Why Drill Sapropels (Again)?
An effort to study the depositional history and environmental development during the formation of Sapropels in the Mediterranean.

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The discovery of multiple layers of sapropels and sapropelic sediments in the Eastern Mediterranean Sea during the Swedish Deep-Sea Expedition (KULLENBERG, 1952) marks the onset of a controversial dispute among marine geologists concerning the depositional environment responsible for their formation. In spite of considerable scientific effort and an increasing data base on their sedimentological, faunal, chemical, and isotopic characteristics, sapropels still elude simple explanations.

Opinions are divided into two broad lines of thinking: One line favors intermittent anoxia of deep waters, which would impede remineralisation of organic matter at the sediment-water interface and enhance its preservation. Anoxia could have been established by either increased fresh-water runoff due to increased monsoonal rainfall or increased runoff after melting of continental ice sheets, by inhibition of deep-water formation, or by capping the Mediterranean surface water with less saline water from the Atlantic. The other line of reasoning argues that pulses of high biological productivity in the surface waters is the key to understanding sapropel formation (PEDERSEN and CALVERT, 1990). It is well demonstrated that most of the correlative and coeval sapropel layers in the eastern Mediterranean were deposited during climatic optima in the Pleistocene glacial epoch (RYAN, 1972; THUNELL *et al.*, 1978; ROSSIGNOL-STRICK, 1984; Fig. 1). In analogy with climatically-induced changes in biological productivity during the Pleistocene in other parts of the world ocean, production and accumulation of organic carbon may have been greatly increased in response to changes in water circulation leading to upwelling of nutrient-rich waters. Both hypotheses agree that sapropels signal distinctive changes in the physical circulation and chemical environment of the Mediterranean Sea (Fig. 2), and that climate changes are the driving factor (CITA *et al.*, 1977). The discovery of sapropels throughout the entire stratigraphic succession of post-messinian marine sediments in the eastern basins of the Mediterranean and the Tyrrhenian Sea shows that the entire basin was affected by the changes, even if resulting facies variations were much less pronounced in the western basins.

A renewed effort to elucidate the responses of the carbon cycle in the Mediterranean to climatic forcing on one hand, and the relative importance of preservation and production in burial of organic carbon in the geologic record on the other hand is needed and timely: Clarification of environmental conditions in the Mediterranean during times of sapropel formation and the exact timing of environmental changes will thus have implications exceeding any regional interest and may be applicable to the entire world ocean. New tools and concepts that evolved during the last few years may aid in this clarification: A transect of piston-core drill sites targeted on hemipelagic, undisturbed sedimentary sections deposited on structural highs since the end of the Messinian and bracketing all major basins of the Mediterranean will permit to trace the physical, chemical, and biological response to external forcing in high resolution. In addition to traditional sedimentological and paleontological work, focus of post-cruise work should be on :

- high-resolution isotope analyses of foraminiferal carbonate to establish a basin-wide and detailed stratigraphy,
- statistical treatment of faunal and floral assemblages to constrain surface- and bottom-water conditions at each site through time,
- analyses of redox-sensitive chemical tracers to establish the importance of bottom-water oxygenation for sapropel deposition,
- reconstruction of biological productivity and carbon burial through organic and inorganic tracers,
- determining the temporal variations of temperature and salinity as recorded by chemical and faunal indicators through time.

Given the large carbon reservoir of the world ocean, study of boundary conditions during sapropel deposition the the Mediterranean will provide a better understanding of the mechanisms which define the architecture of the ocean s carbon reservoir. This in turn controls the atmospheric chemistry and hence Earth's climate.

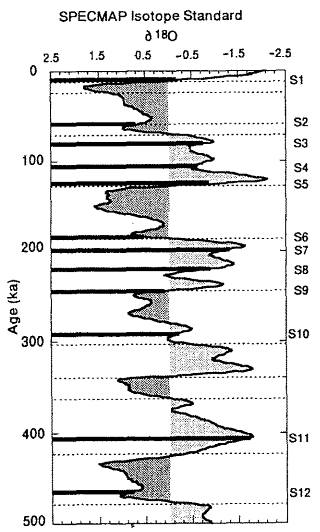

Fig. 1:
Sapropel occurrences in relation to the global record of isotope changes in planktonic foraminifers Shaded are warm and cold periods, respectively.

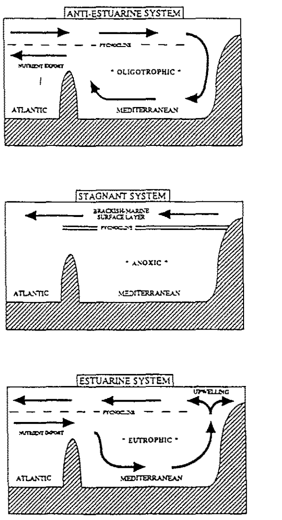

Fig. 2:
Models of possible oceanographic and chemical variability responsible for sapropel formation.

REFERENCES

CITA M.B., VERGNAUD-GRAZZINI C., ROBERT C., CHAMLEY H., CIARANFI N. and D'ONOFRIO S., 1977.- Paleoclimatic record of a long deep-sea core from the eastern Mediterranean. *Quat. Res.* 8/205 - 235.

KULLENBERG B., 1952.- On the salinity of water contained in marine sediments. *GoteborgsKungl. Vetens. Vitter. Handl. Ser. B.* 6/3-37.

PEDERSEN T.F. and CALVERT S.E., 1990.- Anoxia vs. productivity: what controls the formsation of organic-carbon-rich sediments and sedimentary rocks? *AAPG Bull.* 74/454-466.

ROSSIGNOL-STRICK M., NESTEROFF W., OLIVE P. and VERGNAUD-GRAZZINI C., 1982.- After the deluge: Mediterranean stagnation and sapropel formation. *Nature* 295/105-110.

THUNELL R.C., WILLIAMS D.F. and KENNETT J.P., 1977.- Late Quaternary paleoclimatology, stratigraphy, and sapropel history in the eastern Mediterranean deep-sea sediments. *Marine Micropaleontology* 2/371-388.

ODP Targets on sediment deformation and post-Messinian depositional patterns of the outer deformation front of the Mediterranean Ridge accretionary complex

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A re-examination of the multichannel seismic coverage of the Mediterranean Ridge (Eastern Mediterranean) has been done motivated by growing attention to the evolution of accretionary wedges.

Although preliminary results of the extensive geophysical investigations conducted by OGS in the whole Mediterranean Sea from 1969 to 1982 have been published by the principal investigators (FINETTI and MORELLI, 1972 and 1973), most of the MCS lines of the Eastern Mediterranean (FINETTI, 1976 and 1982) are still unpublished and no definitive interpretation has been proposed in the frame of the recent identification of the Mediterranean Ridge as an accretionary prism in a collisional setting.

MCS lines crossing the outer deformation front of the ridge that extends from west to east from the Messina and Sirte abyssal plains (Ionian Sea) to the Herodotus abyssal plain (Levantine Sea) reveal two different styles of initial deformation of the sedimentary sequence entering the subduction zone: 1) to the Southwest, where the deformation front is orthogonal to the direction of plate convergence, a thin post-Messinian sedimentary sequence (up to 450 ms TWT) only slightly disturbed by initial salt-diapirism is coherently and abruptly uplifted. A re-processed version of line MS-33, which includes migration, shows evidence of seaward vergent thrusting and back-thrusting. 2) to the Southeast, where the ridge is oriented at a small angle with the direction of plate convergence and left lateral strike-slip movement occurs in the Pliny and Strabo branches of the Hellenic Trench, a thick post-Messinian sedimentary sequence (over 1800 ms TWT) is gently deformed by seaward vergent folding and reverse faulting with formation of piggyback sedimentary basins (over 2400 ms TWT). Salt deformation and initial salt diapirism in the core of anticlines of the SE margin of the Mediterranean Ridge show typical characteristics of other salt-bearing fold and thrust belts.

In the Levantine portion of the Mediterranean Ridge, the following depositional patterns can be identified in the post-Messinian sequence:

1) The overall Plio-Quaternary sediment thickness decreases from north to south across the deformation front.

2) The internal pattern of the uppermost Messinian and/or lowermost PlioQuaternary units (i.e. post evaporites) indicates a southward sediment progradation directly overlying the top-of-the-evaporites Messinian horizon. Northward sediment progradation occurs in the overlying remaining Plio-Quaternary sequence.

3) The sediment thickness of the Plio-Quaternary sequence does not increase significantly as the Nile Cone is approached from the Herodotus abyssal plain.

Drilling targets:

On the Sirte deformation front: A transect of at least three shallow holes in the post-Messinian sequence across the deformation front would allow the estimation of rates of uplift and outward growth of the outer edge of the western Mediterranean Ridge. Timing of the change of sedimentation pattern (from basinal to hemipelagic) will be provided by the well tested high resolution litho- and bio-stratigraphy of the Pleistocene of the Eastern Mediterranean. Pliocene high resolution stratigraphy is to be refined through drilling a reference site on a all-pelagic Plio-Quaternary site.

On the Herodotus deformation front: A single hole located on a buried anticline crest through a condensed Post-Messinian section would allow to tie the main unconformities, time the rate of folding, and investigate the nature of the northward versus southward sediment progradation. A working hypothesis is that the southward propagating unit overlying the evaporitic sequence may represent a sediment provenance from Paratethys (i.e. Black Sea "Lago Mare") in latest Messinian (post evaporites) time soon replaced by a Nile derived northward prograding sediment provenance.

REFERENCES

FINETTI I., 1982.- Structure, stratigraphy and evolution of Central Mediterranean. *Boll. Geofis. Teor. Appl.*, 24(96):247-312.

FINETTI I., 1976.- Mediterranean Ridge: a young submerged chain associated with the Hellenic Arc. *Boll. Geofis. Teor. Appl.*, 18(69):31-65.

FINETTI I. and MORELLI C., 1973.- Geophysical exploration of the Mediterraneran Sea. *Boll. Geofis. Teor. Appl.*, 15(60):261-241.

FINETTI I. and MORELLI C., 1972.- Wide scale digital seismic exploration of the Mediterranean Sea. *Boll. Geofis. Teor. Appl.*, 14(56):291-342.

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