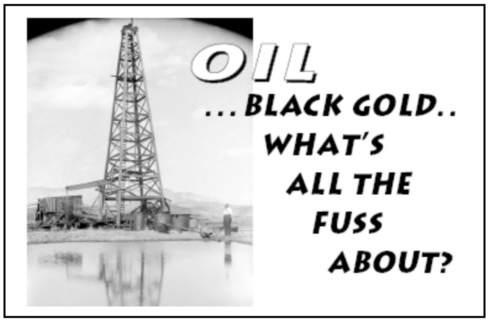
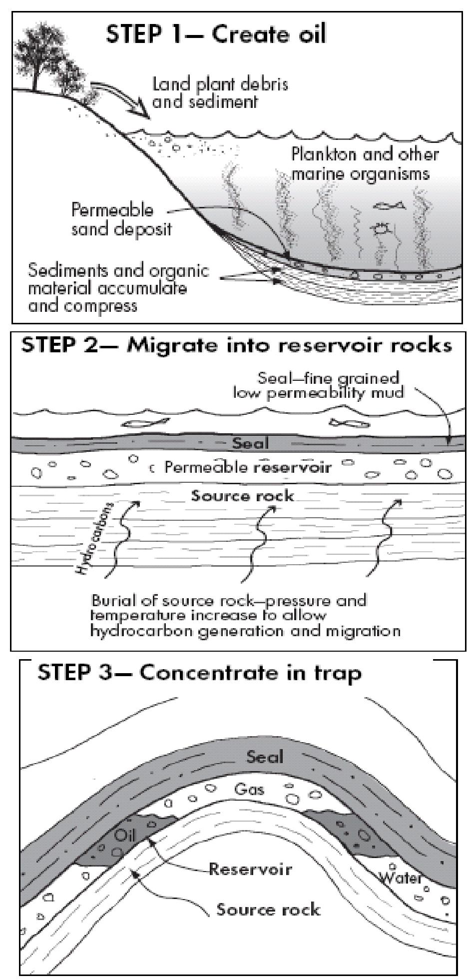
Excerpts for Rock Talk Vol 7 No.2
Colorado Geological Survey



Oil, petroleum, hydrocarbon — words that have become popular in our modern-day vernacular, but what do they really mean to us? What is oil? How does it form? Where do we find it? How do we look for it? Do we really need it? Why? Are we actually running out? Does its use damage our environment? These are all good questions, but some of the answers are not quite so simple. This issue of Rock Talk provides insights into the issues raised by these questions, and hopefully a better understanding of the industry that supplies so much of our energy needs.

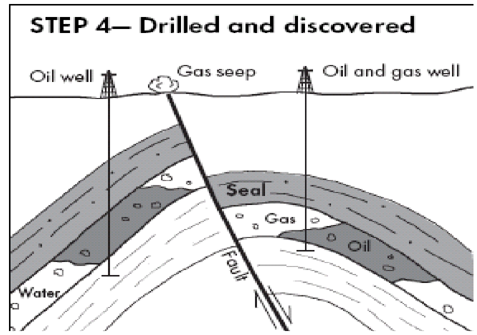
What Is Oil?

Fossil fuels are those energy sources that formed from the remains of once-living organisms. They include oil, natural gas, coal, and fuels derived from oil shale and tar sand. The differences in the physical properties among the various fossil fuels arise from differences between the starting materials from which the fuels formed and changes to those materials after the organisms died and were buried within the layers of the earth. Petroleum means rock-oil, and comes from the Latin petra, meaning rock or stone, and oleum, meaning oil. Liquid petroleum, or oil, comprises a variety of liquid hydrocarbon compounds; compounds made up of different proportions of the elements carbon and hydrogen. There are also gaseous hydrocarbons (natural gas), in which methane is the most common component. Hydrocarbon mixtures usually also contain minor amounts of nitrogen, oxygen, and sulfur as impurities.



How Does It Form?

The production of a large deposit of any fossil fuel requires an even larger initial accumulation of organic matter, which is rich in carbon and hydrogen. Another requirement is that the organic debris be buried quickly to protect it from the air so that decay by biological activity or reaction with oxygen will not destroy it. Microscopic life is abundant over most of the earth's oceans. When these organisms die, their remains can settle to the sea floor. There are also underwater areas near shorelines, such as on many continental shelves, where sediments derived from continental erosion accumulate rapidly. Insuch a setting, the starting requirements for the formation of oil are satisfied; there is an abundance of organic matter rapidly buried by sediment. Oil and most natural gas are believed to form from such accumulated marine microorganisms. Some natural gas deposits that are not associated with oil may form from deposits of plant material buried in sediment. As burial continues, the organic matter begins to change. Pressures increase with the weight of the overlying sediment or rock; temperatures increase with depth in the earth; and slowly, over long periods of time, chemical reactions take place. These reactions break down the large, complex organic molecules into simpler, smaller hydrocarbon molecules. In the early stages of petroleum formation, the deposit may consist mainly of larger (heavy) hydrocarbons, which have the thick, nearly solid consistency of asphalt. As the petroleum matures, and as the breakdown of large molecules continues, successively "lighter" hydrocarbons are produced. Thick liquids give way to thinner ones, from which lubricating oils, heating oils, and gasoline are derived. In the final stages, most or all of the petroleum is broken down further into very simple, light, gaseous molecules—natural gas. Most of the maturation (cooking) process occurs in the temperature range of 50° to 100° C (approximately 120° to 210° F). Above these temperatures, the remaining hydrocarbon is almost entirely methane (natural gas); with further temperature increases, methane can also be broken down and destroyed.



Where Do We Find It?

Once the solid organic matter is converted to liquids and/or gases, the hydrocarbons need to migrate out of the source rocks in which they formed in order to form a commercial deposit. The majority of petroleum source rocks are finegrained sedimentary rocks (like shale), from which it would be difficult to extract large quantities of oil or gas quickly. However, oil and gas are able to migrate out of their source rocks into more permeable rocks over the long spans of geologic time. Most people have the incorrect notion that there are underground "lakes" of oil. The oil industry has helped feed this misconception by talking about oil "pools." The truth is that virtually all the oil is contained in tiny holes in solid rock. These holes, or pores, are filled with water, gas, or oil. But if the holes are not connected, then oil can't flow out of the rock. The ability of liquid to flow through the pores is permeability. So, in addition to high porosity, which allows the rock to hold large amounts of oil, the rock must have good permeability, which allows oil to flow quickly out of the rock. A rock with good porosity and permeability is a reservoir rock. Mostoils and all natural gases are less dense than water, so they tend to rise as well as to migrate laterally through the water-filled pores of permeable rocks.

Unless sealed by impermeable cap rocks, oil and gas may keep rising right up to the earth's surface. These substances escape into the air, the oceans, or they flow out onto the ground at oil and gas seeps. These natural seeps, which are one of nature's own pollution sources, are not very efficient sources of hydrocarbons for fuel compared with present day extraction methods.

Commercially, the most valuable deposits are those in which a large quantity of oil and/or gas is concentrated and confined) by geologic traps, such as folds and faults. If the reservoir rocks are not naturally permeable enough, it may be necessary to fracture (crack open) them artificially with explosives or with water or gas under high pressure to increase the rate at which oil or gas flows through them.

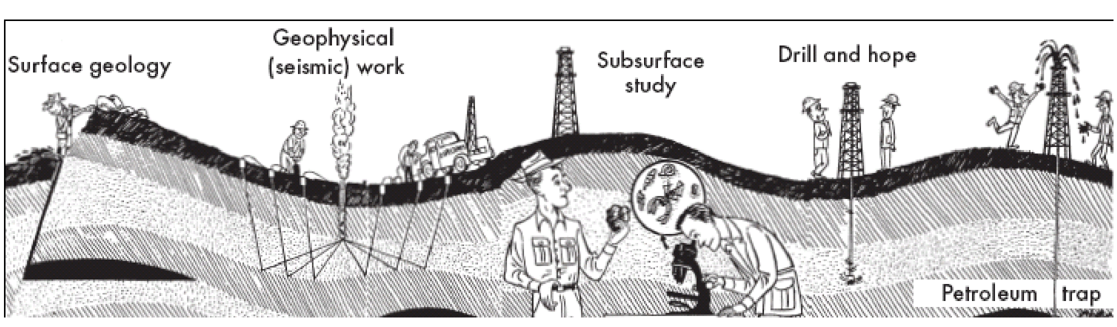
How Do We Look For It?

Before any production activity can begin, oil and gas must first be found. For this purpose, the industry relies heavily on exploration, which is the artful application of creative thinking to rigorous science (with a measure of good luck). The geoscience professionals who perform this function are very often the first and most important in the successful discovery of new fields and proving additional reserves.

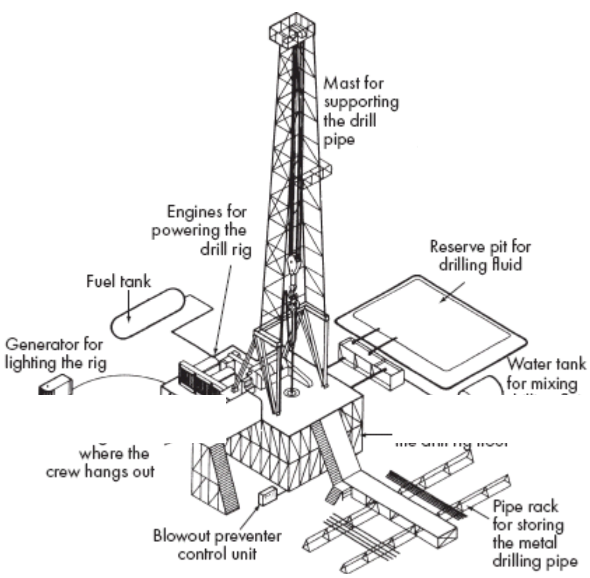
The search for oil and gas beneath the earth's surface is a risky undertaking. Indeed it is quite a gamble to invest money in an exploration "wildcat" well, because there are so many unknowns involved in the analysis and study of the earth. A number of conditions must exist before an oil or gas accumulation can develop—hydrocarbons must have been generated and they must have migrated to a suitable location to be trapped. Geoscientists use several scientific and technical procedures to "predict" whether these conditions may have combined to create an oil or gas field, but the results are never guaranteed.

Not all exploration wells drilled result in the discovery of oil and gas. The success rate can vary from drilling five or ten exploration wells to achieve one successful producing well; it may take as many as 50 or 100 exploration wells to discover a "significant" new oil field. The risk is further increased by the high cost of drilling new wells. In 2002, the average cost of drilling a new well in the United States was nearly $1 million assuming a well depth of 5,000 feet (typical for onshore oil wells). The high cost of finding new oil and gas fields demands that proper exploration work be completed before extensive drilling is started.

The use of exploration techniques to find oil and gas began nearly 150 years ago when Edwin Drake drilled the first successful oil well in Pennsylvania in 1859. Early oil explorers originally looked for oil in seeps and slicks along low places in river valleys and their adjoining creeks. Water wells with their occasional oil shows provided additional clues to the existence of petroleum beneath the earth's surface. It was during this early period that the term "wildcat well" was first used. In those days, the woods of Pennsylvania were full of wild cats (bobcats) and mountain lions. At night, while oil drillers were working on their rigs, the wild cats often could be heard screaming in the woods. As a result, the early exploratory wells drilled in this part of the country became known as "wildcat wells." This term has been used throughout the history of oil



exploration, and still refers to those wells that are drilled to find oil and gas in previously unexplored areas. The modern science of exploring for petroleum deposits combines methods of describing the geology that can be observed at the earth’s surface with sophisticated subsurface techniques that allow the geoscientist to visualize below the earth’s surface. Equally important as the techniques themselves, however, is their application to the general exploration process. Most exploration goes through a typicalcycle or pattern, although more research is required to find new fields than locating extensions of older or existing ones. The exploration geologist’s first task is to choose a general area for exploration. In the United States, there are numerous locations, generally known as sedimentary basins, where major exploration activities are conducted. The Rocky Mountains have many large basins of sedimentary deposits that contain hydrocarbons. Geologists must choose a particular area or basin that they consider promising, and further define their target by making regional studies of the basin. They will identify the hydrocarbon traps or potential reservoirs using both surface and subsurface methods.



Prospects must be well defined in order to obtain oil and gas leases from landowners prior to the drilling of a wildcat well. After the necessary land work has been completed, the next step is to drill test wells to determine whether producible hydrocarbons are present. Once a successful test well or series of wells has been drilled, the economic potential of the hydrocarbon discovery must be determined. This step includes estimating how much oil and gas is present (reserves), the probable selling price, the cost of continuing the exploration effort as well as the cost of full field development, and the taxes, royalties, and other expenses associated with producing the oil field. If the venture looks promising, the final step is taken—development of a newly discovered field. At this point, the exploration team may turn the project over to a production team to manage the drilling and completion of the additional wells required to define the limits of the field, and to fully develop the field. Often, there is only a fine line of distinction between the exploration and production teams; they both utilize the same methods and engage in similar activities. Although the production geologist works in areas where oil or gas production has already been established, the geologic problems are no less challenging. New subsurface geological and production information requires constant detailed study and evaluation to ensure that the field is efficiently and completely developed. New information about the reservoir is constantly being accumulated from field production data and engineering studies, and is used to revise and refine the knowledge at hand.

Do We Really Need It? Why?

It seems like a complicated process to go through just to find and produce hydrocarbons! It begs the question—why is it so important? Petroleum plays a significant, even critical role in the modern industrial world. Petroleum products and petrochemicals affect almost every aspect of our civilization and the quality of our lives as individuals, including transportation, food, clothing, shelter, and recreation. The supply, production, and consumption of petroleum influence national economics, and security issues and have a bearing on global politics and international relationships—nations even fight wars over petroleum!

The petroleum industry has attained its present position of importance and prominence in a relatively short span of time. For example, the history of the industry in the United States only dates back to 1859 when the first well drilled specifically for oil proved successful. Since that time, technological advances, along with dramatic social changes, have contributed to the emergence and growth of the petroleum industry. Even though the petroleum industry has a relatively short history, the use of petroleum itself extends much further into the past.

The knowledge and use of petroleum can be traced back for centuries, and may well predate recorded history. Today petroleum has become a vital part of our everyday life and the economics of our nation. Daily, Americans use more than 3,000 products that are derived from petroleum—gasoline, jet and other fuels, aspirin, makeup, synthetic fabrics, and fertilizer to name but a few.

Even with conservation efforts, our consumption of petroleum averaged 20 million barrels of oil per day in 2002. Meanwhile, the oil industry has grown to service this need and demand for petroleum in our society. Production of oil in this country was about 2.5 billion barrels in 2002. The United States consumed nearly four billion barrels of oil more than we produced in 2002. Therefore, as a net importer, our nation must concern itself with global issues that affect the long-term outlook for energy supply and demand.

Are We Running Out?

The amount of time required for oil and gas to form is not known precisely. Since virtually no petroleum is found in rocks younger than one to two million years old, geologists infer that the process is comparatively slow (in human terms). Even if it took only a few tens of thousands of years (a geologically short period), the world's oil and gas resources are being used up much faster than significant new supplies can be produced by geologic processes. Therefore, oil and natural gas are considered nonrenewable energy sources. Worldwide, more than 500 billion barrels of oil have been consumed, and the estimated remaining reserves are about one trillion barrels. (One barrel is equal to 42 gallons.) That does not sound too ominous until one realizes that close to half of the consumption has occurred in the last quartercentury or so. Also, global demand continues to increase as more countries advance technologically. Oil supply and demand are very unevenly distributed around the world. Two-thirds of the world oil reserves are located in the Middle East. In contrast, the United States has only 4 percent of the world oil reserves but consumes over 25 percent of the oil used worldwide—we are the largest consumer in the world.

Since the mid-1970s, the United States has used as much domestic oil each year as we have discovered; in many years, we have used more. As a result, U.S. oil reserves are declining. Furthermore, the United States has for many years relied heavily on imported oil to meet part of its energy needs. Currently, more than half the oil we consume is imported from other countries; principal sources are Saudi Arabia, Venezuela, Canada, and Mexico. Simple arithmetic demonstrates that the rate of oil consumption in the United States is very high compared to the estimated total domestic resources available. Some of those resources have yet to be found, however, and will require time to discover and develop.

Both U.S. and world oil supplies could be nearly exhausted within decades especially considering the likely acceleration in world energy demands. Occasionally explorationists do find the rare, very large concentrations of petroleum—the deposits on Alaska's North Slope and beneath Europe's North Sea are examples. Yet even these make only a modest difference in the long-term picture. The Alaskan oil discovery, for instance, represented reserves of about 10 billion barrels—a great deal for a single region, but less than 18months of current U.S. consumption at our rate. However, large finds such as that in Alaska do reduce U.S. reliance on foreign imports and thus our balance of payments.