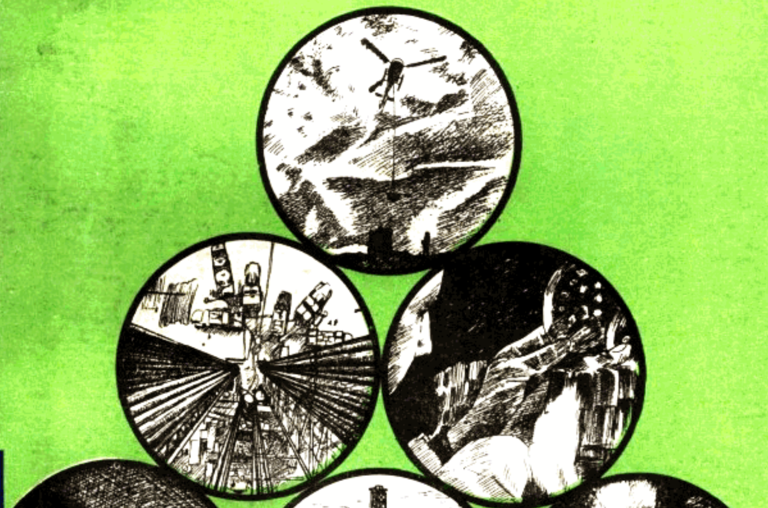
英汉对照石油科普丛书

石油勘探与开发



石　油　工　业　出　版　社

出 版 说 明

英国石油公司出版的《Our Industry Petroleum》一书，迄今为止已重版（包括修订）了五次。这本书对于刚刚投身石油事业的工作者，对于希望概括了解石油工业结构、历史和各个生产部门情况的人士，起到了指南的作用。

我社以此为蓝本，按章（或几章）分册出版了这套“英汉对照石油科普丛书”，旨在为石油系统各院校的学生和自学英语的同志，提供有关石油基本知识方面的英语读物。这套丛书计划出十二个分册。每一分册约3～5万字，并尽可能配用与内容密切联系的插图。为利于读者自学，除采用英汉两种文字相互对照的形式外，还对英语中某些语言难点（包括复杂的句子结构、短语等）做了必要的注释。因此，凡具有相当于理工科大学二年级英语水平的读者，都可以毫无困难地阅读这套丛书。为了保证丛书的质量，每一分册都由熟悉专业的同志提供通顺可诵的准确译文，然后统一请南京大学大学外语部的教师对译文作进一步校订，并加做必要的语法注释。但能否真正收到预期的效果，则要由读者作出评定了。我们衷心希望能得到广大读者的批评、指正。

石油部科技情报所的张淼同志，倡导并协助我社组织了“英汉对照石油科普丛书”的编译工作，在此表示感谢。

Contents 目　　录

PART 1 THE ROLE OF GEOLOGY

INTRODUCTION

Our industry is petroleum, so the exploration for oil and gas (known collectively as petroleum) occupies a central position in it. * Petroleum being a natural material of the earth[1], this phase of our industry* is staffed by[2] geologists and geophysicists, * supported by technicians, draughtsmen and secretaries—and engineers and drillers[3] to drill the exploratory boreholes. * Put in its simplest terms,[4] their job is to maintain or improve the company's supply of crude oil and natural gas at competitive cost. * An integrated international company such as BP[5], therefore, maintains an exploration programme* sufficient to fill its future needs, operated by an international staff working in many countries of the world[6], The word "integrated" means that the company explores for, produces, transports, refines, and markets petroleum and petroleum products; each function is dependent on the others but, if the company does not* have access to sufficient petroleum of its own[7], it must buy from those that have a surplus.

The basic skills of the exploration staff are related to geology, the science of the earth. * The need for specialists, as great in our industry as elsewhere, [8]means that emphasis is placed on teamwork so that the special fields may be integrated. * We find, therefore, geologists whose main interest is the distribution of rock types in time and space (stratigraphers) working with others[9] whose main interest is the rocks themselves (sedimentologists), fossils (palaeontologists), and the chemistry of the rocks and their contained fluids (geochemists). Geologists searching for new petroleum supplies must also work closely with geophysicists, * who use certain physical properties of the rocks to detect and map the distribution of the different rock types below the surface of the earth[10]. So the modern petroleum geologists and geophysicists not only require the skills of their own science but also the ability to appreciate those of related sciences. All these skills must be directed to the finding of new supplies of oil and gas at a competitive cost.

* The methods used to achieve these aims will be described later, and for the present can be seen broadly as a focusing on to a target[11]. General geological understanding, knowledge and experience indicates broad areas of the earth in which further supplies of petroleum could be expected. These prospective areas are studied by geologists using conventional surface mapping to determine the distribution of the rocks at the surface, and by geophysicists using geophysical surveys to determine the distribution of the rocks in the subsurface. * From these, smaller areas of greater interest are chosen for more detailed study[12], * then still smaller areas of still greater interest[13], If this process reveals

one or more areas that could contain commercial oil or gas accumulations, * it will now have to be tested by drilling[14]–which remains the only sure way of determining the presence of oil and gas.

* All these activities are carried out with the consent and under the control of the host government, and in competition (direct or indirect) with other companies also seeking to meet their future needs[15], The final decision to drill is not made on the basis of geological merit alone, but must also take into consideration government requirements and conditions, drilling costs, transport costs and market opportunities;and since companies rarely have enough money to take all the opportunities that are available the relative merits of the various opportunities must be considered. If all this leads to the discovery of a new oil or gas field that is commercially viable, it will normally be at least five years from initial discovery before it is on production, and many millions of pounds must be spent before any income is received from the new field.

Petroleum exploration is, therefore, challenging: it is also a professional gamble for very high stakes. When all the skills have been used effectively, * there remains an element of chance[16], The chances of commercial success are very unfavourable for the individual prospect (about ten to one against a commercial discovery), so * the more prospects drilled the better the chances of success[17], This remains the most powerful factor favouring the large international company over the small domestic company. Geological skill (combined with luck) enabled BP to grow into a large international company. * Petroleum will become harder and harder, and more and more expensive to find[18] because the more obvious accumulations have already been found. The future depends on greater geological understanding, improved technology, and continued investment.

GEOLOGICAL BACKGROUND

The concept of a sedimentary basin is fundamental to geology in general and to petroleum geology in particular because all * but a very small proportion of commercial petroleum[19] has been found in sedimentary basins. A sedimentary basin is not the same thing * as a physiographic basin[20], but they are related. A physiographic basin is a depression in the surface of the earth and is best understood by example. The mid-continent region of North America is a physiographic basin * drained largely by the Mississippi and Missouri rivers (and their tributaries), bounded by the Rocky Mountains on the west, the Appalachian Mountains on the east, and by the continental divide in southern Canada in the north[21]. To the south, it includes the northern part of the Gulf of Mexico. Within the physiographic basin, sediment is derived by erosion of the hilly and mountainous margins and transported by the rivers (mainly) towards the Gulf of Mexico. As this sediment is the product of weathering and erosion of the rocks in the hills and mountains, so its nature is related to these rocks.

Some of the sediment accumulates in the flood plains of * the lower reaches of the rivers[22], but most ultimately reaches the sea. * Here it comes under the forces of the waves and currents and is distributed to form beaches, mudbanks, etc[23]. But, if the supply of sediment is greater than can be moved by the sea, some of it accumulates to form a delta, such as the Mississippi delta. * The guiding principle is that sediment is moved by the energy of its environment until it arrives in a position from which it cannot be moved further[24]. This position depends not only on the energy of the environment but also on the physical properties of the grains of sediment; so we find that sand tends to accumulate in the higher-energy areas near the coast, while clay tends to accumulate further out in quieter water. * If this were the only process of sediment accumulation, sedimentary layers would be rather thin[25]- on the continental shelf, less than 200 metres thick. Yet we find both in outcrop on the surface and in boreholes, thousands of metres of sediment that accumulated in water less than 200 metres deep: so clearly subsidence is also involved.

Sedimentary basins, then, are areas in which sediment accumulated at a greater rate than surrounding areas, * accumulating a greater thickness in a given time[26]. They are situated in physiographic basins, which provide the sediment. The nature of the sediment that accumulates in a sedimentary basin depends on its position in the physiographic basin. If it occupies an area of the land, terrestrial sediments accumulate; * if of the sea[27], marine sediments accumulate; and * if it occupies a coastal area (as is commonly the case) both types accumulate[28].

But a sedimentary basin develops over several tens of millions of years and, during this time, its relative position with respect to the physiographic basin may change. These changes are recorded in the sedimentary rocks of the geological record, and they are * of great importance in petroleum geology for reasons that will become apparent[29].

The normal history of a sedimentary basin is that it begins with subsidence of the land and a consequent invasion by the sea, so that the physiographic environments migrate towards the land (Fig. 1a) . * To begin with[30], the amount of sediment brought to the sedimentary basin is less than the space made available by subsidence, so the sea becomes deeper with time. This is known * as a *transgressive* phase[31], with the accumulation of a transgressive sequence of sediments (in vertical sequence, marine sediments overlie terrestrial). Later, the amount of sediment brought to the area increases, eventually becoming greater than the space created by subsidence so that the sea near the coast fills with sediment and the shoreline moves progressively seaward. This is known as a * *regressive* phase[32], with the accumulation of a regressive sequence of sediments (in vertical sequence, terrestrial and shallow water sediments overlie deeper water marine sediments). An idealized * *sedimentary cycle*[33] (as it is called) is shown in Fig. 1b.

Further generalisations can be made about the rock types in such a cycle. The transgressive sequence may be of sands and shales or limestones and shales, but almost all important limestone sequences are transgressive. The regressive sequence is almost exclusively of sands and shales.

The usual history is * for a relatively brief transgressive phase to be followed by a protracted regressive phase[34], but many sedimentary basins have a more complicated history. Some areas, such as the important petroleum province centred on the Middle East Gulf, are difficult to classify in these terms because sediment accumulation and subsidence appear to have been roughly in balance over great spans of time. Nevertheless, Fig.1 is a useful generalization that applies to many important sedimentary basins, and some important principles can be derived from it.

In the first place, there is good evidence to believe that petroleum is generated largely in the fine-grained shales on top of the more permeable part of the transgressive sequence and below the more permeable part of the regressive sequence. (A rock is said to be *porous* if it contains voids or cavities, usually filled with brine: it is said to be *permeable* if fluid can flow through the pore spaces through the rock)* It is the permeable sedimentary rock associated with physiographic environments close to a shoreline that may become the main petroleum reservoirs[35], and * it is the minor fluctuations within transgressive and regressive phases that bring these two, the potential source rocks and the potential reservoir rocks, into close association[30]

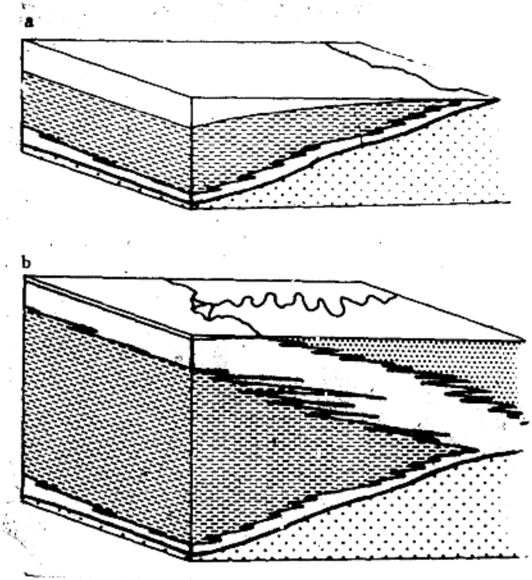


FIGURE 1a, b Schematic block diagrams of the accumulatio of a transgressive sequence of sediments (a) followed by a regressive se quence (b).

DIFFERENT APPROACHES

We tend to think of the rocks in the earth's crust in terms of their solid constituents–sand, clay, limestone. etc.–because that is what we see in outcrop, can hold in our hands, examine under a lens or microscope, and describe[3] The petroleum geologist, however, must also think of the pore spaces between the grains, and the fluids in these spaces. * It is important that these different approaches should exist[38]. The sedimentary basin may equally be regarded as a mass of water with sediment in it, and the movement of this water, with some oil and gas, is of fundamental importance in petroleum geology (and several other aspects of geology that are not relevant to this discussion).

As sediment accumulates, * each grain comes to rest on other grains, supported by its neighbours[39]. In its turn, it too will be loaded by another grain; and so a sequence of sediments is built up. * Two mechanical processes operate that tend to compact the sediment into a rock[40]. Agitation from earthquakes, surf, waves and currents, tends to sort the grains into a more compact arrangement; then the weight of the overlying sediment, * transmitted through the grain framework[41], tends to compress and deform the grains. Both these processes lead to a reduction of pore volume, so water must escape if compaction is to take place. Evidently the fluid medium in a sedimentary basin is in constant motion * relative to the sedimentary grains[42] during the evolution of a sedimentary basin. Petroleum geology is concerned, directly and indirectly, with this movement.

If we consider the sediments of the simple sedimentary cycle shown in Fig.1b * to be shales and sands[43], we can infer the directions of fluid movement from the physical properties of the rocks. The quartz grains of sands are strong and, * when loaded[44], deform elastically to some extent. There is a consequent loss of porosity, but the grains remain intact and the fluid that must escape can do so easily. Clays and shales, on the other hand, are more plastic; the grains deform more easily and in doing so tend to constrict the connections between the pore spaces and so reduce the permeability. The pore water is hindered from escaping by the * very[45] process that requires it to escape. Until it can escape, the pore water takes some of the load, and its pressure is increased. A mechanical driving force is thus created * that will expel the pore water from the clays and shales to the sands above and below it[46].

But it is wrong to think of pressure alone as the driving force, because even in water at rest (such as in a swimming-pool) the pressure increases with depth without creating a driving force. There is happily a conceptual device that permits us to understand the process without recourse to mathematics. * Imagine a manometer inserted into the sequence of sediments that will measure the porefluid pressure by allowing the water to rise in the tube until the pressure of the water at the base of the tube is equal to the pressure of the pore–fluids there[47]. The pressure of the water at the bottom of the manometer will support a column of water in the manometer. The elevation of the top of the water in the manometer * relative to some arbitrary horizontal surface[48], such as sea–level, is a measure of the *fluid potential* at the bottom of the manometer. Elsewhere, the pressure may support a column of different elevation relative to sea–level.

Fluid moves from high potential to low potential, like an electric current.

In the shales in Fig.1b, the water movement will be essentially vertical (upwards and downwards) when the shales are loaded by gravity. But once the permeable sands are reached, the water moves laterally within the sands towards the land.

* Against this background[49] we can now discuss the origin, generation, migration, and entrapment of petroleum because it seems clear that the movement of oil and gas * is subject to[50] the same physical influences, and they are always found associated with water.

ORIGIN AND GENERATION OF OIL AND GAS

There is little doubt in the minds of most petroleum geologists, * from the evidence of association[51], * that petroleum originates from organic matter of both plant and animal origin that accumulates in finegrained sediment under quiet conditions relatively deficient in oxygen[52]. These ideas receive firmer support from geochemical studies of sedimentary organic matter, * indicating that petroleum is generated[53] during burial of the sediment, primarily under the influences of heat and time, and that it is expelled from the source rocks during compaction.

Crude oils are complex mixtures of hydrocarbons and non–hydrocarbons. In the present context * it is interesting to note that there is as much variation between crude oils of the same age–or, more precisely, crude oils in rocks of the same age—as between crude oils of different ages[54]. Since there has been a continually changing pattern of life over the last 600 million years or so, the general similarities of crude oils suggest that they are generated from the fundamental biochemical components of organisms.

Geochemical evidence suggests that conditions favourable for significant generation of petroleum do not normally occur above depths of about 1 500 metres below the surface. There is some geological evidence, * based on oil occurrence and inferred source rocks, suggesting a shallower "threshold" of about 600 metres[55]. This distinction is not academic because it is important to be able to assess the possibilities of petroleum generation and migration at an early stage of exploration. The matter will be resolved when source rocks for specific petroleum accumulations can be identified and their burial history accurately determined.

The basic problem in petroleum geochemical studies is that the generation processes cannot be reliably duplicated in the laboratory because in nature they are very slow and take place under conditions that change with time. Qualitative information can, however, be obtained from laboratory "simulated maturation" experiments[56] that have provided indications of the likely chemical transformations * giving rise to petroleum[57]. Organic geochemical arguments relating to the origin of petroleum are, therefore, extensively based on the observed transformations of organic matter in rocks * as revealed by analysis[58]. Geological arguments are based on inference from the worldwide occurrences of petroleum. The indications are that the chemical changes are brought about by the combined effects of temperature, time, pressure, and probably catalysis in the source rock and the rocks through which the petroleum moves. After entrapment, the petroleum may undergo further changes under the influence of these factors.

Most of the world's oil occurs between the depths of about 600 and 3,000 metres. Gas tends to occur deeper than oil, and is more stable at higher temperatures. Gas also occurs in some areas at shallower depths than oil, and may, in some instances, be a primary product (i.e. the source rock yielded[59] gas only). Coals can sometimes give rise to gas accumulations, and it is thought that the gas from the southern North Sea gas fields, Holland, and N.W. Germany was derived from the devolatilisation of older coals.

MIGRATION OF PETROLEUM

The migration of petroleum in general terms is better understood than its origin. It is useful to distinguish two phases of migration: *primary migration* within the source rock, *secondary migration* through the permeable carrier beds to the trap or to the surface. It is also important to make this distinction because the processes are probably different in important respects.

Primary migration takes place under the mechanical driving force of the compaction of the source rock under gravity, and may also be aided by molecular diffusion pro-