GEOLOGY AND MINERALOGY OF NATURAL BITUMEN AND HEAVY OIL RESERVOIRS

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Keywords: Bitumen, heavy oil, extra heavy oil, geology, minerals, Athabasca deposit, world deposits, properties, recovery, secondary recovery, enhanced oil recovery, porosity, permeability.

Contents

Summary

Tar sand (also known as oil sand and bituminous sand) is a sand deposit that is impregnated with dense, viscous petroleum-like material called bitumen. Tar sand deposits are widely distributed throughout the world and the various deposits have been described as belonging to two types: (a) stratigraphic traps; (b) structural traps although gradations between the types of deposit invariably occur.

Heavy oil reservoirs and tar sand deposits are widely distributed throughout the world in a variety of countries. Although the heavy oil reservoirs can be seen as reservoirs that are very similar in geological character to petroleum reservoirs, tar sand deposits can differ considerably from conventional crude oil and heavy oil reservoirs. In addition, the mineralogy of the reservoirs and deposits varies from location to location.

Whether it is a heavy oil reservoir of a tar sand deposit, the reservoir rock must possess fluid-holding capacity (porosity) and also fluid-transmitting capacity (permeability). Thus, the mineralogy of the reservoir or deposit can determine whether or not a geological stratum (or strata) has the necessary properties to hold fluids. As part of the mineralogy, a variety of different types of openings in rocks are responsible for these properties in reservoir rocks. The most common are the pores between the grains of which the rocks are made or the cavities inside fossils, openings formed by solution or fractures, and joints that have been created in various ways. The relative proportion of the different kinds of openings varies with the rock type, but pores usually account for the bulk of the storage space. The effective porosity for oil storage results from continuously connected openings. These openings alone provide the property of permeability, and although a rock must be porous to be permeable, there is no simple quantitative relationship between the two.

In the more localized context of the Athabasca deposit, inconsistencies arise presumably because of the lack of mobility of the bitumen at formation temperature (approximately 4°C, 39°F). For example, the proportion of bitumen in the tar sand increases with depth within the formation. Furthermore, the proportion of the non-volatile asphaltenes or the non-volatile asphaltic fraction (asphaltenes plus resins) in the bitumen also increases with depth within the formation that leads to reduced yields of distillate from the bitumen obtained from deeper parts of the formation. In keeping with the concept of higher proportions of asphaltic fraction (asphaltenes plus resins), variations (horizontal and vertical) in bitumen properties have been noted previously, as have variations in sulfur content, nitrogen content, and metals content.

Obviously, the richer tar sand deposits occur toward the base of the formation. However, the bitumen is generally of poorer quality than the bitumen obtained from near the top of the deposit insofar as the proportions of non-volatile coke-forming constituents (asphaltenes plus resins) are higher (with increased proportions of nitrogen, sulfur, and metals) near the base of the formation.

The determining factor is site specificity.

1. Geology and Mineralogy of Natural Bitumen and Heavy Oil Reservoirs

When petroleum occurs in a reservoir that allows the crude material to be recovered by pumping operations as a free-flowing dark to light colored liquid, it is often referred to as conventional petroleum. On the other hand, heavy oil is much more difficult to recover from the subsurface reservoir. The higher viscosity (and lower API gravity) than conventional petroleum, and primary recovery of these petroleum types usually requires thermal stimulation of the reservoir. In addition to the character of the heavy oil, the difficulties encountered in recovery may also be due to reservoir structure as well as the mineralogy of the reservoir.

2. Permeability and Porosity

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Reservoir rocks tend to show far greater variations in permeability than in porosity, and in addition, these two properties, as measured on core samples from reservoir rocks, are not always identical with the values indicated for the rock in bulk underground. The differences arise from the non-representative nature of cores, especially when there are wide variations in the sizes of the openings in the rocks and irregularities in their distribution. Porosity is generally in the range of 5% to -30% while permeability is commonly between 0.005 darcy and several darcies as measured on small samples. It should be noted that pores might be, at best, only a millimeter or so in width, whereas fossil and solution cavities may sometimes be thirty times to fifty times wider. Many joints and fractures are probably only a millimeter across, although they may extend for considerable distances.

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Biographical Sketch

Dr. James G. Speight has a Ph.D. in Organic Chemistry from the University of Manchester, England, and works for CDW Inc. as an Author/Lecturer/Technical and Business Advisor. Previously, he was Chief Executive Officer at the Western Research Institute (1990–1998). Chief Executive Officer. Dr. Speight has thirty years of experience in areas associated with the properties and processing of conventional and synthetic fuels. He has participated in, as well as led, significant research in defining the use of chemistry of heavy oil and coal. He has well over three hundred publications, reports, and presentations detailing these research activities. Dr. Speight is currently editor of the journal Petroleum Science and Technology (formerly Fuel Science and Technology International), editor of the journal Energy Sources, and co-editor of the journal Reviews in Process Chemistry and Engineering. He is recognized as a world leader in the areas of fuels characterization and development. Dr. Speight is also Adjunct Professor of Chemistry and Adjunct Professor of Chemical Engineering at the University of Wyoming as well as Adjunct Professor of Chemical and Fuels Engineering at the University of Utah. Dr. Speight is the author/editor/compiler of nineteen books and bibliographies related to fossil fuel processing and environmental issues. As a result of his work, Dr. Speight was awarded the Diploma of Honor, National Petroleum Engineering Society, For Outstanding Contributions to the Petroleum Industry in 1995 and the Gold Medal of Russian Academy of Sciences (Natural) for Outstanding Work in the Area of Petroleum Science in 1996. He has also received the Specialist Invitation Program Speakers Award from

NEDO (New Energy Development Organization, Government of Japan) in 1987 and again in 1996. Dr. Speight also received the degree of Doctor of Sciences from the Scientific Research Geological Exploration Institute (VNIGRI), St. Petersburg, Russia For Exceptional Work in Petroleum Science in 1997.