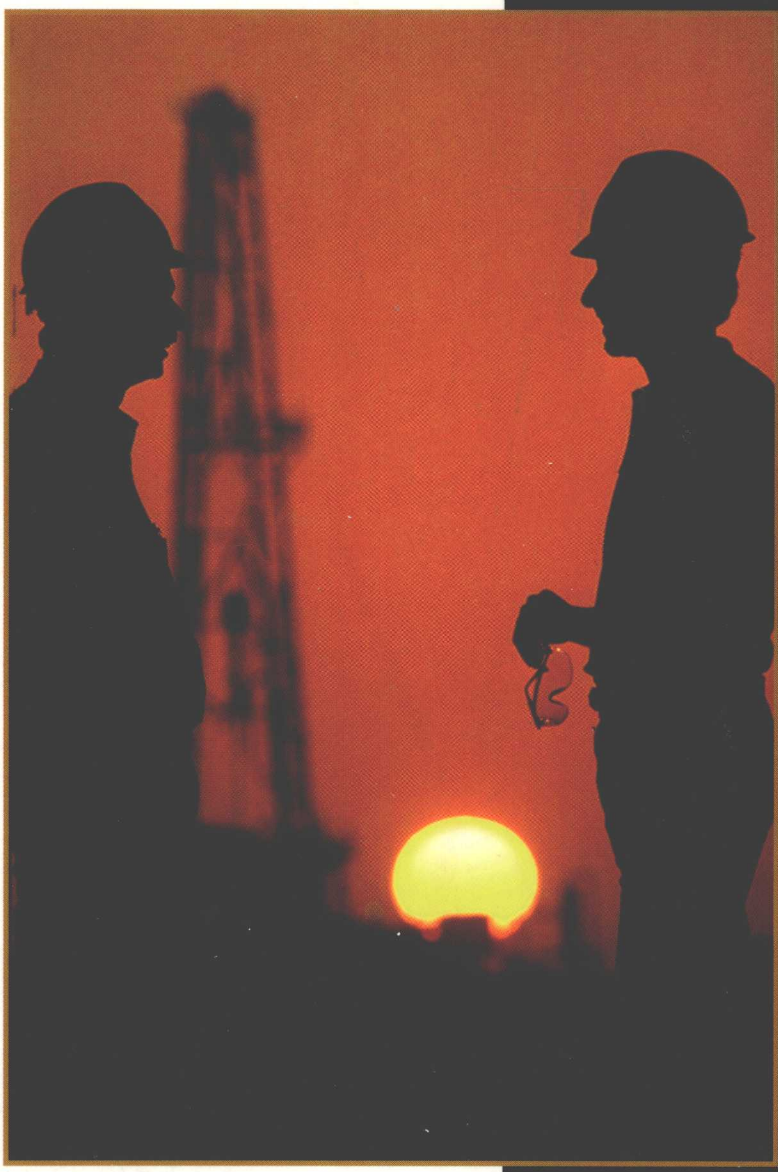
FUNDAMENTALS OF PETROLEUM

FOURTH EDITION



Fundamentals of Petroleum

FOURTH EDITION

by Kate Van Dyke

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Foreword

Our nation cannot live without energy. Oil and natural gas provide about 70 percent of the energy used in the United States. Because of its importance, people directly related to and affected by this industry should know more about it. The better people understand the petroleum industry, the greater the chances are for making the proper decisions toward solutions to our energy problems.

The petroleum industry is a leader in developing and applying advanced technology. The Association of Desk and Derrick Clubs recognizes the need for a better understanding of this complex and diversified technology and endorses *Fundamentals of Petroleum,* which is dedicated to individuals seeking knowledge of the petroleum industry. Designed for both the professional and layperson as a basic guide to the practical aspects of the petroleum industry, this book is intended to be used by the association as a primary text for training in house, in colleges, and through correspondence courses. It is also intended to serve as an educational tool for allied industries, as well as professional and governmental agencies. It provides a basic discussion of the petroleum industry from geology through exploration, drilling, production, transportation, refining and processing, and marketing.

Desk and Derrick is a unique organization of approximately ten thousand members employed in the petroleum and allied industries who are dedicated to the proposition that *greater knowledge* of the petroleum industry will result in *greater service* through job performance. Nonshareholding, noncommercial, nonprofit, nonpartisan, and nonbargaining in its policies, the organization has very positive concepts on the value of education for women.

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Preface

This fourth edition of *Fundamentals of Petroleum* retains the purpose of the first edition: namely, to give a nontechnical and overall view of the petroleum industry. Like its predecessors, this edition does not cover all the procedures and equipment used in the industry; nor does it give detailed descriptions. Instead, it presents general and useful information that should help lay persons understand the complex world of oil and gas. Technical advances and other changes in the industry made a new edition necessary.

While the book uses simple terms, readers may occasionally run across a word or phrase that they do not understand. In such cases, they may wish to refer to *A Dictionary for the Petroleum Industry* or the *Petroleum Fundamentals Glossary*, also published by PETEX.

PETEX produced the first edition with a great deal of help and support from the Association of Desk and Derrick Clubs (ADDC). Further, the ADDC Education Committee gave a considerable amount of input to PETEX's author and editors. Similarly, this fourth edition incorporates not only changes suggested by ADDC, but also by students, teachers, and readers of preceding editions.

PETEX sincerely hopes that this book will meet the needs of persons outside the industry who are interested in petroleum. We also hope it assists those in the industry, especially members of the Desk and Derrick Clubs everywhere, for it is these men and women who inspire PETEX to provide training materials.

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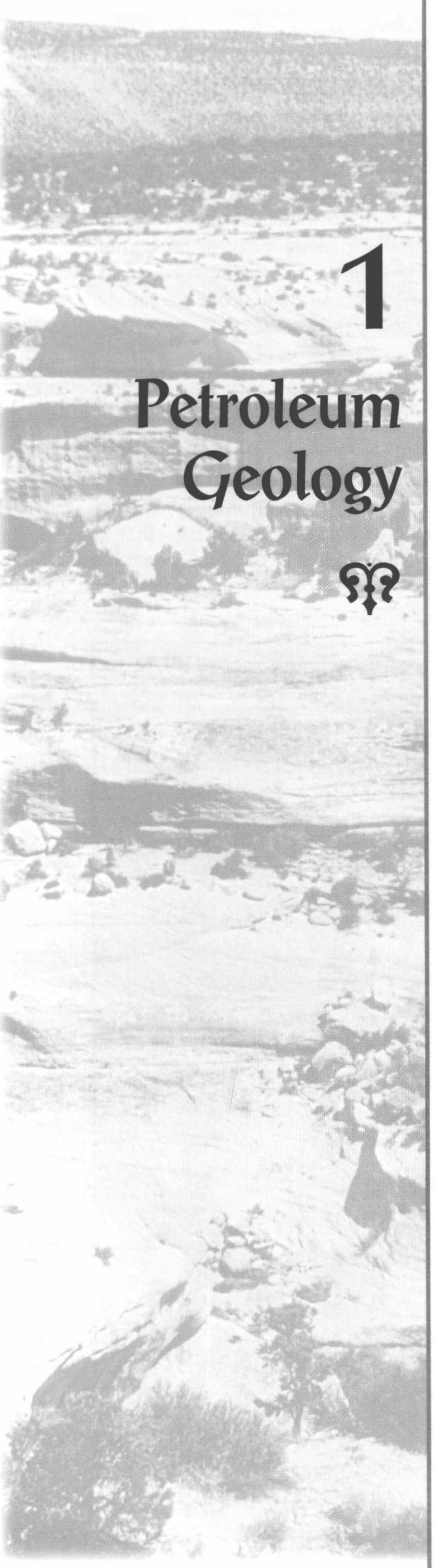

1 Petroleum Geology

Geology is the science that deals with the origin, history, and physical structure of the earth and its life, as recorded in rocks. It is a science essential to the petroleum industry because most petroleum is found within rocks far underground. Anyone interested in the petroleum industry needs to be familiar with the basic principles of geology.

Geologists try to answer such questions as how old the earth is, where it came from, and what it is made of. To do this, they study the evidence of events that occurred millions of years ago, such as earthquakes, volcanoes, and drifting continents, and then relate these to the results of similar events happening today. For example, they try to discover where ancient oceans and mountain ranges were, and they trace the evolution of life through fossils. They also study the composition of the rocks in the earth's crust. In the course of their investigations, geologists rely on the knowledge derived from many other sciences, such as astronomy, chemistry, physics, and biology.

The petroleum geologist is concerned with rocks that contain oil and gas, particularly rocks that contain enough petroleum to be commercially valuable. The company that drills for oil wants a reasonable chance of making a profit on its eventual sale, considering the market price of oil and gas, the amount of recoverable petroleum, the expected production rate, and the cost of drilling and producing the well. So petroleum geologists have two jobs: first, they reconstruct the geologic history of an area to find likely locations for petroleum accumulations; then, when they find one of these locations, they evaluate it to determine whether it has enough petroleum to be commercially productive.

Before we go on, it is important to clear up a common misunderstanding about what an oil reservoir is. Many people think that a reservoir is a large, subterranean cave filled with oil or a buried river flowing with pure crude from bank to bank. Nothing could be further from the truth. Yet it is easy to understand how such notions come about. Even experienced oilfield workers often refer to a reservoir as an *oil pool*. And since many cities store their drinking water in ponds or lakes called reservoirs, this term adds to the confusion. In reality, a *petroleum reservoir* is a rock formation that holds oil and gas, somewhat like a sponge holds water.

And how big is a reservoir? In the oil business, a reservoir's size is determined by the amount of oil and gas it contains. Physically, however, a large reservoir may be broad and shallow, narrow and deep, or some shape in between. The East Texas field covers thousands of acres or hectares but is only 5 to 10 feet (1.5 to 3 metres) thick. On the other hand, the Gronigen field in Holland extends over only about 5 acres (2 hectares) but is some 85 feet (26 metres) thick.

BASIC CONCEPTS OF GEOLOGY

Astronomers and physicists think today that the earth was formed at least 4.55 billion years ago out of a cloud of cosmic dust. As gravity pulled the planet together, the heat of compression and of its radioactive elements caused it to become molten. The heaviest components, mostly iron and nickel, sank to the earth's center and became the *core*. Geologists believe that the core has two parts: an inner, solid core and an outer liquid core (fig. 1.1). Both are very hot, dense, and under tremendous pressure. Lighter minerals formed a thick, probably solid *mantle* around the outer core. Certain minerals rich in aluminum, silicon, magnesium, and other light elements solidified into a thin, rocky *crust* above the mantle.

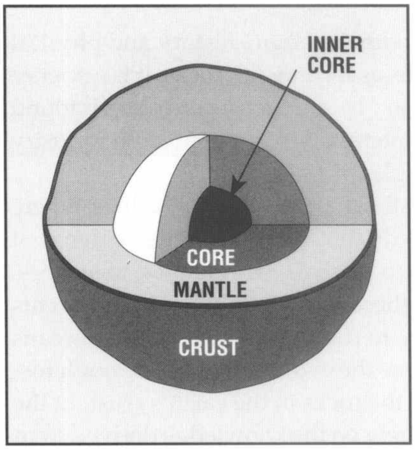

Figure 1.1 A cross section of the earth shows its inner and outer cores, the mantle, and the crust.

Plate Tectonics

Geologists used to assume, quite naturally, that the continents always lay where they are now. However, resemblances between certain fossil plants in Europe and America, plus an apparent fit between the coastlines, led to the theory that the continents have moved over time (fig 1.2). Most geologists today believe that the crust is an assemblage of huge plates that fit together like a jigsaw puzzle. But unlike a jigsaw puzzle, pieces of the earth's

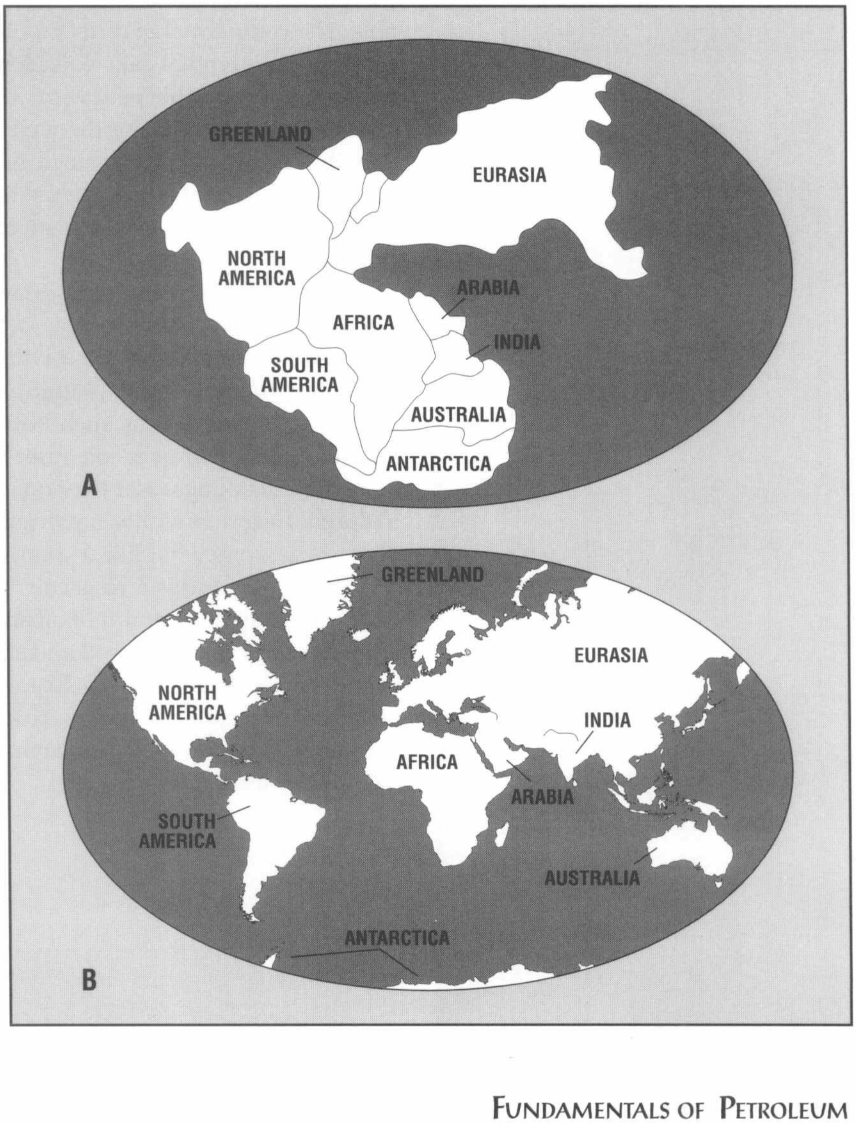

Figure 1.2 The relative positions of the continents as they looked 200 million years ago (A) and today (B).

crust continue to move and change shape. In some places they slide past one another; in others, they collide with or pull away from each other. The theory that explains these processes is called *plate tectonics.*

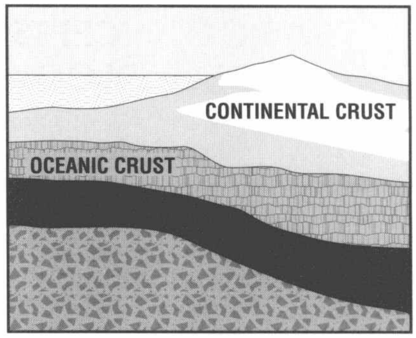

Figure 1.3 Oceanic crust is heavier than continental crust.

Crustal Plates

Geologists distinguish between *oceanic crust,* which lies under the oceans, and *continental crust,* of which the continents are made (fig. 1.3). Oceanic crust is thin—about 5 to 7 miles (8 to 11 kilometres)—and made up primarily of heavy rock that is formed when molten rock (*magma*) cools. The rock of continental crust, however, is thick—10 to 30 miles (16 to 48 kilometres)—and relatively light. Because of these differences, continents tend to float like icebergs in a "sea" of heavier rock, rising high above sea level where they are thickest—in the mountains.

Some of the best evidence for moving plates comes from the bottom of the sea. In the middle of the Atlantic Ocean is a mountain range 10,000 miles (16,100 kilometres) long that snakes from Iceland to the southern tip of Africa (fig. 1.4). It has a deep rift, or trench, along its crest. Investigation of this Mid-Atlantic Ridge has suggested that it is a place where two great plates are moving apart. Along the rift is a string of undersea volcanoes. Each time one erupts, the pressure of the lava pouring out pushes the sides of the rift farther apart. Lava then hardens into rock and becomes new crust between the two plates.

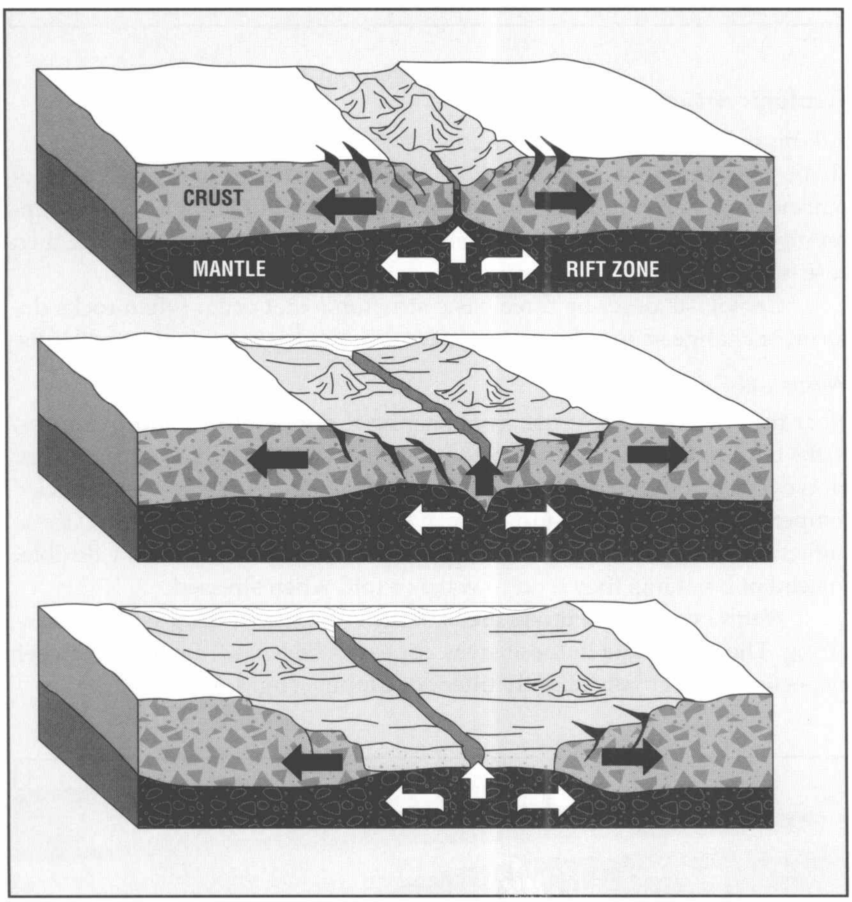

Figure 1.4 The Mid-Atlantic Ridge is an example of two plates moving apart, forming new oceanic crust as lava rising from beneath the plates hardens.

If the plates in the Atlantic are moving apart, then the Pacific Ocean basin is presumably becoming smaller. In fact, geologists believe that the westward movement of the North and South American continents (lighter continental crust) is forcing the Pacific plate (heavier oceanic crust) downward into the mantle (fig. 1.5). This collision of an oceanic and a continental plate accounts for the volcanoes and earthquakes common along this zone.

Geologists also have evidence of what happens when two continental plates collide. They believe that the tallest mountains in the world, the Himalayas, formed when India smashed into Asia. Like an incredibly slow head-on collision between two cars, the crustal collision buckled and folded the rocks along the edges of the two plates. In fact, the Himalayas are still rising by a measurable amount today.

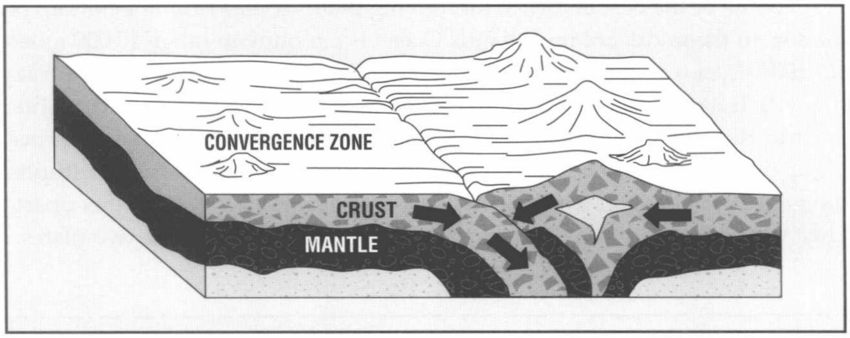

Figure 1.5 Along the Pacific coast, the North and South American continental plates are forcing the Pacific plate downward.

Geologic Structures

All this movement of the earth's crust over millions of years means that the shapes and locations of land masses and oceans have changed. Fossils of marine organisms found in some of the highest mountains and in the deepest oilwells prove that the rocks there were formed in ancient seas and then rose or fell to their present positions.

Geologists describe three basic structures that occur when rocks deform, or change shape, due to tectonic movement: warps, folds, and faults.

Warps and Folds

Near the surface of the crust, at atmospheric temperatures and pressures, rocks tend to break when subjected to great stresses such as earthquakes. However, deeper into the crust, heat rising from the mantle raises the rocks' temperature, and the pressure of overlying rocks compresses them. At these higher temperatures and pressures, the rocks become somewhat flexible. Instead of breaking, they tend to warp or fold when stressed.

Warps occur when broad areas of the crust rise or drop without fracturing. The rock strata in these areas appear to be horizontal but, on closer inspection, are actually slightly tilted, or dipping (fig. 1.6).

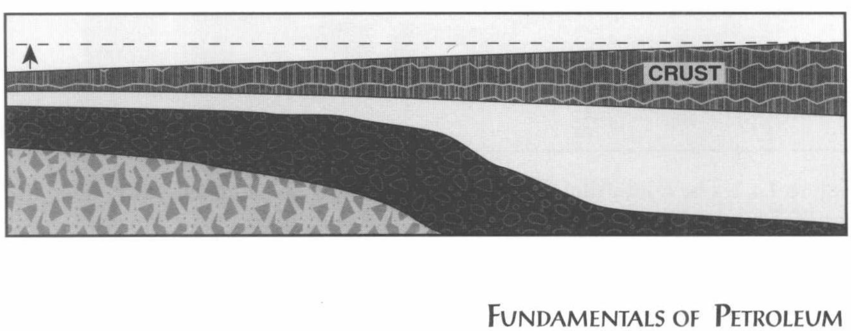

Figure 1.6 A warp is a gently tilted area of horizontal crust.

Figure 1.7 This photo shows deformation of the earth's crust by the buckling of layers into folds.

Rock strata that have crumpled and buckled into wavelike structures are called *folds* (fig. 1.7). Folds are the most common structures in mountain chains, ranging in size from wrinkles of less than an inch to great arches and troughs many miles across. The upwarps or arches are called *anticlines*; the downwarps or troughs are *synclines* (fig. 1.8).

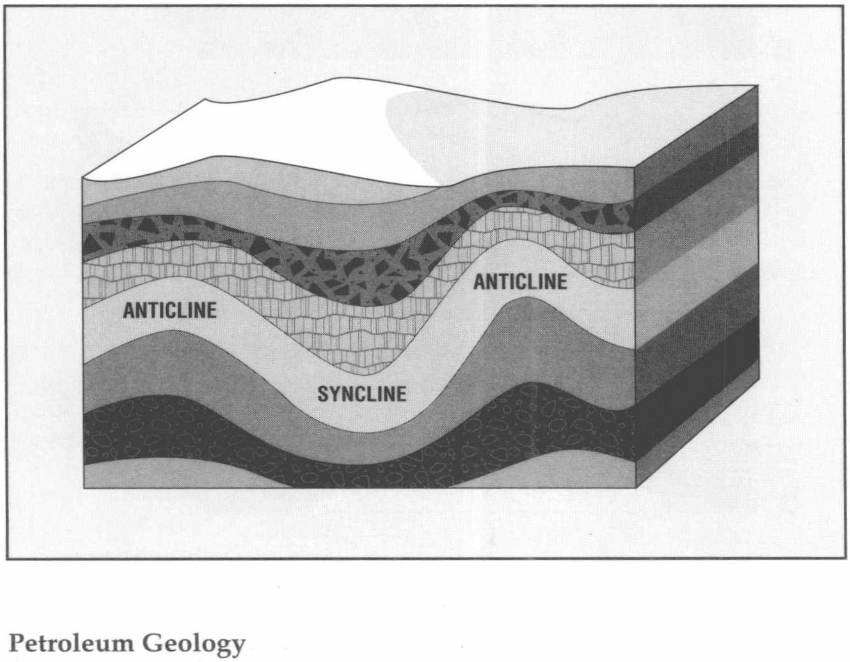

Figure 1.8 Geologists group folds into anticlines and synclines.

Geologists further divide anticlines and synclines according to how the folds tilt. A short anticline with its crest plunging downward in all directions from a high point is called a *dome* (fig. 1.9). Many domes are almost perfectly circular. Some of them have a core of one type of rock that has pushed up into the surrounding rock and lifted it, such as the salt domes along the U.S. Gulf Coast. A syncline that dips down toward a common center is called a *basin* (fig. 1.10). Anticlines and synclines are important to petroleum geologists because they often contain petroleum.

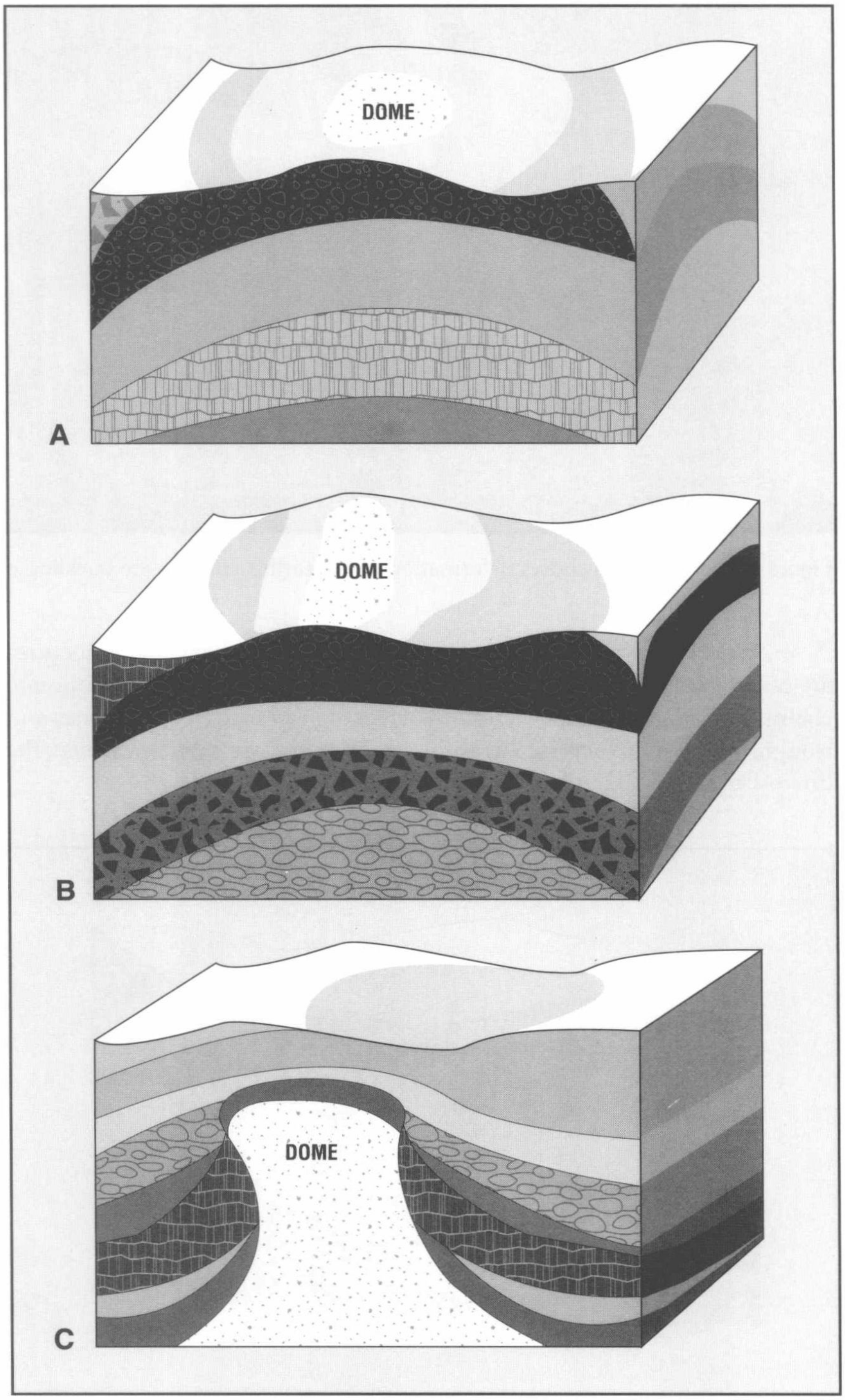

Figure 1.9 A dome may be nearly circular (A) or elongated (B). Some have an intrusive core of salt or other type of rock that pushes up the surrounding rock (C).

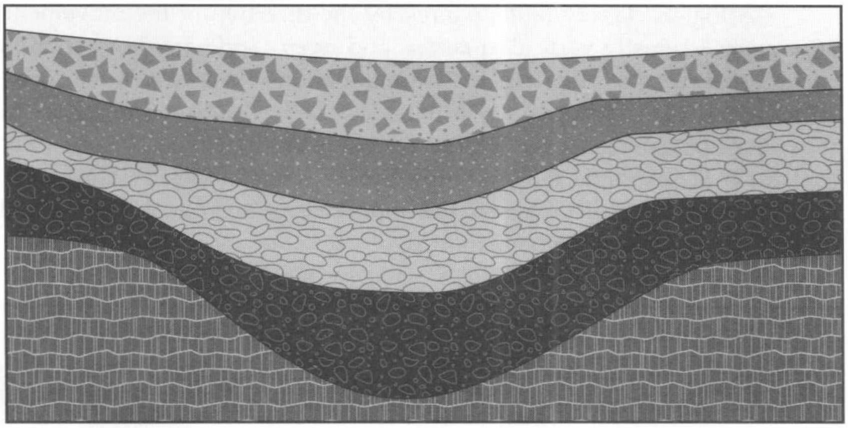

Figure 1.10 A basin is the opposite of a dome.

Faults

When rocks near the surface break, or fracture, the two halves may move in relation to each other. If they do, the fracture is called a *fault*. The two halves along a fault may move apart only a few millimetres or many yards or metres, as along the San Andreas Fault in California (fig. 1.11). Remember that the west coast of the Americas is the boundary between two of the earth's largest crustal plates. The ground next to parts of the San Andreas fault moved horizontally 21 feet (6.4 metres) during the great San Francisco earthquake of 1906.

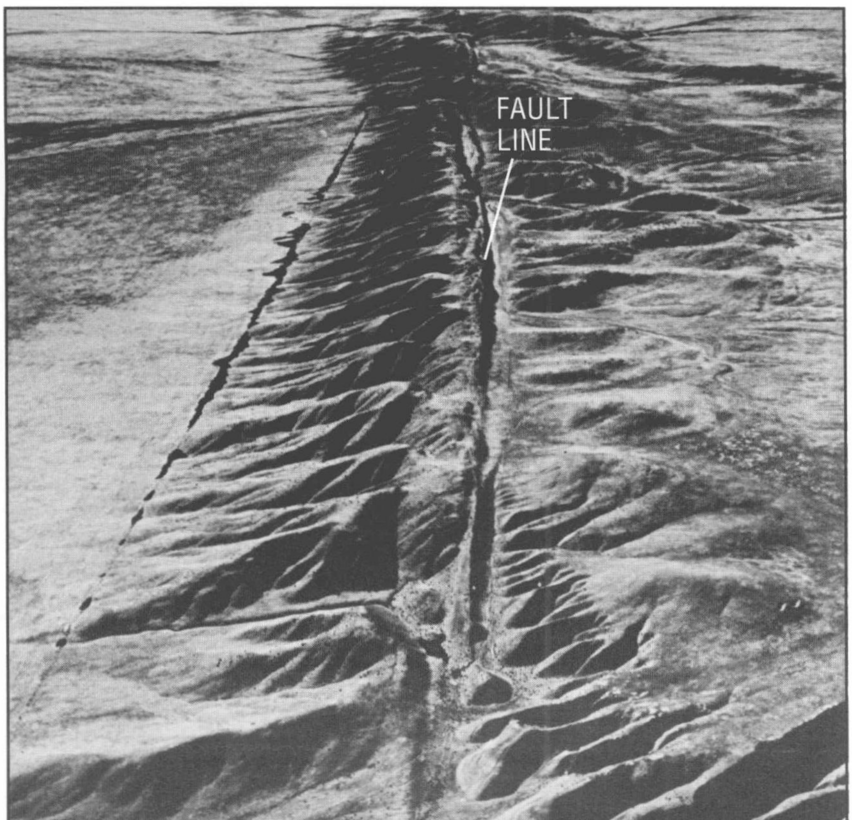

Figure 1.11 This view of the San Andreas Fault in the Carrizo Plain in California shows a distinct fault line.

Geologists classify faults mainly by the direction of the movement. Movement is mostly vertical in *normal* and *reverse faults* but horizontal in *overthrust* and *lateral faults* (fig. 1.12). Combinations of vertical and horizontal movement are also possible, as in *growth faults*. Faults are important to the petroleum geologist because they affect the location of oil and gas accumulations. For example, if a fault runs through a bed of rock containing oil, the geologist can predict where in the same area another part of the original oil-containing rock might have moved.

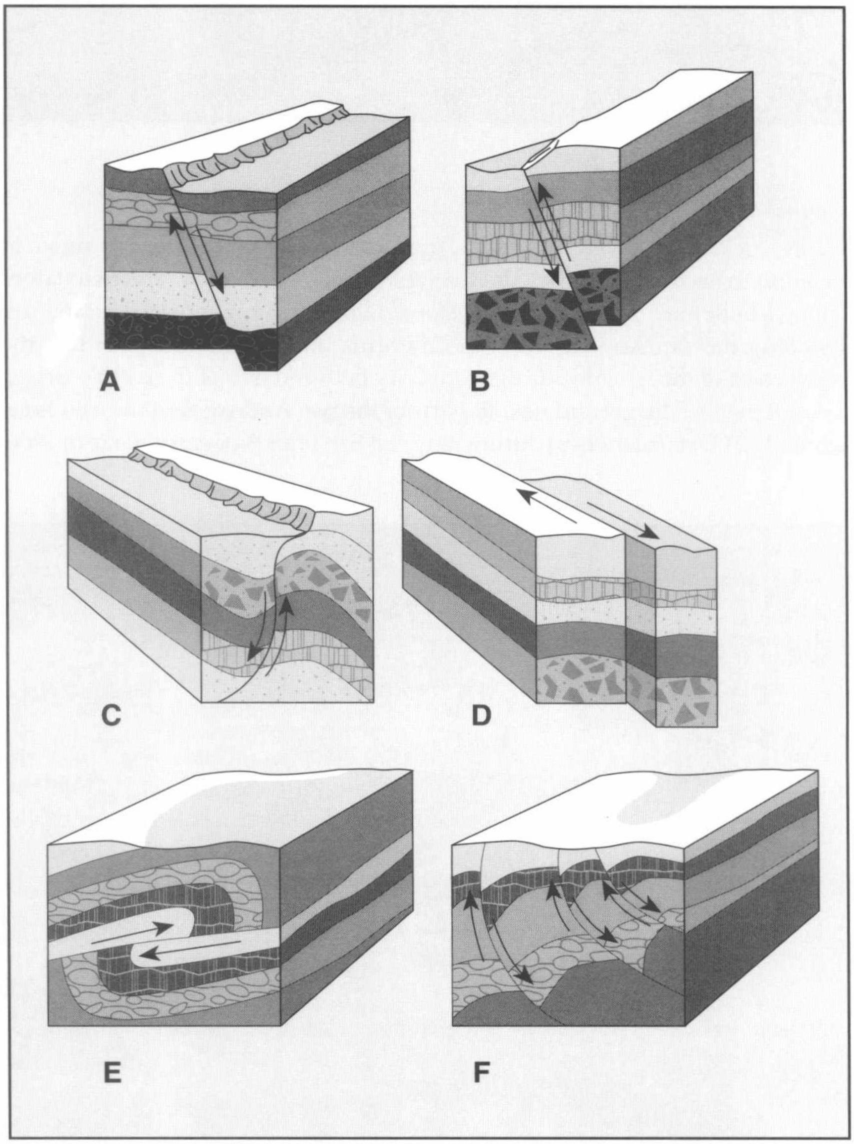

Figure 1.12 Several common types of faults are normal dip slip (A), reverse or thrust dip slip (B and C), lateral (D), overthrust (E), and growth (F) faults.

Sometimes faulting can produce certain recognizable surface features (fig. 1.13). A *graben* is a long, narrow block of crust between two faults that has sunk relative to the surrounding crust. A *horst*, on the other hand, is a similar block that has risen. In the North Sea, oil has accumulated in sediment-filled grabens beneath the ocean floor.