PALAEO-ENVIRONMENTAL CHANGES LEADING TO THE PARTIAL OR COMPLETE REMOVAL OF EASTERN MEDITERRANEAN SAPROPELS

G. J. De Lange [1*], P. Van Santvoort [1], H. Passier [1], C. Langereis [1], M. Dekkers [1], J. Thomson [2], C. Corselli [3], and A. Michard [4]

[1] Dept. Geochemistry, Institute for Earth Sciences, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands
[2] Southampton Oceanography Centre, Southampton, United Kingdom
[3] Dipt. Scienze della Terra, Univ. Milano, Italy
[4] Géosciences de l'Environnement, Aix-en-Provence, France

Abstract

The occurrence of distinct organic-rich intervals (sapropels) in the eastern Mediterranean appears to be cyclic and to be associated with the Monsoonal / Insolation Index. A postdepositional downward migrating oxidation front may result in the partial or complete removal of a sapropel unit. Using the Ba/C.org relationship established for eastern Mediterranean sediments, the initial C.org content of sapropel units may be determined. The distribution of Ba and some trace elements on the one hand, and of the paleomagnetic parameters NRM/ARM on the other hand, appear to be accurate recorders of the initial occurrence of distinct organic-rich units, even if now invisible.

Key-words : sapropel, deep sea processes, geochemistry, paleoceanography, eastern Mediterranean

Understanding the mechanisms of sapropel formation and sapropel preservation is not only necessary for an improved reconstruction of palaeoenvironmental conditions in the E. Mediterranean, but may also assist in understanding the present-day situation and possible future developements. The Corg-rich marine sediments, sapropels, may be regarded as modern analogues for Corg-rich black shales. In addition, there are similar uncertainties on the conditions and environments under which black shales and sapropels are formed and preserved. In the deep marine environment, the Corg content preserved in a sediment is primarily a balance between the input flux of organic matter and its oxidation by bottom water O2. Most marine sediments have Corg contents in the range 0.2 - 2%. The E. Mediterranean sedimentary record therefore comprises an intercalation of unusually Corg-rich sediments (the sapropels) within Corg-poor sediments (*e.g.* 1), caused by repeated fluctuations through time in either or both the Corg flux from surface ocean export production and bottom water O2 levels.

Interpretations of the environmental conditions leading to sapropel formation are based on the sedimentology, micropalaeontology and geochemistry of the dark-coloured layers and the cream/brownish sediments above and below them. Generalised sequences of sapropel formation, based on examination and interpretation of a large number of sapropel units and the sediments enclosing them, have been presented (*e.g.* 2,3). The interval of dark colour associated with a sapropel is often somewhat thicker than that defined by the >2% Corg definition (4). Three sharp colour changes are generally associated with the most recent sapropel S1: the upper and lower limits of the dark Corg-rich sapropel layer itself, (typically 6-8 cm thick in the central basin), and at the base of the grey "protosapropel" layer of variable thickness which underlies the sapropel layer. A few cm above the S1, a dark-brown interval of 2-3 cm thickness is usually found, having a diffuse often mottled upper boundary and a relatively abrupt colour transition at the lower boundary. This colour is characteristic of Mn oxyhydroxide enrichments. In the interval from the dark-brown layer to the visible upper S1 boundary, an increasingly red-brownish colour usually appears (*e.g.* 5,6,7).

For a full understanding of the observations described above, the Ba / C.org relationship found for sediment trap samples and sediments at various sites is important (*e.g.* 8). Although mobilization of barite-Ba is possible during severe anoxic conditions, this does not seem to have influenced the Ba profile around the eastern Mediterranean S1 sapropel (*e.g.* 6,7,9). Using barite-Ba as a paleo- productivity indicator, enhanced fluxes hence accumulation rates of Organic carbon to the seafloor must have occurred from aproximately 9 - 5 ky BP, in uncorrected 14-C years (Fig. 1). The perfect correlation of the C.org calculated from the C.org / Ba relation, in the visible S1 interval, as well as the complete lack of such correlation in the interval between the darkbrown layer and the visible S1 layer are remarkable. It seems, therefore, that S1 deposition extended from 9 - 5 ky BP but that the organic carbon for the upper part has been removed. Such removal processes have been known to occur for the upper parts of organic-rich distal turbidites deposited in the Madeira Abyssal Plain (10,11,12,13).

At the end of S1 deposition, high organic carbon accumulation rates were followed by low organic carbon fluxes. As a consequence, only part of the oxygen diffusing from the bottomwater into the topmost sediment was, and is, consumed by the oxidation of the reactive organic matter. Subsequently, the remaining oxygen continues to diffuse into the sediment, leading to an oxidizing front slowly moving downward into the S1 sediments, degrading via microbial processes most of the organic matter on its way. Depending on the post-S1 organic carbon accumulation rates, the sediment accumulation rates, the organic carbon content and thickness of the S1 sediments, this oxidation front may have resulted in the removal of organic matter in part or even in all of the S1 sediment interval. As a consequence, the age found for the lower S1 boundary is relatively constant at approximately 9 ky BP, whereas that for the uper boundary usually varies between 6 and 8 ky BP (*e.g.* 14).

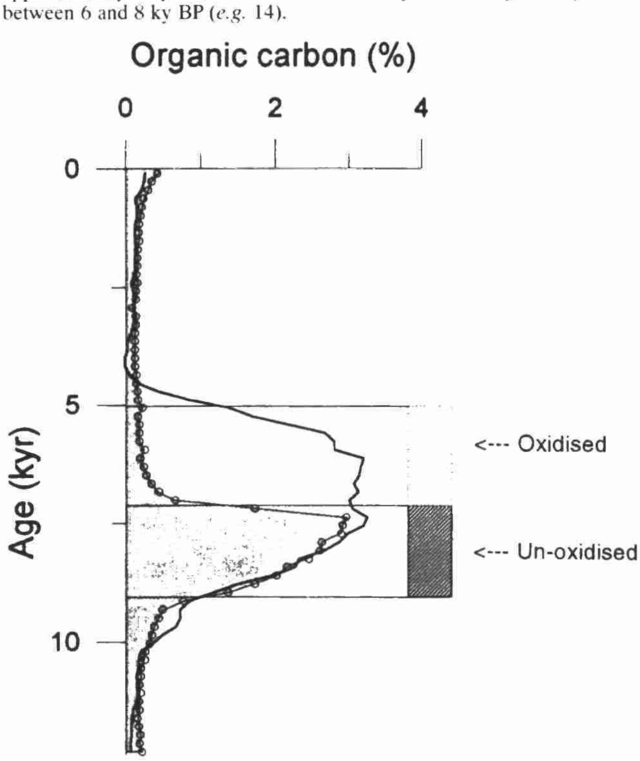

Fig. 1. Organic carbon content from the top 30 cm of sediments typical for the eastern Mediterranean. Organic carbon content calculated from C.org/Ba relationship (solid line; see text), and observed (open symbols) have been indicated. The dark-brown interval occurs at approx. 5 kyr.

During such downward oxidation process certain trace elements are relocated in a characteristic sequence, which allows the recognition of paleo-sapropel occurrences even after the (nearly) total removal of their visible evidence, *i.e.* organic carbon. Even if some mobilization of barite-Ba has occurred, it seems not to have moved far away from the sediment interval of its initial deposition. This is probably due to the rather local and limited time of sulphate reduction during formation of each sapropel (Fig. 2; 15,16). In the case of remobilized barite-Ba, it is not possible to determine C.org accumulation rates directly from the Ba content of the samples. Only after assigning the total Ba content to the associated initial sapropel interval, the extent of which is detemined from trace element characteristics, it is possible to assess an average organic carbon accumulation rate for that sapropel interval.

In this way Ba appears to be a reliable indicator for (initial) sapropel deposition in eastern Mediterranean sediments. In addition, some trace elements, and in particular paleomagnetic parameters such as NRM/ARM appear to be additional and accurate recorders for the initial occurrence of