Clim. Past Discuss., 11, C2715–C2727, 2015
www.clim-past-discuss.net/11/C2715/2015/

Climate
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Discussions

Interactive comment on "A distal 145 ka sediment record of Nile discharge and East African monsoon variability" *by* W. Ehrmann et al.

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Received and published: 21 December 2015

We appreciate to have had Dr. Marie Revel as a reviewer and that we could benefit from her expertise on the Nile River system. We are grateful that the reviewer brought our attention to several papers that were not published when we submitted our manuscript. Below we respond to all comments raised by the reviewer.

Main comment:

This is a nice piece of work that presents clay mineral assemblages in a sediment core from the distal Nile discharge plume off Israel. Clay mineral assemblage variations

are used to reconstruct the behaviour of the Nile basin during the dry-glacial/humid-interglacial transitions over the last 145 ka.

Response:

Thank you for the generally very positive vote.

General comments:

1) The authors interpret their results in terms of a simple dichotomy between Blue Nile and Atbara sediment inputs (Smectite abundances) and Wadis (Kaolinite abundances) and an eolian dust contribution for the Sapropel 5. What about the White Nile branch contribution at the scale of the Quaternary? In fact, the reality is more complex. During times of renewed overflow from the Ugandan lakes and before the Sudd swamps had become re-established, both water and sediment input from the White Nile were considerable (see the recent paper of Williams: Williams, M.A.J., Usai, D., Salvatori, S., Williams, F. M., Zerboni, A., Maritan, L., Linseele, V., 2015. Quaternary Science Reviews (in press). Late Quaternary environments and prehistoric occupation in the lower White Nile valley, central Sudan). In the recent paper of Garzanti (Garzanti , E., Ando, S., Padoan, M., Vezzoli, G., Kammar, A. E., 2015 in press. The modern Nile sediment system: Processes and Products. Quaternary Science Reviews, 1-48.), figure 15, the authors have mentioned Âń Âń that smectite rich assemblage is obtained for the tropical southern Africa whereas kaolinite dominated assemblages for the humid equatorial Kagera catchment. In my opinion, clay minerals are not perfect tracer to identify geographical provenance, clay minerals from the Nile reflect changes in local depositional procedures rather than climatic signals in source areas ? Smectite could also originate from authigenous processes in marine sediment? Authigenic processes at the water/sediment interface are often underestimated to the benefit of the biogenic or terrigenous process studies. It is better to use Nd-Sr isotopic composition and thus to integrate the age of the sediment compared with the age of the different outcrops/soils (see fig 30 in the paper of Garzanti 2015 and Revel et al., in press QSR

in the same special issue of QSR). However, clay mineral assemblage can be used as a first-order indication of relative change in the amount of fine terrigenous components supplied to the core site from the Nile River discharges. It is probable that increase in smectite and kaolinite % in core SL110 mainly reflect a better transport of fine sediment load with more intense flood in the whole Nile fluvial system (Fig 3 Silt/Clay ratio). → So, perhaps the authors could add a paragraph to show that they are aware of these issues.

Response concerning the aeolian flux:

We do not argue for an aeolian contribution to sapropel S5 but to the sediments of glacial MIS6 (see discussion chapter).

Response concerning the complexity of the Nile river system:

We agree that the Nile discharge history is quite complex and involves not only the Blue Nile and Atbara but also the White Nile. However, as outlined in our introduction chapter, the present-day White Nile contribution to the total Nile sediment discharge is almost negligible (Adamson et al., 1980; Foucault and Stanley, 1989; Williams et al., 2006; Garzanti et al., 2015). This is due to the storage of White Nile sediments in Lake Victoria, Lake Albert and in the Sudd basin of South Sudan. In fact, more than 95% of the Nile sediment is derived from the Ethiopian highlands via Blue Nile and Atbara (Garzanti et al., 2015; Williams et al., 2015). The contributions of the Blue Nile and Atbara versus White Nile may have varied through time. We cannot exclude a somewhat higher White Nile discharge during humid periods, when the tropical lakes and the Sudd possibly were overflowing.

Dr. Revel points to the paper by Garzanti et al. (2015) and notes that smectite-rich clay mineral assemblages may also be provided by the White Nile. Garzanti et al. (2015) refer to data by El-Attar and Jackson (1973) for the high smectite content in the White Nile. These authors present data from two samples from the lower White Nile, downstream of the confluence of the Sobat River. Sobat river has its headwaters in

the Ethiopian highlands, just as Blue Nile and Atbara, and thus discharges a similar smectite-rich clay mineral composition into the lower White Nile. This is corroborated by a similar Nd-Sr fingerprint of the Sobat and Blue Nile sediments indicating the same source region (Garzanti et al., 2015: Fig. 11). South of the confluence of the Sobat, the White Nile shows a considerably different clay mineral signature with significantly lower smectite contents. Alluvial sediments from central Uganda have smectite contents <20% (Nyakairu and Koeberl, 2001); no smectite was described from lake-bottom sediments of Lake Victoria (Mothersill, 1976). Thus, humid periods in the Ethiopian highlands increase not only the discharge of Blue Nile and Atbara, but also of the Sobat. High smectite contents at SL110 therefore can be related to humid periods in the Ethiopian highlands but not to the White Nile headwaters.

Furthermore, the smectite content in SL110 correlates with the Fe content documented by Revel et al. (2010) in delta sediments of the Nile, especially during humid periods (see Fig. 4 of our manuscript). Because Fe is unequivocally derived from the volcanic rocks of the Ethiopian highlands, this also suggests that the overwhelming part of the smectite comes from that source.

Tropical weathering in the equatorial region produces mainly kaolinite, but only traces of smectite (Garzanti et al. 2015). If one argues that the kaolinite found in SL110 originates from the White Nile headwaters, we should expect a decrease in smectite at the same time due to dilution. This, however, is not the case. Therefore we argue that the kaolinite found in SL110 predominantly comes from the North African wadi regions (Egyptian wadi assemblage with 40–55% kaolinite and 35–45% smectite; Hamann et al., 2009).

We will make these points clear in our revised paper.

Response concerning authigenic clay minerals:

Smectite in southeastern Levantine Sea sediments is generally regarded to be a detrital clay mineral derived from the Nile (Maldonado and Stanley, 1981; Stanley and

Wingerath, 1996; Foucault and Mélières, 2000). This origin is also reflected in the smectite distribution pattern in the seafloor surface sediments (Venkatharatnam and Ryan, 1971; Hamann et al. 2009). Furthermore, also the reviewer Revel successfully used smectite as a “proxy for Nile input” (Revel et al., 2014: 1689). Also in other parts of the Eastern Mediterranean Sea smectite is considered as a detrital clay mineral (cf. Aksu et al. 1995: 49). In general, authigenic smectite formation is a minor process, but may be important locally. Authigenic smectites derive mainly from the weathering of basaltic oceanic crust, hydrothermal activity or diagenetic processes (e.g. Chamley, 1989; Weaver, 1989; Hillier, 1995; Fagel, 2007). Thus, authigenic smectites at SL110 are unlikely given the young age of the sediments and the absence of volcanic activity. Although we cannot exclude minor authigenic smectite, its presence would not change the major findings of our study on the history of Nile sediment discharge. We will insert a sentence on the authigenic versus detrital origin of smectite in the revised manuscript.

Response concerning the validity of the clay mineral proxy:

The mentioned Fig. 30 of Garzanti et al. (2015) does not show any Nd and Sr data. It is an unsatisfactory discussion what is a "perfect" proxy, because a perfect proxy simply does not exist. At present, the scientific community is in a phase of collecting as many different proxy data as possible for a better understanding of the complex history of Nile water and sediment discharge. However, to our opinion we have strong arguments for using smectite as a provenance indicator (see discussion above).

Comment:

2) Overall, the authors need to interpret their dataset more thoroughly before the discussion. For example, the abrupt change in sand % at ∼100 cm ? Is it related to change in Quartz grain contribution? To change in marine calcite or dolomite shell contribution? The authors explained it is a thin silt layer. Is it a turbidite, slump or debris flow layer ? Is there fingerprint of erosional turbidite characterized by an erosional basal

contact, and a normal sorting ? Are there any tephra layers such as the well-known Y2 tephra dated from about 22 ka? (See and add the different papers of Ducassou et al., for the sedimentological approach along the Nile turbidite system. Ducassou, E., Capotondi, L., Murat, A., Bernasconi, S., Mulder, T., Gonthier, E., Migeon, S., Duprat, J., Giraudeau, J., Mascle, J., 2007. Multiproxy Late Quaternary stratigraphy of the Nile deep-sea turbidite system – Towards a chronology of deep-sea terrigeneous systems. Sedimentary Geology 200, 1-13. Ducassou, E., Mulder, T., Migeon, S., Gonthier, E., Murat, A., Revel, M., Capotondi, L., Bernasconi, S.M., Mascle, J., Zaragosi, S., 2008. Nile floods recorded in deep Mediterranean sediments. Quaternary Research 70, 382-391. Ducassou, E., Migeon, S., Mulder, T., Murat, A., Capotondi, L., Bernasconi, S.M., Mascle, J. 2009. Evolution of the Nile Deep-Sea Turbidite System during Late Quaternary: influence of climate change on fan sedimentation. Sedimentology 56, 2061-2090. Ducassou, E., Migeon, S., Capotondi, L., Mascle, J., 2013. Run-out distances and erosion of debris-flows in the Nile deep-sea fan system: Evidence from lithofacies and micropaleontological analyses. Marine and Petroleum Geology 39, 102-123.

Response concerning the silt layer:

As can be seen from Fig. 3, the coarse sediment layer at 103-102 cm depth is not characterized by high sand but silt contents. We mentioned in the manuscript that we regard the grain size composition of the terrigenous sediment fraction; carbonate was dissolved by 10% acetic acid prior to the analyses. The silt consists of quartz grains; no tephra particles are present. The layer is light gray in colour. No gradation is visible. We will add this information to our revised manuscript.

Response concerning the deep-sea fan system:

The investigated core SL110 (32°38.95′N, 34°06.22′E, 1437 m water depth) does not contain indications for slumping, debrites or turbidites. The core indicates rather constant sedimentary conditions in the distal discharge plume of the Nile. We will add this information to our revised manuscript. The only indication for slumping can be seen in the described hiatus in early MIS5. Also the papers of Ducassou et al. (2009, 2013) mentioned by the reviewer show no evidence for debrites or turbidites in sediment cores east of 33°E, with the exception of some levée turbidites during MIS6. In addition, the recent study of Katz et al. (2015) shows that the main landslide areas are located further to the east at shallower water depths on the shelf break and uppermost continental slope. We therefore do not see the need for a discussion of the Nile deep-sea fan system, but will mention the work of Ducassou in the revised version of our manuscript when describing MIS6.

Response concerning tephra layers:

In the search for age control points we had checked all samples for the presence of volcanic glass or pumice but did not find any indication for a tephra layer. The Minoan Ash (Z2; 3.65 ka), the Y2 tephra (21.95 ka) and the Y5 tephra (Campanian Ignimbrite, 39.28 ka) so far have not been detected in the southeastern Levantine Sea (Keller et al., 1978, Narcisi and Vezzoli, 1999, Pyle et al., 2006). They also were absent in nearby core GeoTü SL112 (Hamann et al., 2008). However, in SL112 a tephra layer was detected within sapropel S1. No such tephra was detected in SL110. We will add this information to our revised manuscript

Comment:

3) Sedimentation rates (SR) in the beginning of the discussion (§6) should be presented in §5 Results. In my opinion, sedimentation rate do not significantly change and the low resolution of the age does not allow to precisely describe the timing of the SR changes and so to discuss the synchronous changes with clay mineral assemblage.

Response:

Also reviewer #1 comments on the presentation and discussion of the sedimentation rates. The data will be included in Fig. 3 in the results chapter of the revised manuscript, and will be discussed in the discussion chapter.

Comment:

4) I feel that δ18O G. ruber data is not fully exploited. First, I recommend plotting this curve in function of age and clay mineralogy assemblage. Then, the δ18O signal and clay mineral changes are or not synchronous in the core? These data need to be discussed.

Response:

As requested, we will plot the stable isotope data versus age in Fig. 3 of the revised manuscript. The oxygen isotope investigations were done to establish an age model for the core. It is not within the scope of this paper to discuss the data in their full scientific meaning. Of course there is a rough correlation between δ18O and Smr and Kar, with interglacial periods being characterised by enhanced Nile River sediment discharge and sapropel formation. We will add some information on the correlation to our revised manuscript. However, we cannot show a detailed correlation because of the much lower resolution of our isotope record.

Comment:

5) This is a very interesting result and idea: “during the last glacial period (MIS4-2) the long term changes of the monsoonal system were superimposed by millennial-scale changes of an intensified mid-latitude glacial system.

Response:

No reaction needed.

Detailed comments:

Abstract: please attribute the dates to the S3, 4 and 5 layers, otherwise it is difficult to follow

Response:

We will include the requested information in the revised manuscript. We will apply a revised age model as proposed by reviewer #1.

Comment Introduction:

“The Nile flows through different climate zones, from a cool and humid climate”. Why cool? Because of the high altitude? Do you have a reference for this affirmation? “By analysing a distal core from the plume, we document the Nile discharge activity as a whole rather than the activity of only a single channel in the delta”. I agree, however, to be precise, you also document the eolian input from coastal zone transported during wind-blown storm and also the terrigenous input will be controlled by sea-level changes along the coast between the Nile delta and Haifa?

Response:

We will delete the sentence on the “climate zones”. The comment is correct that we also may get an aeolian signal and a signal from coastal sediment transport and changes in sea level. We did not include this information in the introduction chapter in order to keep it short and clear. However, these processes and their effects are dealt with at the beginning of the discussion chapter.

Comment Page 12:

The authors conclude that the MIS6 arid phase in the studied core seems to have been more severe than that of the LGM. It is surprising? It could be due to the geographical position of the core. It appears important to keep in memory that the Nile deep sea fan and in particular global sea level changes can also play a role and influence the sediment dispersal and sorting of minerals from the delta fronts and prodelta. During the Last Glacial Maximum (LGM between 23 to 19 cal kyrs BP) the central and eastern parts of the Nile deep-sea turbiditic system were inactive and only deep-sea fans from the western part received Nile sediment (see paper Revel et al., in press QSR) and also the paper of Migeon: Migeon, S., Ducassou, E., Le Gonidec, Y., Rouillard, P.,

Mascle, J., Revel M., 2010. Late Quaternary lobes in a silt/mud-rich turbidite system: the example of the western Nile deep-sea fan (Eastern Mediterranean). Implication for lobe construction and sand/mud segregation. Sedimentary Geology, 229, 124-143.

Response:

What makes MIS6 unique during the last 140 ka is, based on our data, the stronger aeolian influx resulting from an enhanced aridity. The aeolian influx from the Sahara is well documented by the higher palygorskite concentrations during MIS6. Palygorskite plays a much minor role only in younger times, also during the last glacial. We do not see an enhanced influence of a Nile deep-sea fan system during MIS6. Such a system should also bring Nile-derived smectite to the core location, which, however, is not the case.

Comment Page 14:

“It is not understood why” .. The age model for core MS27PT has been revised with respect to the original age model published in Revel et al. (2010, 2014). I will send you the new age model and data published in Revel et al., in press QSR for the last 25ka and Personal com. for the last 107 ka.

Response:

We appreciate that Dr. Revel makes a new age model accessible to us. However, because the age model largely is not yet published and the reader therefore cannot check its reliability, we refrain from using it in our study. Nevertheless, we checked the new model, compared it with the one published in 2011 and used by us, and found no major changes in the critical time interval around 70 ka that would lead to other interpretations.

Comment Conclusion:

“precipitation and suspension discharge started much earlier and ended later than sapropel formation “ May be the authors can add: as already mentioned by Caley et al., 2010?

Response:

Caley et al. (2011, not 2010) is an accompanying study to Revel et al. (2010). We referred to the latter study in our discussion chapter: “Both the clay mineral record of southeastern Levantine Sea core SL110, the Fe record from the Nile delta (Revel et al., 2010) and the record of Saharan dust influx to the Aegean Sea (Ehrmann et al., 2013) reveal that each phase of sapropel formation occurred within a longer AHP.” We will add the reference to Caley et al. (2011) in the revised manuscript.

Comment Fig 1:

Please plot the location of the core SL-143.

Response:

We could not include the position of SL143 in Fig. 1, because it is located far to the north, in the central Aegaen Sea (38°15.71’N, 25°06.19’E). However, we will mention this in the caption and will include the metadata of SL143 into Table 1 of the revised manuscript.

Comment Fig 3:

I recommend to plot the δ18O, % TOC % sand and Silt/Clay in function of age with smectite/(ill+ Chlo) ratios. So may be to add a new figure ? Fig 3a: please indicate the MIS 6 and MIS 2 ? Is the peak of illite ($\sim$20%) at 100 cm correspond to the LGM ? or to the HS1 ? Fig 3b: it will be nice if the authors can indicate the hiatus by a line.

Response:

Also Reviewer #1 commented on the figure and proposed to plot all data versus age. We therefore will revise the figure.

Additional references, not cited in our manuscript

Aksu, A. E., Yasar, D. and Mudie, P. J.: Origin of late glacial-Holocene hemipelagic sediments in the Aegean Sea: clay mineralogy and carbonate cementation, Marine Geology, 123, 33–59, 1995.

Chamley, H.: Clay Sedimentology. Springer, Berlin, 623 pp., 1989.

Ducassou, E., Migeon, S., Mulder, T., Murat, A., Capotondi, L., Bernasconi, S. M., and Mascle, J.: Evolution of the Nile seep-sea turbidite system during the Late Quaternary: influence of climate change on fan sedimentation, Sedimentology, 56, 2061–2090, 2009.

Ducassou, E., Migeon, S., Capotondi, L., and Mascle, J.: Run-out distance and erosion of debris-flows in the Nile deep-sea fan system: Evidence from lithofacies and micropalaeontological analyses, Marine and Petroleum Geology, 39, 102–123, 2013.

El-Attar, H. A. and Jackson, M. L.: Montmorillonitic soils developed in Nile River sediments, Soil Science, 116, 191–201, 1973.

Fagel, N.: Clay minerals, deep circulation and climate, in: Proxies in Late Cenozoic paleoceanography, edited by Hillaire-Marcel, C. and De Vernal, A., Developments in Marine Geology, 1, 139–184, 2007.

Garzanti, E., Ando, S., Padoan, M., Vezzoli, G., and El Kammar, A.: The modern Nile sediment system: Processes and products, Quaternary Science Reviews, 130, 9–56, 2015.

Hillier, S.: Erosion, sedimentation and sedimentary origin of clays in: Origin and Mineralogy of Clays, edited by Velde, B., Springer, 162–219, 1995.

Katz, O., Reuven, E., and Aharonov, E., Submarine landslides and fault scarps along the eastern Mediterranean Israeli continental-slope, Marine Geology, 369, 100–115, 2015.

Mothersill, J. S.: The mineralogy and geochemistry of the sediments of northwestern

Lake Victoria, Sedimentology, 23, 553–565, 1976.

Nyakairu, G. W. A. and Koeberl, C.: Mineralogical and chemical composition and distribution of rare earth elements in clay-rich sediments from central Uganda, Geochemical Journal, 35, 13–28. 2001.

Revel, M., Colin, C., Bernasconi, S., Combourieu-Nebout, N., and Ducassou, E.: 21,000 years of Ethiopian African monsoon variability recorded in sediments of the western Nile deep-sea fan. Reg. Environ. Change 14, 1685–1696, 2014.

Weaver, C. E.: Clays, Muds and Shales, Developments in Sedimentology, 44. Elsevier, 819 pp., 1989.

Williams, M. A. J., Usai, D., Salvatori, S., Williams, F. M., Zerboni, A., Maritan, L., and Linseele, V.: Late Quaternary environments and prehistoric occupation in the lower White Nile valley, central Sudan, Quaternary Science Reviews, 130, 72–88, 2015.

Interactive comment on Clim. Past Discuss., 11, 4273, 2015.