

Interactive comment on “Drilling disturbance and constraints on the onset of the Paleocene/Eocene boundary carbon isotope excursion in New Jersey” by P. N. Pearson and E. Thomas

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Response to Reviewers' comments.

We are grateful to the reviewers for their comments. All three commentators accept the basic premise of our paper, namely that the regular repetitions in both the Millville and Wilson Lake B cores are caused by drilling disturbance, and that there is no support for the annually resolved chronology for the onset of the CIE as claimed by Wright and Schaller (2013). For the record, we alerted J.D. Wright and M.F. Schaller to the submission of our manuscript at the beginning of the review period, but evidently they have chosen not to respond.

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Pending the editor's advice / assent, we propose to amend the manuscript as described below. Before getting to our detailed response we will address one issue where we propose to make a few substantial additions to the manuscript.

Both Eldrett and Dickens asked for more background information on drilling disturbance in general and biscuiting in particular. There are many ways in which a sedimentary formation can be disturbed during the coring process, depending on the type of coring (e.g., rotary versus piston coring) and the mechanical properties of the formation. Drilling disturbance encompasses various types of plastic and brittle deformation, and their effects can vary from subtle to severe. We cannot find any single general review that enumerates the types of drilling disturbance, or more specifically on the mechanics / physics of how biscuiting is caused in relation to torque, rate of penetration and rock physics. A paper just published by Jutzeler et al. (2014) provides a general introduction to drilling disturbance but focuses on piston coring. At the time of submission, the best description of biscuiting we had found was for schoolchildren on an educator's (excellent) blog for the ANDRILL project (Hubbard 2007). However, in response to the reviewers we have delved deeper and uncovered two very significant papers from the days of the Deep Sea Drilling Project by Kidd (1978) and Leggett (1982), both of which describe and illustrate the phenomenon.

Kidd's description is that cores

"are found to be broken horizontally into pieces. At the breaks, the upcore surfaces of the pieces are convex while the undersurface of those above are concave. This is the result of the individual pieces rotating upon one another inside the core barrel as the core is being cut. Often, the break is along a change in lithology such as a sandy horizon or a silt or shell lamina, although just as frequently no lithological change is apparent... This is referred to as core-discing, a process familiar to rig geologists in the drilling industry, and is found when weight on the bit required to core stiff lithologies (especially waxy clays) causes a hammer or bounce effect." (Kidd 1978, p. 1133-1134).

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This is a slightly different explanation of the cause from ours, so is worth adding to the discussion. Kidd illustrated an example of core-discing and concentric grooving which we reproduce Figure 1A for comparison with our own images from Millville and Wilson Lake B.

Kidd (1978) also discussed and illustrated examples of microfaulting, also similar to those described in our manuscript. He also cited as "in preparation" a JOIDES/DSDP Technical Manual on core disturbance by R.B. Kidd and P. Thompson, but it seems that this never appeared: a general paper on drilling disturbance would still be highly desirable.

Leggett (1982) described and categorized a series of disturbance features seen on DSDP Leg 66 in ascending order of severity, namely "bowed laminations" (where original sedimentary laminations are deflected downward), "drilling laminations" which are not sedimentary but caused by maceration of the rock and "are generally spaced with extreme regularity (2-4 cm)" (Leggett 1982, p. 531), "drilling biscuits" which are discrete blocks of sediment with injected mud in between of unequivocal mechanical origin and which show circular striae on their tops and bottoms, "core discs" which are similar but more severely disturbed with eroded edges, and "drilling breccia" where chunks of broken up and disoriented core sit in a soupy matrix (see Figure 1B and Figure 2).

Kidd's and Leggett's examples are very similar to the New Jersey and Tanzania cores, and emphasize that the repetitive nature and characteristic vertical length scale is mechanical rather than sedimentary in origin. Leggett (1982) also noted that rotation of the biscuits had been proved by variable magnetic inclination and declination.

Kidd's paper has been cited only three times in almost forty years, and Leggett's five. If approved by the editor we propose to extend the discussion of drilling disturbance along the lines above, including reproducing the figures. We also propose to emend the text to give preference to the term 'core-discing' over 'biscuiting' to reflect Kidd's prior usage and to avoid confusion in those parts of the English-speaking world where biscuits are

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cookies, crisps are chips, and chips are fries (Leggett, 1982; the phenomenon has also been referred to as 'core dicing' by Aziz et al., 2008).

Other comments are as follows:

Reviewer 1 (Eldrett)

1-1b. Eldrett challenged us that we did not "definitely rule out" or "irrefutably demonstrate that the layers do not preserve some primary signal and could be cyclic (century to millennia)". Proving such a negative would be very difficult if not impossible to do, especially in a core that is so thoroughly disturbed through drilling. We accept that fracturing in the core barrel may or may not have happened along bedding planes, as already mentioned by Kidd (1978) quoted above. But as we reported, we closely examined the cores with a hand lens and microscope for evidence of sedimentary bedding, but no evidence was found, although the injected mud laminae certainly cut across the fabric of the rock in places.

Wright and Schaller (2013) made a very out-of-the-ordinary statement, i.e. that the transition into the PETM occurred over in just over a decade instead of a millennium, and this statement thus is not based on any evidence. We reject the assertion that our paper lacks balance insofar as we do not sufficiently entertain the possibility that the formation might in reality be rhythmically layered, with the layering controlling the pattern of mud injection and core-discing, and if so what the climatic significance of those layers might be (e.g., if they are not annual, then what - centennial, millennial, etc.). Discussing such hypotheticals is no more warranted than it would be for the examples illustrated by Kidd and Leggett (Figure 1A and B), or our Tanzanian example (which we proffer because the same interval was re-drilled without biscuiting and proved to be massive claystone). Indulging in such a discussion could foster ongoing confusion about the sedimentology of the Marlboro Clay Formation. As we described, previous descriptions of the formation in outcrop describe the lithology as massive. If new evidence of regularly cyclic bedding comes to light from geological exposures or

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new coring, that would be a different matter.

2a-c. We agree with the reviewer that the contention of Wright and Schaller (2013; Fig S2) that $\delta^{18}\text{O}$ maxima correspond to smectite layers is not proven. One would need to know the exact levels from which their samples were taken, and the evidence as originally presented is rather diagrammatic / schematic. We did not pursue geochemical fingerprinting of drilling mud because we think appearances are plain enough in our photographs, especially the part of the core we sectioned and photographed under the microscope. In addition, information on the drilling mud used many years ago is not easy to come by.

2d. In point of fact, we did not mention the $\delta^{18}\text{O}$ data from Millville in our text – the oxygen isotopes discussed are from a different core (Wilson Lake B). For this reason, we plotted only the $\delta^{13}\text{C}$ data from Millville, which we did discuss.

3. We reproduced the field photograph so that all the main evidence is in one place, and we felt it necessary to respond to the interpretation offered by Wright and Schaller (2014) during the discussion process with PNAS. We will remove it only if the editor recommends. To clarify the position regarding the exposure at Medford, a short statement was removed from the initial submission on the advice of the editor pre-review because it added little to the manuscript. It read:

"At that time he [Pearson] was able to discuss the issues constructively with J.D. Wright and M.F. Schaller, who also kindly organized a visit to the outcrop at Medford on 20 March 2014, at which time (despite high stream levels and sub-optimal conditions) a short ~60 cm core was taken using a Livingstone corer (thanks also to C. Lombardi). We will not comment on this core because Wright, Schaller and Lombardi may wish to do that, except to remark that it does show evidence of sedimentary bedding."

Indeed, all parties present agreed that there was bedding. The reason we are not now in a position to comment in detail on this short core is that it is not our property, but the reader can infer that if we had seen good evidence of rhythmic sedimentation we

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would not have proceeded with this paper. Anyone wanting precise locality information should apply to the original authors because we do not have it.

4. Our response to this is covered in the comment above.

Reviewer 2 (Gallagher)

We thank Reviewer Gallagher and see no issues to respond to. We fully agree that there is a positive story here and that further work on the Marlboro Clay with renewed drilling is highly desirable.

Contributor (Dickens)

This short comment hits a tone we have tried to avoid. Drilling disturbance may seem obvious in retrospect, but both Kidd (1978) and Leggett (1986) cautioned that confusion with sedimentary structures had occurred. We would like to re-emphasize that we were treated with nothing but courtesy and respect by J.D. Wright and M.F. Schaller in our investigations and received much constructive assistance. However, we agree there may be issues about the scientific process that we can all reflect on.

We failed to acknowledge K.G. Miller of Rutgers University for access to the as-yet unpublished Wilson Lake B core, for which we apologize (Millville, in contrast, is property of ODP).

Literature not previously cited:

Aziz, H. A., Di Stefano, A., Foresi, L. M., Hilgen, F. J., Iaccarino, S. M., Kuiper, K. F., Lirer, F., Salvatorini, G., and Turco, E.: Integrated stratigraphy and $^{40}\text{Ar}/^{39}\text{Ar}$ chronology of early Middle Miocene sediments from DSDP Leg 42A, Site 372 (Western Mediterranean). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 257, 123-138, 2008.

Kidd, R. B.: Core-discing and other drilling effects in DSDP Leg 42A Mediterranean sediment cores. *Init. Repts. DSDP*, 42, 1143-1149, 1978.

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Jutzeler, M., White, J. D. L., Talling, P. J., McCanta, M., Morgan, S., Le Friant, A., and Ishizuka, O.: Coring disturbance in IODP piston cores with implications for offshore record of volcanic events and the Missoula megafloods. *Geochemistry, Geophysics, Geosystems*, 15, 3572-3590, doi:10.1002/2014GC005447, 2014.

Leggett, J. K.: Drilling induced structures in Leg 66 sediments, *Init. Repts. DSDP*, 66, 531-535, 1982.

Interactive comment on *Clim. Past Discuss.*, 10, 3303, 2014.

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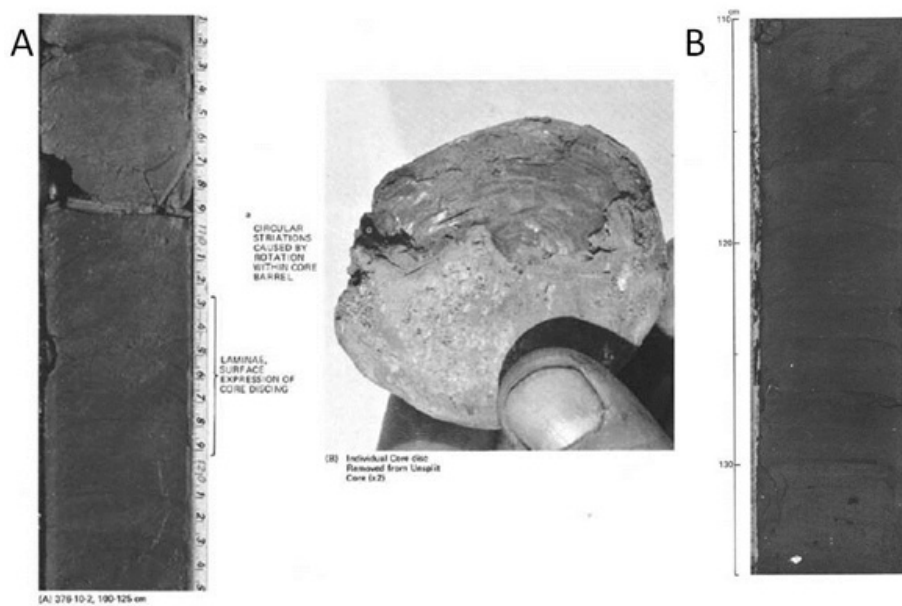


Fig. 1. Figure 1. A: "Core-discing " as illustrated by Kidd (1978) and Leggett (1982) from DSDP Site 376 (Florence Rise, Mediterranean Sea west of Cyprus) and DSDP Site 488 (middle America Trench off Mexico)

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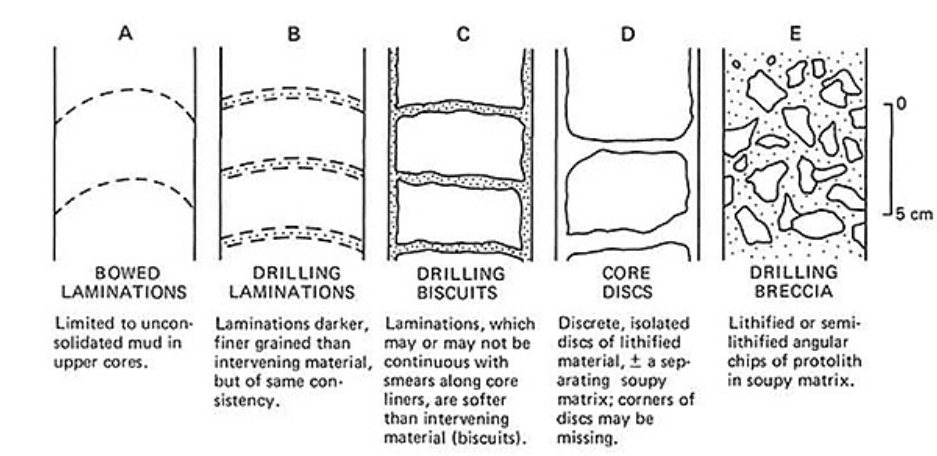


Fig. 2. Figure 2. "Types of drilling deformation in Leg 66 cores" from Leggett (1986).