TECHNICAL RESPONSE

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Response to Comment on "Sensitivity of seafloor bathymetry to climate-driven fluctuations in mid-ocean ridge magma supply"

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Tolstoy reports the existence of a characteristic 100 thousand year (ky) period in the bathymetry of fast-spreading seafloor but does not argue that sea level change is a first-order control on seafloor morphology worldwide. Upon evaluating the overlap between tectonic and Milankovitch periodicities across spreading rates, we reemphasize that fast-spreading ridges are the best potential recorders of a sea level signature in seafloor bathymetry.

We acknowledge the clear distinction made by Tolstoy (*1*) between the ideas put forward in (*2*) and the hypothesis central to (*3*). In (*3*), it is proposed that seafloor relief is caused primarily by changes in the height of volcanic constructions on Milankovich time scales, which reflect a control of sea level cycles on mid-ocean ridge (MOR) magma supply. Meanwhile, (*1*, *2*) point out that seafloor eruption rates may be extremely sensitive to small external perturbations such as orbital stresses. In particular, they suggest that—in addition to sea level cycles modulating overall MOR magma supply—eccentricity cycles may modulate rates of volcanic extrusion on the seafloor. A 100-thousand-year (ky) characteristic periodicity in the bathymetry of the fast-spreading Southern East Pacific Rise (SEPR) is presented to support this idea. In (*2*), however, Tolstoy does not imply that such processes are the primary cause for the abyssal hill fabric of global seafloor, which was the focus of our initial study (*4*).

A characteristic periodicity of 100 ky at the SEPR, with a full spreading rate of 14.7 cm/year, translates into a seafloor length scale of 7.4 km, which is considerably larger than the characteristic ~1- to 3-km spacing of normal faults measured at fast-spreading ridges (*5*, *6*). The biggest tectonic scarps (~50 m) in such settings correspond to axis facing faults that accommodate the small fraction of plate separation not taken up by crustal emplacement (*7*, *8*). Additional, more closely spaced faults form in response to flexural stresses as the lithosphere migrates away from the axial high, but these generally produce smaller scarps (≤20 m) (*5*, *9*–*11*). Overall, the spectral signature of the tectonic fabric of fast-spreading seafloor should consist of several distributed peaks at periodicities near and below ~40 ky (Fig. 1). Such peaks are present in the bathymetric spectrum of the SEPR but are much less energetic than the 100-ky peak (*2*). This 100-ky peak could therefore be the signature of a periodic (but nontectonic) process capable of creating coherent relief on top of the fault-induced fabric.

Based on these observations of fault geometry and distribution, our models suggest that topography-building processes at MORs act as low-pass filters—they only record fluctuations in melt supply on time scales longer than the cutoff period set by intrinsic properties of the lithosphere and magmatic accretion zone. Tolstoy rightfully points out that this cutoff period generally decreases with spreading rate, making fast-spreading ridges the best candidates to efficiently record a climatic modulation in seafloor bathymetry. Our models for volcanic extrusion specifically predict that a 10% modulation in magma supply over a 100-ky period could lead to ~50 m of relief at the SEPR, provided that the off-axis extent of lava flows remains limited. This relief would be on the order of the tectonic relief, although further modeling is needed to determine whether this modulation is sufficient to overshadow the tectonic signal in the Fourier domain.

Tolstoy proposes additional sources of relief beyond a modulation of volcanic constructions. In particular, regular episodes of summit trough collapse after periods of frequent eruptions (and associated drainage of the axial melt lens) could periodically imprint vertical offsets in seafloor bathymetry, potentially as high as ~50 m (*12*). We consider this process more plausible than a magmatic modulation of the growth of stretching faults, which would require fluctuations in magma supply an order of magnitude greater than those expected from the effect of sea level cycles (*4*, *8*). In fact, it is noteworthy that while faster-spreading ridges should constitute the most efficient topographic recorder of climate-related fluctuations in magma supply, the associated faster mantle upwelling rates are expected to damp the relative amplitude of this fluctuation (*3*). This is because the modulation in crustal production roughly scales as the upwelling rate plus the sea level–induced mantle decompression rate, normalized by the spreading rate (*13*).

Finally, we reemphasize that the complexity of the bathymetric signal should motivate additional observations that are more readily interpretable in terms of MOR magma supply. For example, oscillations in the topography of the crust-mantle boundary on 7-km length scales should be resolvable by modern multichannel seismic imaging and could be unambiguously linked to 100-ky fluctuations in crustal production at fast-spreading ridges.

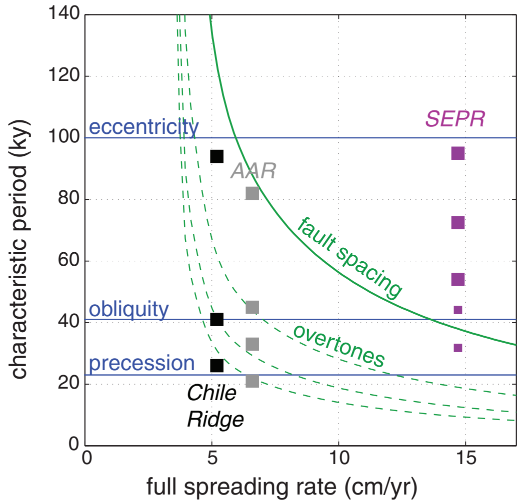

Fig. 1. A global seafloor spectrogram. Period of the strongest peaks in published spectra of seafloor bathymetry plotted against full spreading rate. Data come from cross-axis bathymetry spectra at the Australian-Antarctic Ridge (AAR), gray squares (*3*); Chile Ridge (CR), black squares (*14*); and the SEPR, purple squares (*2*), with two additional small squares showing small-amplitude peaks at ~30 and 44 ky). The solid green curve marks the characteristic period corresponding to the dominant fault spacing, as predicted by models that closely fit the global trend of abyssal hill spacing [green curve in figure 3A in (*4*)]. Dashed green curves indicate overtones of the dominant fault periodicity that may arise in the frequency domain (*15*). Milankovitch periodicities are reported as horizontal blue lines.

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