Figure 1. Location of ODP Site 967.

Earth's Orbit and the Mediterranean

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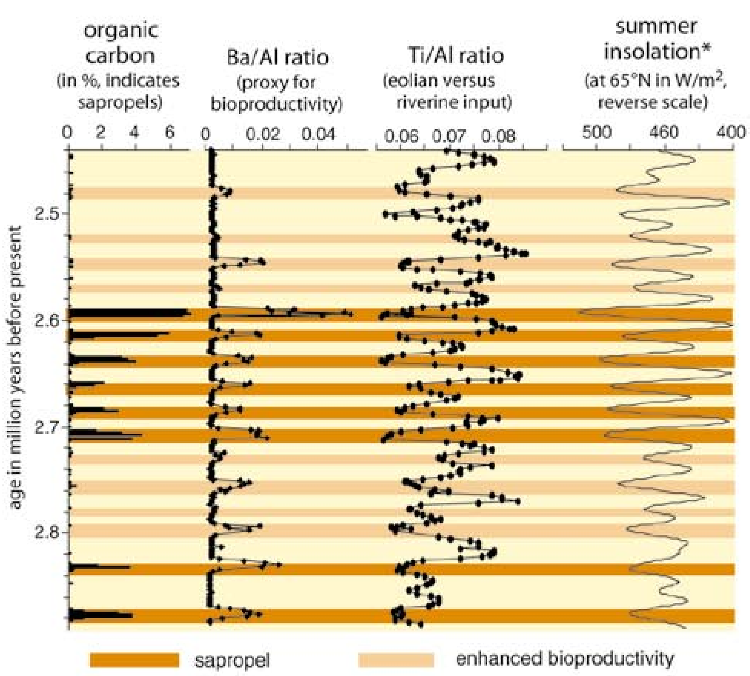
ODP cores from the eastern Mediterranean Sea provide a record of climate change that can be linked to astronomical cycles. These cores reveal sapropels, which are black layers rich in organic matter, sulfides, and heavy metals, indicating that the Eastern Mediterranean has frequently become an oxygen-depleted basin during the past 5 million years. These intervals result from both the 21,000 -year cycle of Earth's orbital precession and the unique basin structure of the Mediterranean. The Eastern Mediterranean is semi-enclosed, with only one shallow connection (Strait of Sicily) to the Western Mediterranean, and contains deep subbasins (up to 4,000 meters): features that cause the environment to be very sensitive to changes in surface water density. Currently, strong evaporation of seawater results in a high salt concentration and high surface water density. During times of sapropel formation, the salt-driven deep water formation of the Eastern Mediterranean slowed considerably because of a higher freshwater contribution, which in turn lowered the surface water density. At the same time, marine plankton grew faster due to a more efficient recycling of nutrients from the subsurface.

ODP Site 967 (Figure 1) is located in the southeastern part of the basin where the most important freshwater source is the Nile River. Each time a perihelion occurred during a Northern Hemisphere summer (i.e., during maximal Northern Hemisphere summer insolation, the Earth's annual closest approach to the sun), the East African monsoon was much more intense than today. This process lead to a strong flood of the Blue Nile in the Ethiopian highlands and subsequently to a strong Nile runoff into the Eastern Mediterranean (Rossignol-Strick, 1983).

The frequent switch over from more arid and nutrient-poor conditions to more humid and nutrient-rich conditions every 21,000 years is not always expressed in form of a sapropel or by an increase in bioproductivity. But each cycle is, however, documented by the chemical composition of the land-derived fraction of Eastern Mediterranean sediments (Wehausen and Brumsack, 1999 and 2000). One specific geochemical parameter, the ratio of titanium (Ti) versus aluminium (Al), was found to provide an exceptional cyclic record that is near-linear and related to changes in Northern Hemisphere summer insolation (Lourens *et al.*, 2001). This element ratio reflects changes in the relative contribution of Saharan dust versus Nile-derived material (Figure 2).

Such a quantitative climate proxy record like the Ti/Al ratio offers, for the first time, the possibility to perform a statistical comparison between geological information and different astronomical solutions (Loutre, 2001). This new approach supports the crucial role of late Cenozoic Mediterranean sediments in the establishment of astronomical timescales (Hilgen *et al.*, 1997).



* La90(1,0.5) solution, see Lourens et al. (2001)

Figure 2. Pliocene sediment sequence from ODP Leg 160 Site 967, south of Cyprus, Eastern Mediterranean