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Biogeosciences Discussions

Interactive comment on "Productivity patterns and N-fixation associated with Pliocene-Holocene sapropels: paleoceanographic and paleoecological significance" *by* D. Gallego-Torres et al.

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REPLY TO DR. ROSELLA CAPOZZI'S COMMENTS We would like to reply Dr. Capozzi's comments, following her suggestions.

1. Selection of sapropel layers: The aim of this sampling was to obtain data from representative time frames. Late Pleistocene and Holocene sapropels are more deeply studied, thus basin-wide correlation is the way to add new information. Similarly, Pliocene layers have also been widely discussed. The time window in between is poorly ana-

lyzed, so this sampling covers this gap. Eventually, sampling was limited by sample availability, since material from ODP Leg 160 has been extensively used for a wide range of analyses. S3 is contained on the available database, but only for Levantine basin sites, and it was not included in the figures due to the difficulty to include such a large database on the graphs. It is actually not a representative sapropel event, although the comparison with other sites deserves some attention, as mentioned on the note on page 4478. In any case, with the aim of reducing manuscript extension, the discussion on S3 will be omitted. 2. Stratigraphic attribution: We correct the age assignment as suggested by Dr. Capozzi.

3. Figures: It was (and still is) a big challenge to compress such an extensive amount of information on suitable plots. We agree that the final results need some improvement, and we propose to split the large figures into 2 or 3 more detailed ones, based on age or period correlations. The new set of figures will be provided upon manuscript resubmission. 4. "Productivity" and "Export Productivity" are not used as synonyms, but their direct relation often allows the use of both of them for the same purpose. Productivity refers to all biological process on the upper ocean layers that imply primary production of organic matter. Export productivity refers to the excess of organic matter that is not decomposed and sinks through the water column. This flux has been directly related to the primary productivity on the surface layers (see transfer function relating Ba-accumulation on the seafloor to organic carbon fixation on the ocean surface REFS!!). 5. The boundary conditions determining formation of sapropels is one of the unresolved issues on the topic. Assuming that both the increase in primary productivity and the altered water circulation pattern are consequence of climate variations, particularly intensified monsoonal activity in the region related to insolation maxima, we propose that higher intensity of this change led to more restricted water circulation. Although enhanced productivity is a common factor, (and we consider it as a sine quanum requirement) Pliocene sapropel events coincide with extreme insolation maxima that lead to minima in deepwater circulation and thus enhanced preservation. Thus, increasing sedimentation rates diluted Corg

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so that TOC is lower, but it should not be considered as the main differentiating factor between younger and older sapropels. Alternatively, the different intensity of climatic changes induced different degrees of altered circulation within the basin and more or less intense productivity increases. 6. MAR is calculated for each sample as Linear Sedimentation Rate X Dry Bulk Density. LSR's is calculated based on tuned ages and composite depth of sapropels, and for this corrections also based on isochronous ages described in the literature. DBD was obtained from ODP Database. Babio and TOC MAR's are calculated as Element concentration X MAR. Pexp was not calculated since we believe that Ba can be used only as a semiquantitative proxy, especially when applied to older sapropels layers. 7. The hypothesis of different sources of riverine detrital material other than the Nile was previously proposed (e.g., Rohling et al, 2002), and was extensively discussed recently by Gallego-Torres et al, (2010) and Osborne et al, (2010). It is true that the calculation of MAR's might be affected by error due to incorrect Linear Sedimentation Rate calculation, not only on the Eratosthenes Seamount, but on all studied site for all but the S1 layers (as discussed on Gallego-Torres et al, 2010 and on the reply to the anonymous reviewer). Calculation of LSR's is always approximate, and any assumption is subject to flaws and contradictions. In the case of Site 966, although a certain degree of winnowing cannot rejected, calculated LSR's produce sensible results, compatible with other data obtained in the literature, and thus we consider these values as a "best approximation". 8. The origin of organic matter in sapropels is widely accepted to be mostly marine, as different studies based on independent proxies have shown (references cited on the text, lines 458-459). However, as the Eastern Mediterranean is a nearly closed basin, the presence of a certain percentage of terrestrial organic matter must be assumed, especially in areas close to land masses and/or riverine sources. This is the case of Site 967, described on the manuscript as affected by distal plumes from the Nile river mouth. Considering that sapropels are formed during periods of enhanced Nile river discharge, the presence of terrestrial organic matter transported as colloids for long distance can be expected. It was not the intention to put under debate the main origin

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of organic carbon, so we will be more specific on the topic on the second version. A similar ambiguity is pointed out by Dr. Capozzi regarding TOC/TN values, similar to the ones found on C3-C4 plants. However, if we considered that plants exhibit positive δ15N values, much higher than what we find on sapropel organic matter, this interpretation is not consistent. Thus, the most plausible explanation is that remineralization of N-molecules has taken place. 9. In our opinion, production of isorenieratene and the presence of a green sulphur bacteria community is not contradicting the formation of a N-fixing bacterial ecosystem. N-fixing bacteria use atmospheric N and thus they are more efficient on the upper layers of the water column, very close to the surface. Anoxic green sulphur bacteria can still occupy the lower part of the photic zone with no interference with the upper community. Furthermore, green sulfer bacteria are nitrogen fixers themselves. Although different authors have deduced an anoxic water column in the Eastern Mediterranean, the extension of this anoxic water to the surface or methane emission from the water to the atmosphere has never been proposed and it is not considered as plausible. We assume that during sapropel formation and under restricted deepwater circulation the different water layers on the upper part of the water column were compressed, so ecosystem changes would also be more drastic and sharp, so both communities could occur at the same time. In any case, isorenieratene has only been described in Pliocene sapropels, when oxygen-deficient conditions were more severe. 10. Note on page 4470, line 23: Since MAR's depends on LSR and DBD, and density changes for individual samples, there is no direct relation between MAR and LSR. This is in fact what happens during S5 (i-cycle 12); LSR is not maximum, but MAR is particularly high. We also prepared a summary table comparing MAR's calculated considering a) constant LSR for each i-cycle; b) variable LSR from non-sapropel to sapropel periods, considering isochronous sapropel formation. 11. Notes on page 4472: A small increase in δ13C at the base indicates higher C-fixation. The later decrease is influenced by a variety of factors that blur the signal. We actually agree more with the following comment by Dr. Capozzi; the difference between sapropel and non-sapropel sediments is better detected in

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C:N ratios or other proxies, because there are too many factors affecting C isotopic composition (as mentioned on page 4471). 12. Comment by Capozzi, page 4475: Faster nitrogen cycling relative to organic carbon is indeed indicated by the large C/N values, but both nitrogen and carbon cycling are depressed to form the organic matter rich sapropel layers. 13. Note on page 4477, line 18; It is true that higher the LSR will produce higher MAR (and vice versa) but, as mentioned before, this is not the only factor. In the above mentioned table we show also TOC-MAR/Babio MAR. MAR is the same for both C and Ba, but the ratio shows variations. This way we want to show that as a whole, during the Pliocene more Corg was accumulated under similar Ba deposition rates. 14. Note on page 4477, line 25; We believe these high TOC values are facilitated by high productivity together with anoxic bottom waters that enhanced preservation. Even though sedimentation rate is lower and thus organic matter is exposed longer, the lack of oxygen prevents oxidation, so preservation factor is higher. 15. Note on page 4477, line 28; The process of barite precipitation is not still well understood. Both options proposed by Capozzi are possible, although a scenario of such a diminished sulphate concentration in seawater does not seems likely in the Eastern Mediterranean. The process of bacterial mediated sulphate reduction has been described in the literature, so if we have to chose, we would be inclined towards this second option. However, neither of them is proven, so the first proposed scenario is the more probable; enhanced productivity stopped but restricted circulation and lack of oxygen continued to favour TOC preservation. 16. Note on page 4479, line 24; TOC in the sediment is controlled by several factors. In the case of Site 966, which is at a much shallower depth, preservation is a very important factor to be considered. At this site sedimentation rate is lower, organic matter is exposed for a longer time and at a shallower depth. Partial degradation of organic matter, and thus relatively lower TOC final value, is expected. 17. Notes on page 4483; Lower sedimentation rate during Pliocene (line 7) is (at least partially) related to decrease carbonate production, which can be related to the same processes: change in bacterial community, altered circulation in the basin and lower surface salinity climatically induced. On the other

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hand (line 14) late Quaternary increases in SR's are related to a more constant carbonate production (always decreasing, but to a lesser degree) and increasing riverine detrital input, related to progressive aridification on the region. During periods of high input of riverine material, the higher concentration of clay minerals suspended on the water column may facilitate flocculation and transport of organic matter to the sediment, as suggested on the comment on line 24.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/7/C2869/2010/bgd-7-C2869-2010-supplement.zip

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Interactive comment on Biogeosciences Discuss., 7, 4463, 2010.