Comparison of single sapropels in ODP sites and land sections

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Mediterranean Neogene sedimentary sequences are characterized by the cyclic occurrence of organic-rich layers (sapropels) in between 'normal' marine sediments. Mainly on the basis of research on land sections (most notably in Sicily, Calabria, Crete and Gavdos) it has been demonstrated that the occurrence of these sapropels correlates to variations in the eccentricity of the Earth's orbit and the obliquity and precession of the Earth's axis. At Mediterranean latitudes, the precession has the strongest effect on climate. Since one precession cycle lasts 23,000 years on average, that is also the presumed duration of each sapropel cycle. Scenarios detailing how these climatic changes led to sapropel formation have largely been derived from micropalaeontological, sedimentological and geochemical research on sapropels from marine sites. There is general agreement that during precession minima (Northern Hemisphere insolation maxima) precipitation increased, leading to higher river discharge. This enhanced runoff reduced surface water salinities, and may have led to water column salinity stratification or even circulation reversal (from anti-estuarine to estuarine). Under stagnant conditions, bottom waters would eventually become anoxic, leading to enhanced organic matter preservation and sapropel formation. On the other hand, the increased river discharge would also supply more nutrients and increase productivity. Higher export productivity, regardless of bottom water anoxia, may be a cause for sapropel formation as well.

Sediments recovered with traditional marine coring techniques are younger than approximately 1 my, whereas the youngest marine sediments found in land sections are older than 1 my. Therefore, a comparison between relatively organic carbon poor sapropels in land sections, generally formed in shallow environments under high sedimentation rates, and organic carbon rich pelagic sapropels in marine cores, formed in deep settings under low sedimentations rates, has been impossible up until now. However, during ODP Legs 160 and 161 to the eastern and western Mediterranean, respectively, sapropel-containing sediments of a Recent to Miocene age were recovered from several sites by hydraulic coring techniques, enabling such a direct comparison. We have sampled at high resolution (~1 sample per cm) a total of nine different Pliocene-Pleistocene sapropels in four ODP sites and in the Vrica (Calabria, Italy) and Punta Piccola (Sicily) sections (Fig. 1). Time equivalence of the sapropels in the marine cores and the land sections has been proved by astronomical tuning. The samples were analysed for organic carbon, carbonate and opal content, and for major, minor and trace elements (by ICP-AES).

Although the sapropelic organic carbon content varies from slightly <1% in the land sections to >30% in the marine cores, the sapropels share most geochemical characteristics. They are generally enriched in organic carbon, sulphur and phosphorous, terrestrial elements (Al, Fe, Mg, Na, K, Li, Co, Ti, Zr, Sc and Y), barium, and chalcophilic and redox-sensitive trace metals (As, Sb, Se, Mo, Cd, Cu, Ni, V and Zn), whereas they are depleted in carbonate content and manganese. These characteristics are always stronger developed in the marine cores than in the land sections.

There is threefold evidence for increased primary productivity during sapropel formation: (1) Increased barium in the sapropels. The sedimentary barium is

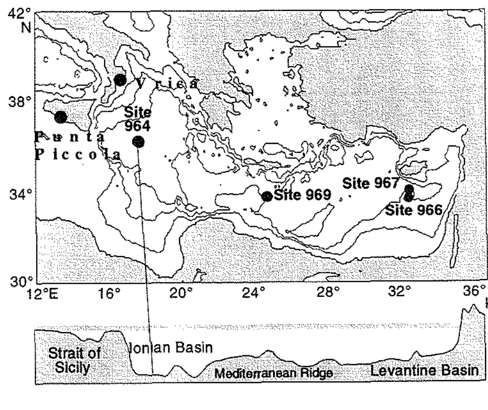

FIG. 1. Location of the ODP Sites and the Vrica and Punta Piccola land sections.

considered a reliable palaeoproductivity indicator. (2) High opal content in some of the sapropels. Sedimentary opal is derived from diatoms and radiolarians which bloom under high productivity conditions. (3) High organic carbon accumulation rates. These accumulation rates are so high, that they cannot be explained by increased preservation alone.

The barium signal is absent in the Vrica section, whereas it is strong in the time-equivalent ODP sapropels. This may be explained by the shallow depositional depth of the Vrica section (Von Breymann *et al.*, 1992).

There is also abundant evidence for anoxic conditions during sapropel formation: (1) lamination of the sapropels, indicating the absence of benthic activity (bioturbation); (2) strong enrichment of chalcophilic and redox-sensitive trace elements; (3) the abundance and sulphur isotopic composition of pyrite (Bosch *et al.*, this volume); (4) the occurrence of isorenieratene-derived molecular fossils, indicating photic zone euxinia in some sapropels (Bosch *et al.*, this volume)

It has been shown that at low sedimentation rates (as in the pelagic Mediterranean) low bottom water oxygen content results in increased preservation of organic matter (Canfield, 1994). Therefore, sapropel formation is the result of both increased productivity and improved preservation.

Calculations performed on the data from marine cores showed that sedimentation rates must have been more or less constant during sapropel formation, because a considerable increase in sedimentation rate would result in unrealistically high organic carbon accumulation rates, whereas a decrease in sedimentation rates would yield sapropel formation times longer than half a precession cycle, which does not fit the pattern of the Ti/Al curve, which closely follows the precession index (Lourens, Wehausen and Nijenhuis, work in progress). Calculating sapropel formation time for the marine Vrica equivalents yields a duration of 6300 years. If we calculate the duration of the sapropel in the land section under the same assumption, a formation time of only ~2000 years is obtained. So unless the sedimentation rate decreased significantly during the formation of this sapropel in the Vrica section, sapropel formation duration must have been much shorter in the shallow parts of the Mediterranean than in the pelagic range.

References

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