



## CHAPTER I

### INTRODUCTION

Crude oil is generally proposed to have been generated from organic-rich sediments containing organic matter derived from biological materials. The organic material consists of a complex assemblage of preserved organic molecules which in many cases can be directly related to the original, ancient, organic sources through their basic structures or carbon skeletons. Such structures or compounds were first utilized by Alfred Treibs when he identified metalloporphyrins in crude oils which in turn lead him to propose a biogenic origin for crude oils. For these compounds Eglinton and Calvin proposed in 1969 the term "biological markers" or "biomarkers" (EGLINTON et al., 1969). A definition of biomarkers proposed by PHILP (1985) was that they are organic compounds present in the geosphere whose basic carbon skeletons can be unambiguously linked to the structure of their precursor compounds which occur in the original source materials. As these compounds still have related structural features inherited from organic molecules of living organisms, they are capable of yielding "specific information" regarding the source, maturity, migration and biodegradation of crude oils (PHILP, 1987). "Specific information" in this context

means the original source of hydrocarbons in the subsurface from which the bitumen or petroleum was derived and the post-burial diagenetic conditions experienced by the organic matter (WAPLES, 1985).

The transformation processes involved in the conversion of the living organic matter to crude oil are very complex. In terms of the preservation and concentration of sedimentary organic matter the energy level in a body of water and rate of sedimentation must be optimally balanced (TISSOT and WELTE, 1978). Furthermore, the dissolved oxygen level will effect the preservation potential. Differences in the type of organic matter deposited and incorporated in the sediments will be characterized by differences in the relative abundance of compounds and detailed chemical structures of the source materials. In addition, the effects of migration, retention and alteration of the crude oils after their formation will also affect the residual organic matter in a sediment. Because the accumulation of organic matter in sediments is controlled by a number of geological boundary conditions, there are three primary factors which influence the amount of organic matter in a sedimentary rock: productivity, preservation and dilution (WAPLES, 1985).

The major process for the production of organic matter as reduced carbon is photosynthesis. Subsequently, an important mechanism for the fixation of organic carbon in the Earth's crust and the liberation of free oxygen

into the atmosphere is the accumulation of sedimentary organic matter. Crude oil is formed by the thermal maturation of organic matter in the sediment and depends upon the nature of the organic matter and/or its thermal history. The main stage of evolution of organic matter into crude oil consists of three stages: diagenesis, catagenesis and metagenesis (HUNT, 1979; TISSOT and WELTE, 1984). These are physicochemical transformations which are a function of several factors: variation of composition of inorganic solid phase, biological activity, organic-inorganic interaction, temperature and pressure. The first stage of evolution, diagenesis, commences in recent and shallow sediments under mild conditions. The temperature range for the alteration process is low and generally below 50°C (TISSOT and WELTE, 1984). The main agent of the transformation in this stage is microbial activity or simple chemical reactions. The organic biopolymer molecules in sediments are changed into "geopolymers" or kerogen precursors, by polycondensation reactions. Simple hydrocarbon molecules are formed at this stage as well as methane, CO<sub>2</sub>, H<sub>2</sub>O and some heavy heteroatomic molecules. This is the initial stage of kerogen and biomarker evolution and is illustrated by Figs. 1 and 2.

As sedimentation and subsidence continue, catagenesis occurs with the accompanying increase in temperature and pressure. Kerogen structures are degraded by thermocatalytic reactions. Wet gas, oil,

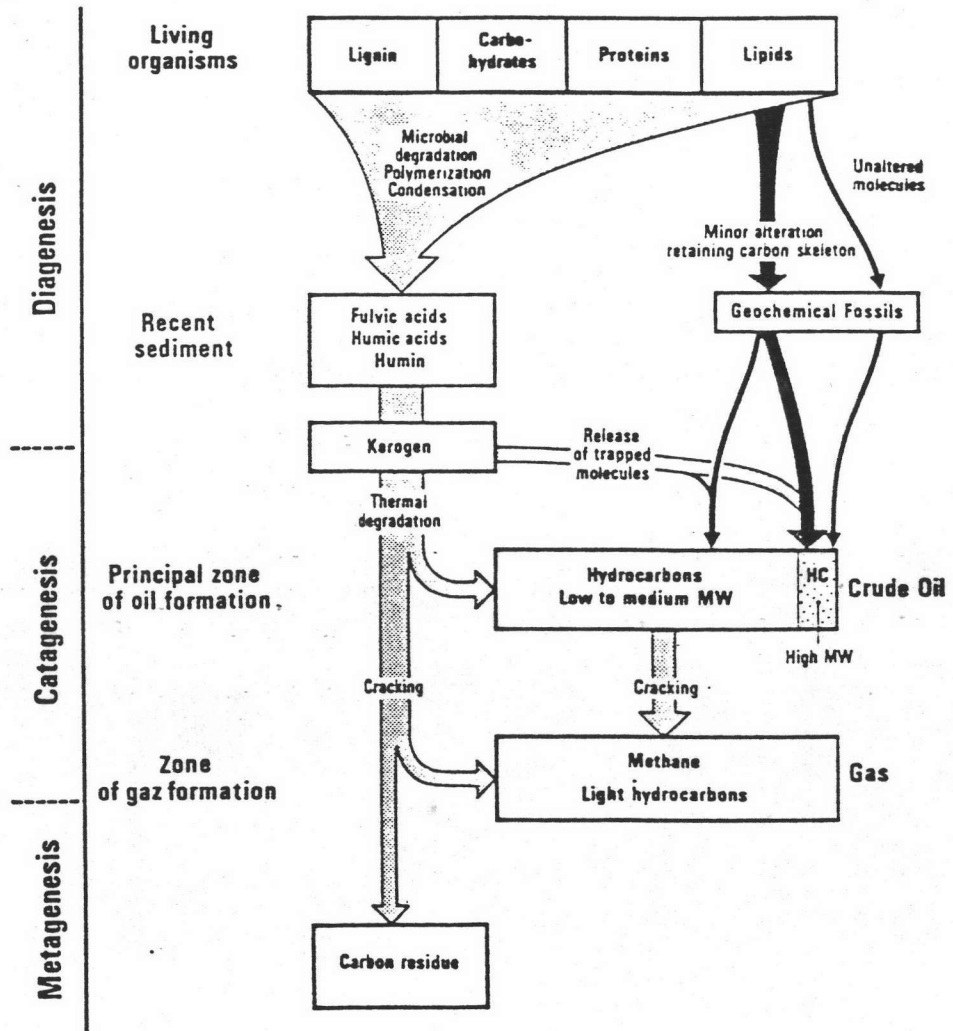


Figure 1. General scheme of evolution stages of organic matter in sediment in geosphere (from TISSOT and WELTE, 1978).

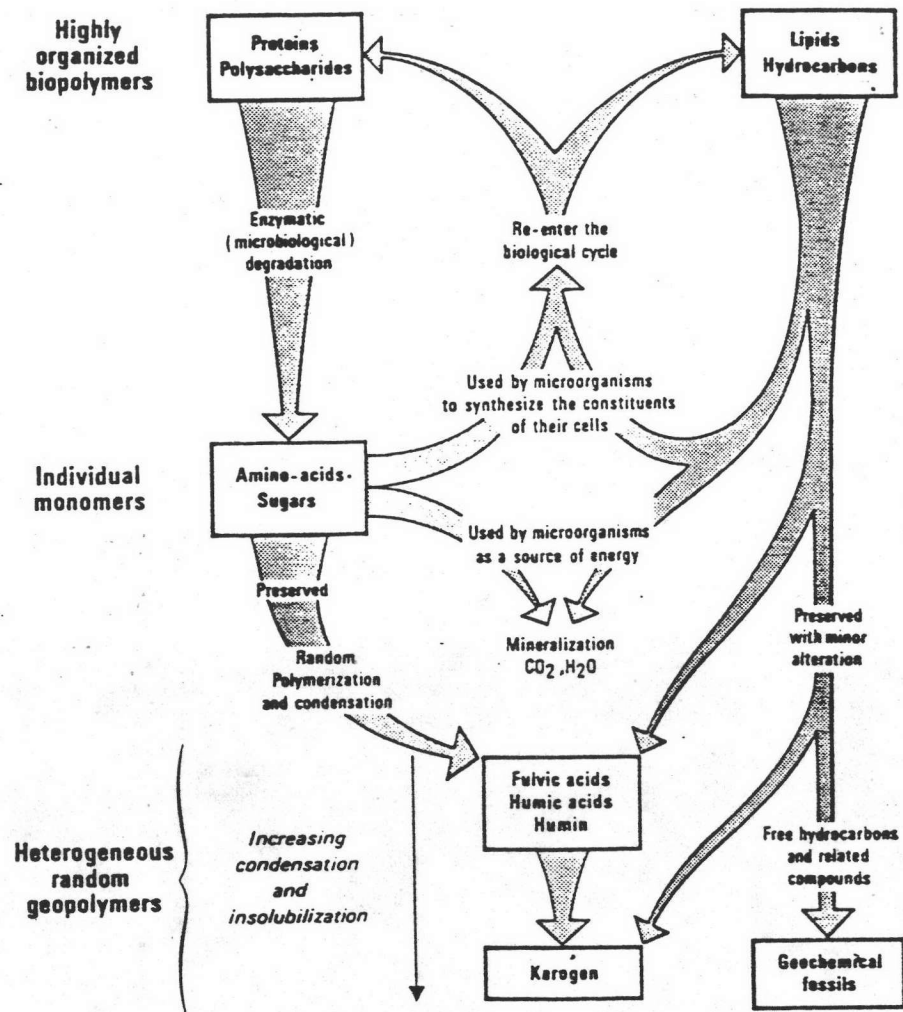


Figure 2. Diagenetic pathway from organic biopolymer molecules to kerogen and biomarker or geochemical fossil in the diagenesis stage (from TISSOT and WELTE, 1978).

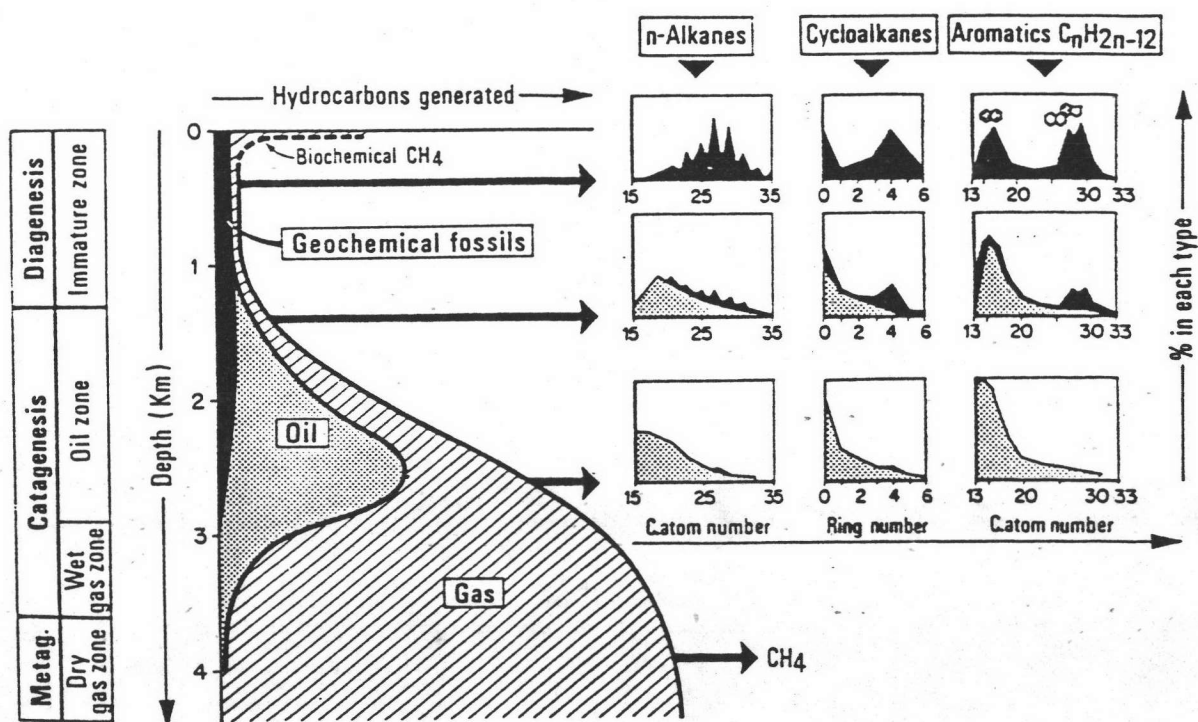


Figure 3 Hydrocarbon generation scheme according to the particular geological conditions : type of kerogen, burial history, geothermal gradient (from TISSOT and WELTE, 1984).

residual kerogen as well as smaller molecular fragments are generated. For this stage the temperature may range from 50-150 C and geostatic pressure may vary from 300 to 1000 or 1500 bars (TISSOT and WELTE, 1984). This is the principal stage of oil formation in which new hydrocarbon molecules are generated within the main zone of oil generation. Biomarkers already present are diluted by new hydrocarbons generated in this process. The general scheme of hydrocarbon generation as a function of the type of kerogen, burial history and geothermal gradient is shown in Fig. 3.

When the sediments reach the maximum burial depth, temperatures and pressures may become high enough such that the sediments undergo metagenesis. Although no significant amount of liquid hydrocarbons are generated from kerogen during metagenesis, large amounts of methane are generated both from the breakdown of the kerogen and the liquid petroleum. However, metagenesis of organic matter is a different process from the metamorphism of sedimentary rocks. From this stage, the temperature and pressure precede metamorphism of rock under lower conditions. During metagenesis, the residual kerogen is converted into graphite, all heavy hydrocarbons are cracked into light hydrocarbons and the resulting metamorphic rock facies are greenschist and amphibolite facies (WAPLES, 1985).

The generation of hydrocarbons from sedimentary organic matter causes an increase in the molar volumes of

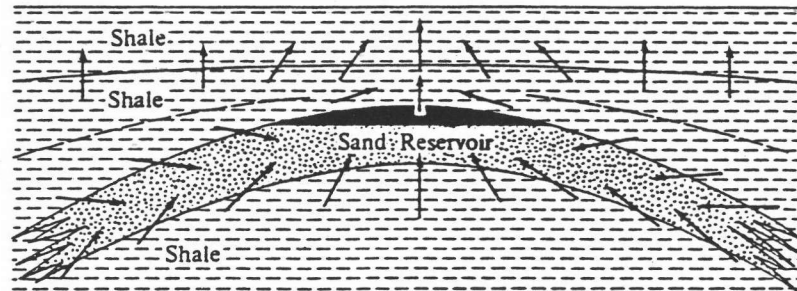
hydrocarbon and an increase in the pressure within the sedimentary source rocks. Microfracturing and expulsion will occur in order to release overpressuring in the rock (WAPLES, 1985) since the shear strength of the source rock will have been exceeded. With an increase in bulk density and the loss of porosity with increasing depth, temperature and time produces compaction of the rock. Fluid flow through sedimentary rock due to compaction will effect petroleum migration. Because this fluid movement has been guided by the permeability in the sediment, continuous movement of fluid then continues as long as the compaction progresses. The migration of hydrocarbons caused by compaction of source sediment to a reservoir rock is called primary migration. There are three different aspects concerning changes in chemical composition during primary migration. These aspects are the changes in hydrocarbon distribution with migration distance, the differences in chemical composition of crude oils, and of source rock bitumens. The important controlling processes along the migration paths are adsorption and desorption. An increase in the depletion of the total extract will be approached. Differences in hydrocarbon gross chemical composition with respect to migration distance can be investigated by correlation between crude oil and source rock bitumens. In hydrocarbon phase migration, crude oils are usually enriched in saturates rather than polar compounds compared to source rock bitumens. Studying biomarker



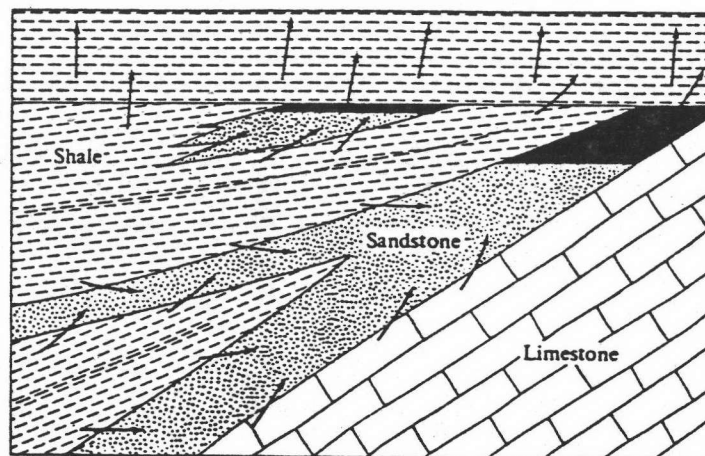
compounds at this stage can reveal hydrocarbon migration pathways and thermal maturation of organic source materials. Schemes proposed for oil migration into several types of reservoir are shown in Figure 4.

Secondary migration is used for the processes by which hydrocarbon are expelled from the source rock in a separated hydrocarbon phase. These processes are influenced by bouyancy and hydrodynamic flow (WAPLES, 1985; TISSOT and WELTE, 1984) which induce petroleum compounds to move along permeable and porous carrier beds into reservoir rock where separation into oil and gas phase would occur. The end result of secondary migration is hydrocarbon pools or petroleum accumulation caused by sufficient capillary pressure effects and lithologic change (TISSOT and WELTE, 1984; HUNT, 1979; WAPLES, 1985). Cap-rock, seals or barriers are necessary for the movement to cease. The direction and pathway of the vertical and horizontal migration through permeable sands, fracture zones and unconformities can be determined by geochemical correlation between reservoir oils and source rock extract. Figure 5 shows displacement and segregation between oil and gas during migration in the anticlinal reservoir by hydrodynamic flow.

Petroleum is ultimately collected following secondary migration into permeable porous reservoir rock. The majority of reservoirs were found in clastic and carbonate reservoir rock, such as sandstones and

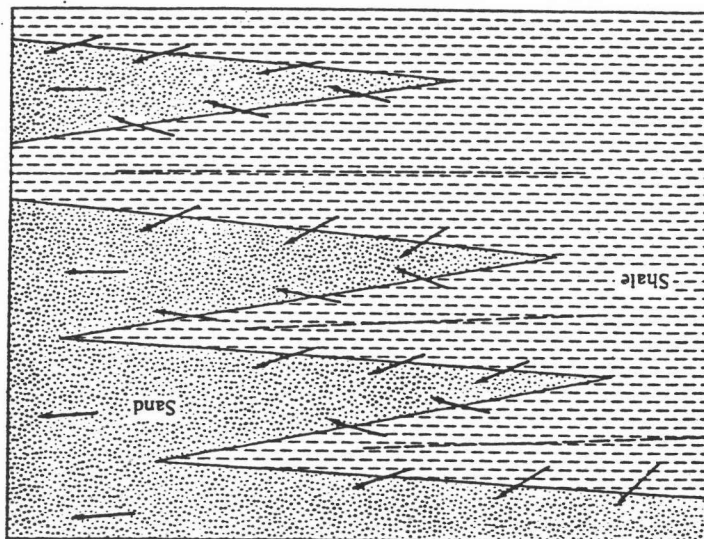


A) Anticline structure migration

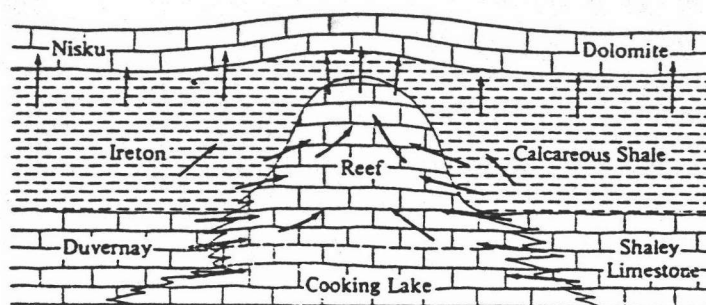


B) Stratigraphic trap migration

Figure 4. Examples of reservoir styles for hydrocarbon migration and accumulation A) and B) (from HUNT, 1979).



C) Interbedded shale-sand migration



D) Pinnacle reef migration

Figure 4. Examples of reservoir styles for hydrocarbon migration and accumulation C) and D) (from HUNT, 1979).

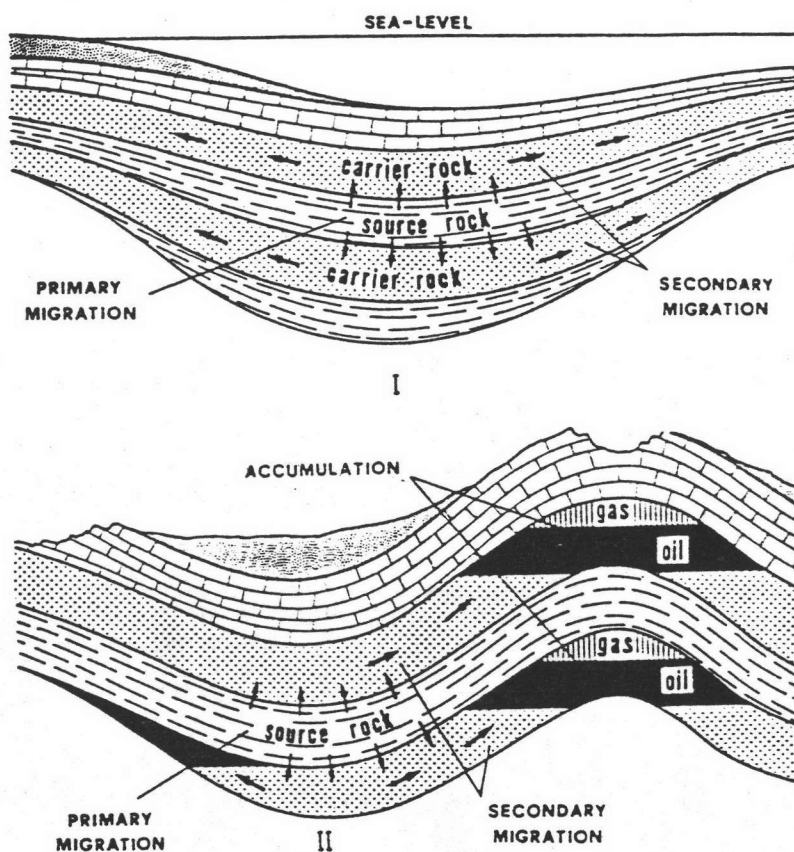


Figure 5. Displacement and segregation between oil and gas during migration in an anticlinal reservoir by hydrodynamic flow (from TISSOT and WELTE, 1978).

limestones, while smaller amounts accumulate in igneous and metamorphic rocks (TISSOT and WELTE, 1984). Compositional changes may occur during primary or secondary migration. The type and timing of hydrocarbon generation during various stages of evolution is a function of kerogen type and in turn depend upon the type of original organic materials and specific diagenetic transformations. Because kerogens are formed from original lipid-rich materials and then generate bitumen which precede petroleum formation, the relationship between the present hydrocarbon composition and the original source materials can be used for source rock evaluation. Biomarkers, derived from biogenic precursor molecules and present in crude oils and bitumen, can in principle be used as indicators of source precursors, depositional environments, diagenesis, maturation and reservoir transformation. In addition petroleum source bed can be recognised by the determination of content, type, and maturity of kerogen. Characterization and correlation by measuring and/or comparing biomarkers in sample can be established to help solve exploration and production problems. There are three important fractions for correlation purposes; the insoluble kerogen of the source rock, the extracted bitumens and the hydrocarbons. All of these fractions are used in oil/oil, oil/source and source/source correlations to determine the degree of similarity or dissimilarity between the various fractions and hence establish correlations.