Solid Earth Discussions

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Reply on RC2

Vincent Famin et al.

Author comment on "Deformation-enhanced diagenesis and bacterial proliferation in the Nankai accretionary prism" by Vincent Famin et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-54-AC2, 2021

The reviewer's comments are recalled hereafter with numbers, and our response is added below each comment:

1. The finding presented are quite compelling. The changes in chemistry and mineralogy between mm-scale deformation structures and matrix are suggestive of fundamental processes that seem to link biology and strain localization. The number of samples that have provided the key findings is very limited, reflecting the exacting work and the very small supply of core material. A broader discussion of the context would highlight additional implications that might be worthwhile to motivate work aimed at reproducing the findings and scaling up the applicability. A couple are presented here for consideration. Site C0001 is in the footwall of a megasplay fault that is crosscut by a slope basin or mass-transport deposit. It is also in the hangingwall of other out-of-sequence thrust faults. The structural setting of the 3.5-5.5 Ma sediments examined could be mechanically connected to either or both of these structures, but the constraints provided in the manuscript suggest that the structures were formed prior to the emplacement of these faults. Is the timing well constrained? If the dewatering is exclusively burial-related (consistent with the fact that the shear zones record normal motion), the link to more mature faults is more of a stretch. Is it possible that the structures are synchronous with the nearby out-of-sequence thrusts?

We thank the reviewer for this very important and useful comment. Indeed, we do have temporal constraints on the formation of deformation bands. We first removed the faults from the histogram log of deformation structures in Figure 1b, because Lewis et al. (2013) showed that many of them were induced by drilling. The modified histogram shows that the deformation bands we are studying (shear zones and veins) almost exclusively occur in the accretionary prism and not in the slope apron. The consequence is that the deformation bands cannot be related to burial (otherwise they would be found in the two units), and must be of tectonic origin. The deformations bands thus formed during accretion and before the deposition of the slope sediment. This is also the timing of activity of the megasplay thrust fault uphill of site C0001. We can thus conclude that the microstructures and the major thrust roughly correspond to the same time intervalley. The manuscript was modified as follows:

- Lines 104-105, we mention that “This study hereafter focuses on shear zones due to their larger thickness than faults, and because Lewis et al. (2013) showed that many of the faults are in fact drilling-induced.”

- We modified Figure 1c to show only shear zones and veins.
- We added a new paragraph lines 323-333: "Another important question concerns the timing of deformation bands and their bacterial proliferation. Given the need of nutriments for metabolic reactions, it is tempting to interpret these structures as formed at shallow depth below the sea floor, in proximity of seawater sulfate supply. However, shear zones as well as veins were almost exclusively found in the accretionary prism (Unit II) and not in the slope sediment (Unit I) above the unconformity (Fig. 1c). This fact implies that most of the deformation bands studied here are not burial-related, but are rather associated with the tectonics of the accretionary prism. A way to reconcile the two inferences is to suggest that deformation bands, and biological diagenesis in them, developed in the upper portion of the accretionary prism during thrusting, and before the deposition of slope sediments. Whether deformation bands are mechanically compatible with thrusting is unfortunately unknown because no kinematics could be assigned to the majority of them. Nevertheless, we note that this proposed timing coincides with the activity of the megasplay fault thrust uphill of C0001 (Fig. 1b). It is thus possible that deformation bands may represent early stages of strain localization, and fluid expulsion, in the context of megasplay fault development."

2. These overarching questions connect to the implications that start on Line 328, specifically the potential relation between structures of the kind the authors nicely characterize and larger faults. The timing questions are thus critical. Given how much interest there is on accretionary prisms, and on the spectrum of time scales over which seismic energy is released, the following specific questions might be worth consideration. For example, if the dewatering structures are tectonic (not simply products of burial) over what timeframes can the authors bracket them to have been active? Are they "one-time" features related to a single seismic event on the megathrust or the more proximal megasplays? Alternatively, are they formed over many seismic cycles, or perhaps even during the inter-seismic phase as fault zone coupling evolves? Are they crosscut by structures with known kinematics that help narrow the timing? Some of the structures are themselves normal sense shear zones. I realize that these questions are challenging. I ask because I wonder whether the fluids produced by the processes described might have been supplied to structures up dip, down dip or even along strike? If these structures immediately precede the development of throughgoing faults, do they shed light on process-zone evolution? If they are coeval with throughgoing faults, do they help us understand feedbacks between damage zones and faults? An entirely different implication/question: could these structures be signatures of aseismic processes such as tremor?

These questions are very interesting, unfortunately we cannot answer them. We do not have a more precise timing for the development of deformation bands, because no kinematics could be assigned to the majority of them, and because core observation seldom provides information about crosscutting relationships. We do not know whether these structures are "one time events", whether they are caused by earthquakes or slow-slip events or anything else. Given our lack of knowledge, we do not feel confident at discussing these points in this manuscript. Nevertheless, we added a sentence to suggest the possibility that microstructures might supply fluids to larger faults, given their coeval timing, lines 348-350: "Given the temporal consistency between megasplay faulting and deformation bands, the dewatering of these many microstructures could be supplied to major faults, which might explain some freshwater fluxes observed in accretionary prisms (e.g. Kastner et al., 1993; Vrolijk et al., 1991)."

3. These questions require timing constraints that are very difficult, if not impossible. Given that the "plumbing of accretionary prisms" remains a hot topic, as the authors rightly note, providing the larger context would elevate the significance of the findings, motivating additional innovative work of this sort. In the Discussion section, the authors

agree with prior work that these deformation structures are in effect byproducts of dewatering. Is it possible that volume fluxes can be estimated so that we have a better sense of the scale? Getting word out about the findings strikes me as important because as more core from similar settings is collected, the community might prioritize this kind of work so that we can begin evaluating the true scales over which these processes operate. The potential feedbacks between biogenic and tectonic processes are quite provocative. If the structures are well constrained to pre-date the megasplays, then the implications for fault evolution are more tenuous and my many questions are not so helpful.

We can neither estimate the fluxes of dewatering produced by microstructures because we do not have a quantified budget of freshwater consumed or produced by bacterial proliferation. This question will require a large amount of experimental work to be solved. We already mentioned in the previous version that quantitative work is needed to assess the importance of biogenic diagenesis in the fluid budget (lines 350-351). In our opinion, our interpretation stretches already very far in the implications section, and we prefer not to discuss this point in more detail.

Technical corrections

4. Line 157: "Petrographic" might be more appropriate than "Petrologic" here given that much of what follows is derived from thin-section work it seems.

Corrected, now lines 176-177.

5. Line 265: The topic has received "much attention." This might be crisper than "a large attention…"

Corrected, now line 291.

6. Line 339: The sentence that starts "This dual biogenic..." is confusing.

We removed this sentence and replaced it by the following sentence, lines 391-392: "Both diagenetic reactions occurred during the development of deformation bands and vanished afterwards. This biogenic diagenesis may be explained by a locally enhanced activity of anaerobic microorganism in deformation bands, which may be related to the generation of H2 by intracrystalline deformation of silicates minerals."