Black Sea: Recent Sedimentary History

Abstract. *Three distinct sedimentary units, which can be correlated throughout the basin, occur in cores collected from the Black Sea. Carbon-14 ages help to define the recent sedimentary history of the Black Sea.*

In the spring of 1969, a detailed oceanographic survey of the Black Sea was made on the R.V. *Atlantis II*. One of our major objectives was to investigate the origin and history of the recent sediments. Over 60 piston, gravity, and kasten (box) cores were obtained from the area; the longest core was 11.5 m. In addition, hydrocasts were taken at most coring stations, and gravity, magnetic, and continuous seismic profiling observations over more than 5,000 km were made between stations. We report here some preliminary results.

One core, from the eastern part of the basin, has been extensively studied and is used as a standard section for comparison with other cores (Fig. 1). This core contains three distinct sedimentary units. The uppermost unit, about 30 cm thick, is distinguished by light microlaminated layers of high carbonate content with intervening darker layers that contain lesser amounts of carbonate and more organic material. These layers number between 50 and 100 per centimeter and suggest some

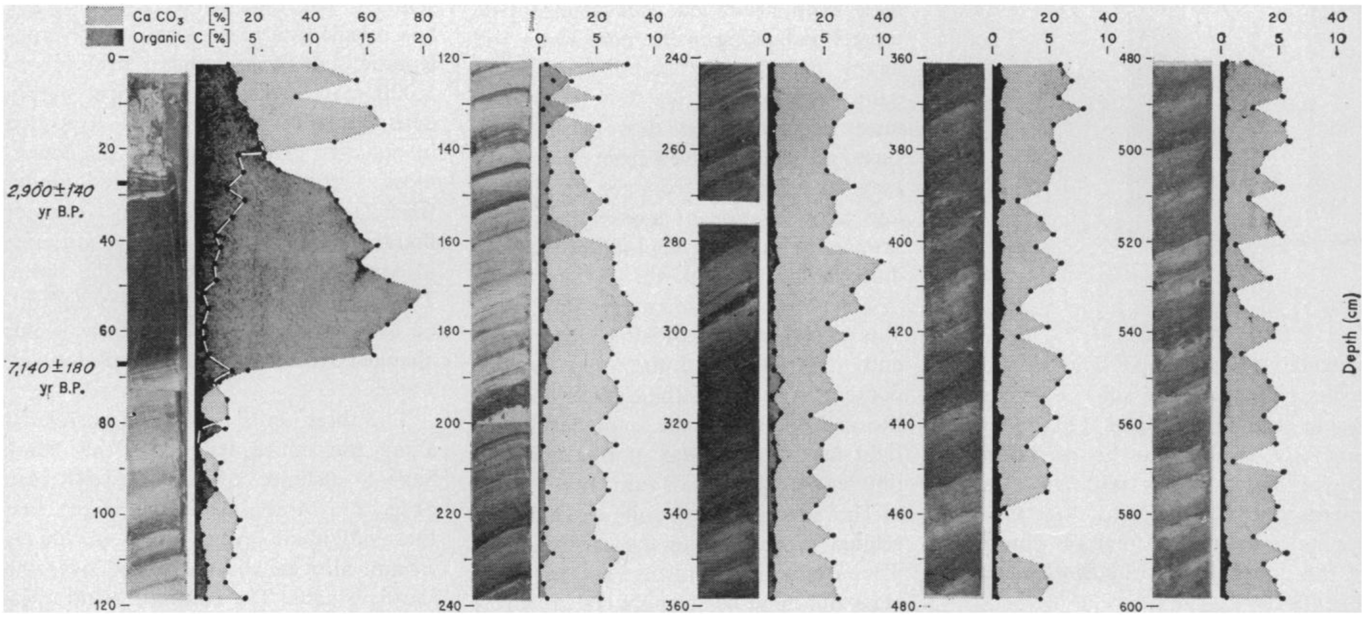

Fig. 1. Distribution of calcium carbonate and organic carbon in the upper 6-m section of core 1474 K (*9*).

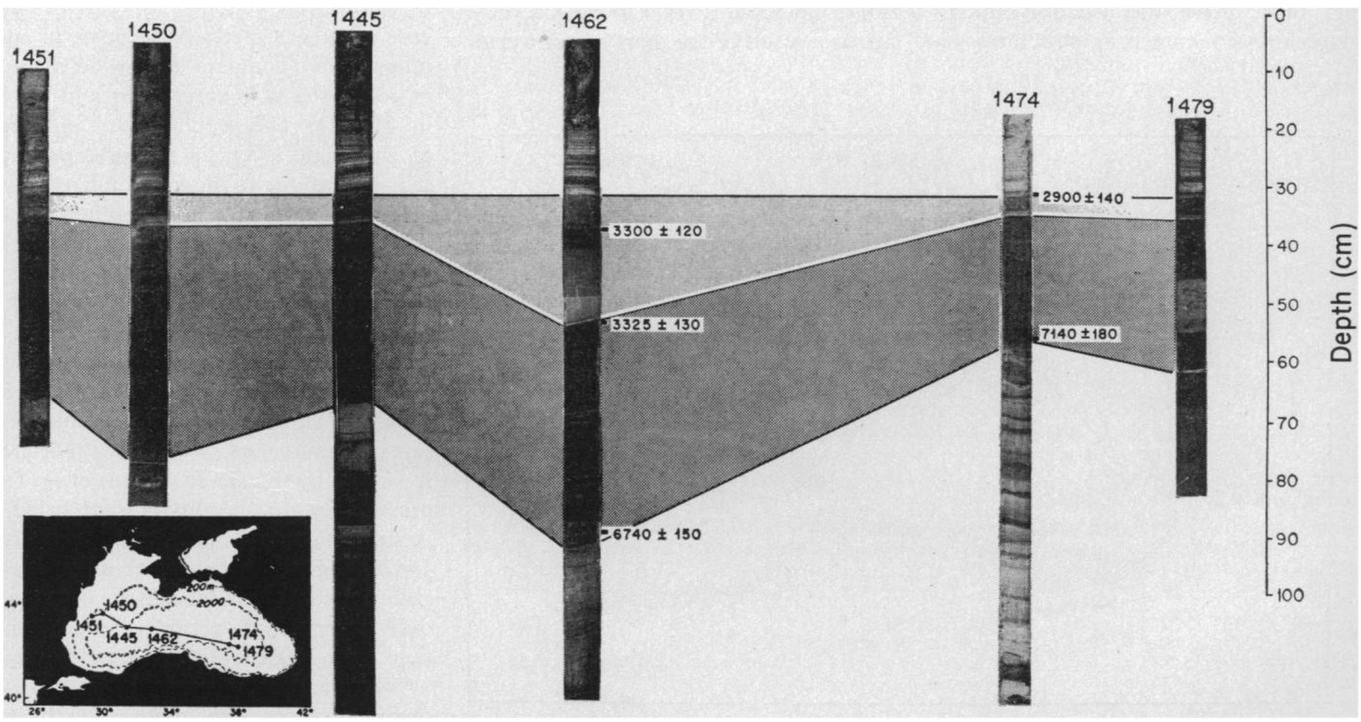

Fig. 2. Sediment core profile across the Black Sea basin. Note the abrupt stratigraphic changes at about 7,000 3,300, and 2,900 years B.P., which can be recognized in most cores from the deep basin.

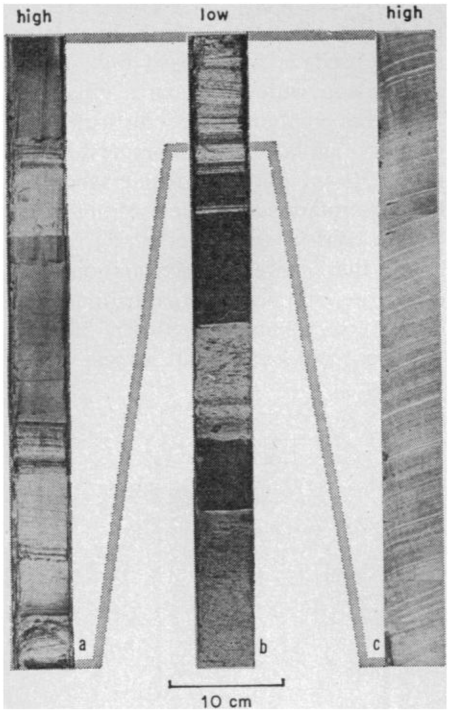

Fig. 3. Relative deposition rate in three representative sedimentary cores. Three kinds of patterns can be recognized in the upper sections of the cores: core a, high rate of sedimentation due to occasional turbidite flows; core b, low rate of sedimentation (about 10 cm per 1,000 years) showing alternate layers of white coccolith and organic-rich bands; and core c, high rate of sedimentation at an evenly distributed rate.

seasonal relationship. The carbonate layers have been the subject of considerable study in the past (*1*) and were generally thought to be of inorganic origin. Recent work with an electron microscope (*2*) indicates that the carbonate fraction is mainly composed of the coccolithophorid *Emiliania huxleyi*.

The second unit, about 40 cm thick, is characterized by an extremely high content of organic matter. Studies of this unit under the electron microscope showed numerous structures resembling biological membranes, features not normally found so deep in marine sediments. These membranes have been preserved because dissolved oxygen is lacking in the pore water and heavy metals have stabilized the organic structures (*3*). The possibility must be considered that these structures, although derived from organisms, may have resulted from the dissolution and reaggregation of membranes in response to salinity fluctuations in the diagenetic environment.

The lowest sedimentary unit consists of a sequence of alternating light- and dark-colored lutite; the organic content is higher in the dark layers and the carbonate content is higher in the light layers. The base of this unit was not reached in any of our cores.

The succession of units obviously is related to changes in the environment. The exact mechanisms are not yet clear but must be strongly controlled by events in the recent geologic history of the Black Sea. The Black Sea was isolated from the Mediterranean for a period from about 20,000 to 10,000 years ago as a result of the most recent world-wide lowering of sea level. During the latter part of this interval, the melting of the ice increased and enough fresh water reached the Black Sea to make it a freshwater lake. Studies of pore water show a general decrease in interstitial salinities with increasing core depth (*4*). The reconnection of the Black Sea with the Mediterranean through the Bosporus probably occurred between 7,000 and 12,000 years ago (*5*). After this reconnection salt water from the Mediterranean entered the Black Sea and slowly increased its salinity. The date at which the Black Sea reached its present salinity is problematic, but it may have been about 3,000 years ago when the upper carbonate sequence started being deposited in quantity. Thus, much of the lowermost sequence was deposited under freshwater conditions when frequent flooding carried relatively large amounts of terrigenous material into the basin. The organic-rich sequence was deposited as flooding decreased and the water changed from fresh to present-day salt water.

The three units have been correlated along the entire length of the Black Sea—a distance of almost 1,000 km (Fig. 2). More impressive is the fact that individual layers, some as thin as 1 mm, also can be correlated over the same distance. The continuity and ubiquity of these layers attest to the uniform depositional environment over most of the Black Sea. However, layers that are a few centimeters apart in one core may be a meter or so apart in another core (compare the middle part of core 1462 with cores 1474 and 1445 in Fig. 2). The separation or spacing of carbonate layers in the stratigraphic sequence is due to increased terrigenous deposition, which can be either catastrophic (slump or turbidity current) deposition, or continuous, relatively fast sedimentation (Fig. 3). The "normal" sequence is shown in the middle core (Fig. 3) (although the organic unit is interrupted by a turbidite). Core a (Fig. 3) shows carbonate sequences several centimeters in thickness that are separated by thicker sequences of lutite, presumably of turbidity-current origin. A similar example can be seen in core 1462 (Fig. 2), where carbon-14 ages indicate that the deposition occurred over a very short period of time, perhaps as a single event. In core c (Fig. 3) the carbonate layers are distinctly separated from one another by lutite layers. This layering pattern, typical of cores collected near large rivers, we be-

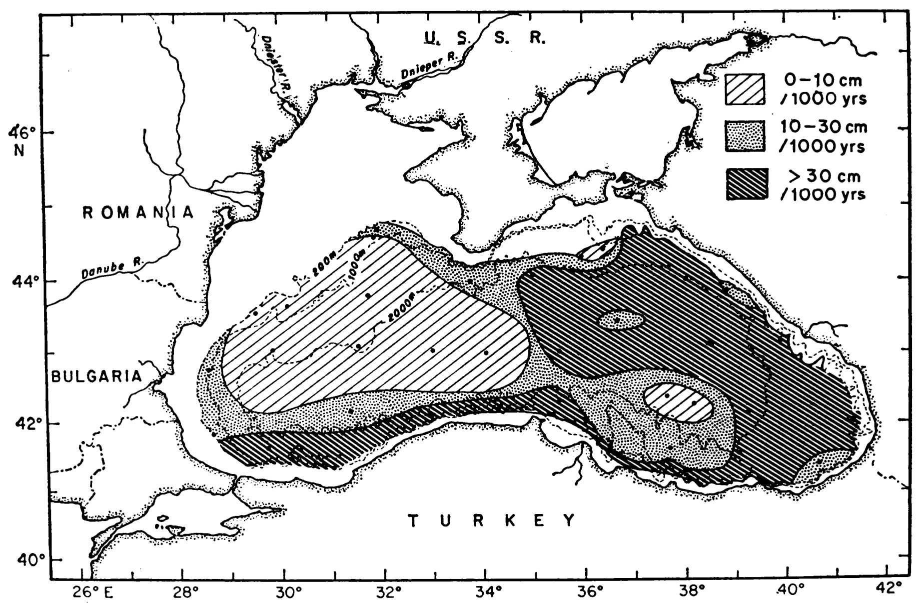

Fig. 4. Sedimentation rates in the Black Sea for the past 3,000 years. ●, Sample locations.

lieve to be due to a continuously high sedimentation rate.

Carbon-14 ages for the base of the upper carbonate unit are about 3,000 years B.P., and for the organic unit about 7,000 years B.P. The sedimentation rate for these two units within the "normal" sequence is thus about 10 cm per 1,000 years. Sedimentation rates for other cores, where the sequences are extended or interrupted, can be established if the base of one of the units can be identified. This has been done for the upper carbonate unit, and using this method, we have determined the sedimentation rates for the most recent sediments of the Black Sea (Fig. 4).

Radiocarbon analyses of the total dissolved carbonate present in the oxygen-containing surface waters of the Black Sea (0 to 100 m) show essentially recent ages, and an isotopic abundance δ for carbon-14 of -20 ± 10 has been calculated for prebomb times (*6*). It can thus be safely concluded that the organic matter produced in such waters reflects this zero age. We thus assume that the age of the organic matter at the sediment-water interface is essentially zero. We also assume that our cores sampled the entire carbonate unit (*7*).

Sedimentation rates greater than 30 cm per 1,000 years occur in the eastern part of the basin and along the Turkish coast. Turbidites are common in cores from the eastern part of the basin. Cores collected along the Turkish coast are similar to those shown in core c (Fig. 3), probably reflecting the high sedimentation rate due to the many rivers along this mountainous coast.

Sedimentation rates are relatively low in the western part of the Black Sea. Sediments from the Danube, Dniester, and Dnieper rivers are apparently trapped in the estuaries and on the broad continental shelf of that area and presently do not reach the deeper parts of the basin. Seismic reflection profiles in this area indicate that these rivers were an important source of sediment in the past and that the rivers had built a fan almost across the basin (*8*).

In the results reported here we have touched only on the general aspects of the recent sediments. As more detailed studies proceed, widespread events of shorter duration will certainly become evident. For example, several thin white layers are present in the organic-rich unit; the uppermost of these layers is composed of coccolithophorids; the lowermost band is aragonite of a so far unidentified origin. Clearly, the Black Sea sediments offer rare possibilities for the establishment of detailed correlations and the interpretation of changes in a recent depositional environment.

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7. We used several different coring devices, and in all instances (in the "normal" sequence) we obtained about 30 cm of the carbonate unit. If our assumption of satisfactorily coring the entire carbonate unit is incorrect, the sedimentation rates are conservative.
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9. E. T. Degens and D. W. Menzel, unpublished data.
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Thermal Conductivity of Lunar and Terrestrial Igneous Rocks in Their Melting Range

Abstract. *The thermal conductivity of a synthetic lunar rock in its melting range is about half that of a terrestrial basalt. The low conductivity and increased efficiency of insulating crusts on lunar lavas will enable flows to cover great distances without being quenched by high radiant heat losses from the surface. For a given rate of heat production, the thermal gradient of the moon would be significantly steeper than that of the earth.*

Any attempt to interpret the origin and behavior of lunar magmatic rocks requires an evaluation of their thermal properties at high temperatures. Previous measurements of the thermal diffusivity and conductivity (*1*) of Apollo 11 specimens have been made at temperatures below 150°C. We have obtained data up to 1500°C for a synthetic sample of lunar composition and have made comparable measurements on a variety of terrestrial volcanic rocks.

The sample of lunar composition used in our measurements was prepared according to the reported major-element analysis of Apollo 11 specimen 22. The sample was prepared by the method described in our earlier report on the viscosity of the same sample (*2*). By adding small amounts of sample during the melting it was possible to eliminate bubbles. Samples of basalt and andesite were found to have negligible porosity at all temperatures. The synthetic lunar sample contained no bubbles when quenched from 1000°C but developed about 3 percent interstitial pore space on crystallizing. The porosity of rhyolite was about 3 percent, and the measured thermal conductivity values were corrected to zero porosity (*3*).

We used a radial heat-flow technique (Fig. 1) in which conductivity k is calculated from the relation (*3*):

$$k = \frac{I\,V}{2\pi LJ(T_1 - T_2)} \ln \frac{R_2}{R_1}$$

where I and V are the electrical current and potential through a platinum resistance heater of length L (5 cm), J is the mechanical equivalent of heat, R_1 and R_2 are the radial distances of the inner and outer thermocouples, and T_1 and T_2 are the temperatures of the inner and outer thermocouples. The sample was placed in a cylindrical platinum crucible 5 cm in diameter and 5.5 cm high with the heater positioned at the axis of the crucible and with the two thermocouples at distances of about 0.7 and 1.1 cm from the heater. A temperature difference of less than 10°C was produced by 10 watts of power supplied to the heater.

Initial measurements were made at 1500°C, and measurements were repeated at successively lower temperatures, several hours apart, so as to allow the system to reach a steady state. A second series of measurements was made as the temperature was raised, and close agreement was obtained between heating and cooling cycles. A