Prof. Derry's suggestion to illustrate more clearly the implications of different ocean response times of oxygen isotopes and Sr isotopes (eg the attenuation of the input forcing by the long residence time of Sr), which we had previously mentioned only in the text. We fully agree that rapid short term changes in the ocean 87Sr/86Sr ratio require large changes in fluxes and or isotopic compositions. An ocean box model can be used to simulate the effect of the long residence time on the phasing of the forcing. As Prof. Derry mentioned previously, the Sr cycle of the Oligocene is underconstrained, so we do not propose that a unique inverse solution (e.g. weathering flux or its isotopic ratio) can be attained from the present data. As an example, we propose to illustrate in a supplemental figure, for a 2.5 Ma residence time (Hodell et al., 1990), the required changes in isotopic composition of the Sr influx to the ocean which would be needed to match the observed high frequency changes in the ocean 87Sr/86Sr ratio. We note that some studies suggest a shorter residence time in the Oligocene (Paytan et al., 2021), which would require less extreme forcing to simulate the variations. We hope that these examples elucidate more clearly the relationship between Sr isotope forcing and the climate variations and stimulate future work.

We propose to add three sentences to the discussion of this process (new sentences in bold):

In either case, the long residence time of Sr in the ocean would result in lags between onset of elevated fluxes and peak response in ocean chemistry and would cause significant attenuation of the time-varying input signal. **An example of the phasing and amplitude variation in the ^{87}Sr/^{86}Sr of the Sr influx which could yield the observed trends in marine ^{87}Sr/^{86}Sr is illustrated in Supplementary Figure 1, for a sample residence time of 2.5 million years as suggested by Hodell et al., 1990. A shorter residence time has been proposed for the Oligocene by Paytan et al., (2021); for a shorter residence time, a less extreme forcing would be required to simulate our observations. We caution that because the Sr isotopic system of the Oligocene to Early Miocene is underconstrained, the observations of oceanic ^{87}Sr/^{86}Sr do not provide a unique solution for the variation in fluxes and/or their isotopic composition.**



Supplementary Figure illustrating the response time of variation in Sr influxes in relation to benthic δ^{18}O. a) Measured Site 1218 ^{87}Sr/^{86}Sr (symbols) and the smoothed fit from local linear regression (blue line) as well as a model fit to the curve (dashed red line) forced as illustrated in panel d). b) the derivative of the smoothed fit (black line) and the slope of each linear segment (purple square), together with the 1σ uncertainty on the slope (vertical error bar, 68% confidence interval) and the age range of the local linear fit (horizontal bar). Shading indicates sectors in which ^{87}Sr/^{86}Sr rises more slowly than the average rate over 32 to 18 Ma. c) Modeled changes in the Sr isotope ratio of the influx albe to generate the red dashed curve illustrated in panel a) using a single ocean box with a residence time of 2.5 million years (Hodell et al., 1990) for an oceanic Sr concentration of 87µM, and constant influx and outflux. d) Benthic δ^{18}O measurements (gray points) and lines showing 20 point running mean, as illustrated in Figure 3, from (Pälike et al., 2006) (Holbourn et al., 2015) and (Westerhold et al., 2020). All data are plotted on the orbitally tuned CENOGRID timescale(Westerhold et al., 2020) with shading and time intervals of interest as in Figure 3.

Overall this is a paper that shod be published with modest changes. In my view the most important changes needed are to take a more cautious approach to proposing drivers for the short term isotopic variability.

Louis Derry

References in the response

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