Chapter 1
Diagenesis, Catagenesis and Metagenesis of Organic Matter

The physicochemical transformation of organic matter during the geological history of sedimentary basins cannot be regarded as an isolated process. It is controlled by the same major factors that also determine the variations of composition of the inorganic solid phase and of the interstitial water of the sediments: biological activity in an early stage, then temperature and pressure. Furthermore, organic–inorganic interaction can occur at different stages of the sediments evolution. Nature and abundance of organic matter may result in different behavior of the mineral phase, shortly after deposition; composition of minerals and structure of the rock may influence composition and distribution of organic fluid phases at depth. An excellent picture of the conditions of deposition and early history of sediments has been given by Strakhov (1962), and will be frequently used in the following paragraphs.

A general scheme of evolution of the organic matter from the time of deposition to the beginning of metamorphism, is shown in Figure II.1.1. To understand the discussion, the following stages of evolution are considered: diagenesis, catagenesis, metagenesis and metamorphism. The acceptance of these terms in this book is somewhat different from that of Vassoevich et al. (1969, 1974). The two scales of evolution are shown in Figure II.1.2, with reference to the equivalent coal ranks and to the stages of petroleum generation.

1.1 Diagenesis

Sediments deposited in subaquatic environments contain large amounts of water (porosity amounts to about 80% in clay mud at 5 cm depth, i.e., water is 60% by weight of total sediment), minerals, dead organic material (contemporaneous autochthonous or allochthonous, and reworked), and numerous living microorganisms. Such a mixture results from various sedimentary processes and primary components of very different origins; it is out of equilibrium and therefore unstable, even if microorganisms are not present. **Diagenesis** is a process through which the system tends to approach equilibrium under conditions of shallow burial, and through which the sediment normally becomes consolidated. The depth interval concerned is in the order of a few hundred meters. In rare cases it may reach 2000 m. In the diagenetic interval, the increase of temperature and pressure is small, and transformations occur under mild conditions.
During early diagenesis, one of the main agents of transformation is microbial activity. Aerobic microorganisms that live in the uppermost layer of sediments consume free oxygen. Anaerobes reduce sulfates to obtain the required oxygen. The energy is provided by decomposition of organic matter, which in the process is converted into carbon dioxide, ammonia and water. The conversion is usually carried out completely in sands and partly in muds. At the same time $E_h$ decreases abruptly and pH increases slightly. Certain solids like organodetrital CaCO₃ and SiO₂ dissolve, reach saturation and re-precipitate, together with authigenic minerals such as sulfides of iron, copper, lead and zinc, siderite, etc.

Within the sediment, organic material proceeds also towards equilibrium. Previous biogenic polymers or “biopolymers” (proteins, carbohydrates) are destroyed by microbial activity during sedimentation and early diagenesis. Then their constituents become progressively engaged in new polycondensed structures (“geopolymers”) precursing kerogen. When deposition of organic matter derived from plants is massive compared to mineral contribution, peat and then brown coals (lignite and sub-bituminous coal) are formed. The most important hydrocarbon formed during diagenesis is methane. In addition organic matter