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Annotated bibliography of potential oil shales of the western United States exclusive of the Green River Formation

by

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INTRODUCTION

Oil shale is a fine-grained sedimentary rock that contains kerogen, an indigenous organic material insoluble in ordinary organic solvents, and yields significant amounts of oil when heated. Potential oil shales are herein defined as those portions of stratigraphic units that will yield at least 4 gal/ton (17 l/mt) of oil by Fischer assay so that they may have economic potential sometime in the future.

The largest resources of oil shale and the most extensively examined deposits are in the Green River Formation of northwestern Colorado, southwestern Wyoming, and northeastern Utah. The Green River oil shales overshadow all other oil shales of the western U.S., but that does not mean that the other deposits should be ignored. Deposits in the Elko Formation near Elko, Nevada, in many respects resemble those of the Green River Formation but are less extensive and structurally more complex. The Elko oil shales yield up to 85.5 gal/ton (358 l/mt) and contain at least 191 million barrels (30 million m^3) of oil. For comparison, the Green River oil shales yield up to about 100 gal/ton (417 l/mt) and contain approximately 1.8 trillion barrels (0.3 trillion m^3) of oil. The Catlin Shale Products Co. produced about 12,000 barrels of shale oil at Elko during the period 1917-1930 and outperformed all other U.S. oil shale operations at the time. It is conceivable that the Elko Formation, which is somewhat younger than the Green River Formation, may once have covered a large part of northeastern Nevada and was subsequently deformed and mostly either buried or eroded away.

Other potential oil shales include the Barnett Formation of central Texas; the Crevasse Canyon Formation of northwestern New Mexico; the Heath Formation of central Montana; the Monterey Formation of California; the Niobrara Formation of Colorado, Wyoming, South Dakota, and Nebraska; parts of the Phosphoria Formation of Montana, Idaho, Wyoming, Utah, and Nevada; and the Sharon Springs Member of the Pierre Shale in Colorado, Kansas, Nebraska, and South Dakota. Most of these deposits are of low grade or limited extent but are still considered to have some oil shale potential.

This bibliography is not exhaustive but is representative of the potential oil shales of the western U.S. as reported in the literature. For some states only a limited amount of information was available.

Alderson, V.C., 1919, The oil shale industry: Colorado School of Mines Quarterly, v. 14, no. 4, p. 1-15.

Dwindling supplies of petroleum and natural gas in 1918 necessitate that oil shale be given serious consideration as a source of oil. Oil shale is found in Colorado, Utah, Wyoming, Nevada, Montana, and California as well as outside the United States. Brief descriptions of foreign oil shale deposits and more extensive descriptions of the Colorado oil shales are given.

Angino, Ernest, Dellwig, Louis, Berg, James, Stanley, Barbara, and Walters, Robert, 1981, Inventory and evaluation of potential oil shale development in Kansas: U.S. Department of Energy Report no. DOE/R7/01060--T1, 42 p.

Authors review certain oil shales in Kansas with emphasis on proximity to mineable coal beds as an economic incentive. Five black shales in eastern Kansas were studied and mapped in detail. "These shales have an estimated reserve of oil of 33.5 x 10^8 barrels at 75% recovery." No new oil yields are given for the oil shales in this report, but oil yields are taken from Runnels and others (1952).

Baughman, G.L., and Cox, C.H., 1982, Oil shale symposia proceedings index. 1964-82: Golden, Colorado School of Mines Press, 110 p.

This is a comprehensive index by subject, author, company, and chronological order of presentation of the proceedings of the Colorado School of Mines Oil Shale Symposia through 1982.

Bay, K.W., 1969, Stratigraphy of Eocene sedimentary rocks in the Lysite Mountain area, Hot Springs, Fremont, and Washakie Counties, Wyoming: Laramie, Wyoming, University of Wyoming, Ph. D. thesis, 181 p.

Middle and Upper Eocene volcanic-rich sedimentary rocks at Lysite Mountain in north-central Wyoming are divided into a lower sequence characterized by carbonaceous sediments including oil shale and an upper sequence devoid of oil shale. Oil yields of up to 35.5 gallons per ton (148.0 liters per metric ton) were obtained from individual samples of lower sequence rocks. [The lower sequence of Bay is approximately the same as the Aycross(?) equivalent of Love (1964).]

Bowen, C.F., 1918, Phosphatic oil shales near Dell and Dillon, Beaverhead County, Montana: U.S. Geological Survey Bulletin 661-I, p. 315-320.

Oil shales occur in the Phosphoria(?) Formation and in Tertiary lake beds in southwestern Montana. Distillation tests on samples of shale from the Phosphoria(?) gave 7.5 to 24 gallons of oil per ton (31.3 to 100 liters per metric ton), and tests on samples of the lake beds gave about 8 gallons of oil per ton (33 liters per metric ton).

Bramlette, M.N., 1946, The Monterey Formation of California and the origin of its siliceous rocks: U.S. Geological Survey Professional Paper 212, p. 35-37.

The Monterey Formation of Miocene age, located along the California coast, is commonly bituminous and contains source beds of petroleum. Many California oil fields owe their source of petroleum to the Monterey.

Cadman, W.H., 1948, The oil shale deposits of the world and recent developments in their exploitation and utilization, reviewed to May 1947: Journal of the Institute of Petroleum, v. 34, no. 290, p. 109-132.

This is a survey of the oil shale deposits in various countries including Great Britain, France, Estonia, Sweden, Spain and Portugal, Italy, Czechoslovakia, U.S.S.R., Turkey, Bulgaria, Germany, Japan, Australia, New Zealand, Canada, South Africa, India and Burma, Brazil, and the United States.

Cane, R.F., 1976, The origin and formation of oil shale, in Yen, T.F., and Chilingarian, G.V., eds., Oil shale: New York, Elsevier Scientific Publishing Co., p. 27-60.

The insoluble organic matter in oil shale known as kerogen originated at least in part from algae. The organic precursors of kerogen are probably the lipids. Torbanite, the richest kind of oil shale, in New South Wales, Australia, and tasmanite from Tasmania are described in some detail.

Cogbill, A.M., 1958, A study of oil from shale: Compass of Sigma Gamma Epsilon, v. 35, no. 3, p. 154-172.

Author reviews the nature, origin, and distribution of oil shale in the United States. Author also gives a history of the shale oil industry and discusses the processing and refining of shale oil. A close relation between oil shale and some coals is pointed out. Report briefly describes oil shales from the Green River Formation of Colorado, Utah, and Wyoming, those from Nevada, California, and Montana, and the Devonian black shales of the eastern United States.

Condit, D.D., 1920, Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah, in Contributions to Economic Geology, 1919: U.S. Geological Survey Bulletin 711-B, p. 15-40.

Shales in the Phosphoria Formation and in Tertiary lake beds in southwestern Montana, black shales in the Three Forks Formation and Quadrant Quartzite of west-central Montana, and shales from western Montana southward to Utah were investigated for their oil shale potential. In the Dillon-Dell area of southwestern Montana, oil shale in the Phosphoria Formation yielded 25 to 30 gallons of oil per ton (104 to 125 liters per metric ton) while shales in the Phosphoria of southeastern Idaho yielded only a trace of oil. With one exception, shales in the Quadrant Quartzite and Three Forks Formation yielded only a few gallons of oil per ton. Samples of Tertiary shales (actually impure lignite) collected along Medicine Lodge Creek yielded as much as 36 gallons of oil per ton (150 liters per metric ton). Several factors make this oil yield figure less attractive than it would appear.

Constenius, K.N., and Dyni, J.R., 1983, Lacustrine oil shales and stratigraphy of part of the Kishenehn basin, northwestern Montana: Mineral and Energy Resources, Colorado School of Mines, v. 26, no. 4, 16 p.

The Kishenehn Formation of Oligocene age contains oil shale in the Middle Fork region of the Kishenehn basin of northwestern Montana. The oil shale and sapropelic coals yield from 34 to 155 l/mt (8.1-37.2 gal/ton) of oil by the modified Fischer assay method. It is unlikely that these oil shales will be mined in the near future.

Cox, W.E., and Cole, G.A., 1981, Oil shale potential in the Heath and Tyler Formations, central Montana: Montana Bureau of Mines and Geology Geologic Map 19.

Authors show a generalized geologic map and photos of the Heath Formation in central Montana and give oil yields from several sources mostly in the 10 gal/ton (42 l/mt) range or less. The Tyler Formation was determined to have very low oil potential. Authors conclude that in situ retorting and recovery processes are probably best suited for obtaining oil from the Heath Formation.

Cressman, E.R., and Swanson, R.W., 1964, Stratigraphy and petrology of the Permian rocks of southwestern Montana: U.S. Geological Survey Professional Paper 313-C, 569 p.

This is a comprehensive treatment of the Permian rocks of southwestern Montana including the Phosphoria Formation. The Meade Peak Phosphatic Shale Member and the Retort Phosphatic Shale Member of the Phosphoria Formation contain significant amounts of carbonaceous material. The report includes a number of measured stratigraphic sections.

Culbertson, W.C., and Pitman, J.K., 1973, Oil shale, in Brobst, D.A., and Pratt, W.P., eds., United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 497-503.

Oil shale resource estimates for the United States are presented. Although the resources of the Green River Formation overshadow all others, the resources of Alaskan oil shales and the oil shale resources of the Monterey Formation in California are significant. No oil shale operation has yet been commerically successful in the United States.

Decker, R.W., 1962, Geology of the Bull Run quadrangle, Elko County, Nevada: Nevada Bureau of Mines Bulletin 60, p. 56.

Report includes a 1:62,500 scale geologic map of the Bull Run quadrangle, Elko County, Nevada, showing the distribution of the Miocene Humboldt Formation which includes oil shale in its lower part. [The lower part of the Humboldt Formation was reassigned to the Elko Formation by Smith and Ketner (1976).]

Derkey, P.D., Abercrombie, F.N., Vuke, S.M., and Daniel, J.A., 1985, Geology and oil shale resources of the Heath Formation, Fergus County, Montana: Montana Bureau of Mines and Geology Memoir 57, 100 p.

"The primary purpose of this study was to document the thickness, lateral continuity, oil yield and metal content of oil shale in the Mississippian Heath Formation. The oil shale bed contains anomalously high values of heavy metals associated with carbonaceous shale and limestone. Average values (weighted for sample interval thickness) for the bed are 385 ppm Cr, 352 ppm Mo, 269 ppm Ni, 948 ppm V, 1,737 ppm Zn, 11.4 weight percent organic carbon and 10.4 gal of oil per short ton. A direct correlation exists between oil yield (in gal per short ton) and organic carbon content (in weight percent)."

Desborough, G.A., Poole, F.G., and Green, G.N., 1981, Metalliferous oil shales in central Montana and northeastern Nevada: U.S. Geological Survey Open-File Report 81-121, 14 p.

"Metalliferous oil shales in the Heath Formation of Late Mississippian age underlie more than 2,700 mi^2 (7,020 km^2) in central Montana. Metals in the oil shales (values are expressed in weight percent) include vanadium (as much as 0.8 V_2O_5), molybdenum (as much as 0.09), nickel (as much as 0.11), zinc (as much as 0.69), and selenium (as much as 0.012); the highest metal values are present in strata that also have the highest yields of syncrude oil. Estimates of shale-oil resources in the Heath Formation in central Montana exceed 180 billion barrels of syncrude oil based on a minimum thickness of 160 ft (48 m) of shale with an estimated oil yield of 10 gallons per ton of rock. A similar metalliferous oil shale in the Woodruff Formation of Devonian age in southwestern Elko County, Nevada, contains significant amounts of vanadium."

Desborough, G.A., Poole, F.G., Hose, R.K., and Radtke, A.S., 1979, Metals in Devonian kerogenous marine strata at Gebellini and Bisoni properties in southern Fish Creek Range, Eureka County, Nevada: U.S. Geological Survey Open-File Report 79-530, 31 p.

The Gebellini facies of the Woodruff Formation of Devonian age in east-central Nevada has potential for shale oil as well as vanadium, zinc, selenium, and molybdenum resources. Oil yields of fresh black rock are as much as 12 gallons per ton (50 liters per metric ton). In unoxidized samples vanadium oxide (V_2O_5) ranges from 3,000 to 7,000 ppm (parts per million), zinc ranges from 4,000 to 18,000 ppm, selenium ranges from 30 to 200 ppm, and molybdenum ranges from 70 to 960 ppm.

Dibblee, T.W., Jr., 1950, Geology of southwestern Santa Barbara County, California: California Department of Natural Resources Bulletin 150, 95 p.

Author describes the Monterey Formation and other stratigraphic units in the Santa Barbara area, California, and includes geologic maps showing the distribution of the Monterey at 1:62,500 scale. The Monterey Formation contains bitumen and significant amounts of carbonaceous material.

Donnell, J.R., 1976, Environments of deposition of oil shale [abs.]: American Association of Petroleum Geologists Bulletin, v. 60, no. 4, p. 666.

"Oil shale deposits are present throughout the world in marine, brackish-water, and freshwater sedimentary sequences that range in age from Cambrian to Holocene. Oil shales were deposited on shallow-marine platforms, in geosynclines, and in lagoons that were marginal to both. They also were deposited in lacustrine environments and in environments transitional between paludal and lacustrine."

______1977, Oil-shale resource investigations of the U.S. Geological Survey: U.S. Geological Survey Open-File Report 77-637, 41 p.

The oil shale resource investigations conducted by the U.S. Geological Survey in 1977 including future plans are discussed. Most of the research effort is focused on the Piceance Creek basin in Colorado and the Uinta basin in Utah. Individual projects that were active at the time are briefly described.

Donnell, J.R., Tailleur, I.L., and Tourtelot, H.A., 1967, Alaskan oil shale, in Fourth symposium on oil shale: Colorado School of Mines Quarterly, v. 62, no. 3, p. 39-43.

Oil shales are contained in the Mississippian through Lower Cretaceous rock sequence of the Southern Foothills belt on the northern side of the Brooks Range in northern Alaska. The highest grade oil shales occur in rocks ranging in age from Triassic to Early Cretaceous. Content of barium is unusually high in almost all oil shale samples, and unusually high concentrations of Ag, Au, B, Cr, Cu, Co, Hg, Pb, Mo, Ni, Sr, V, and Zn were also found in some samples. Several negative factors render initiation of any commerical oil shale operation in Alaska unlikely in the foreseeable future.

Duncan, D.C., 1967, Geologic setting of oil shale deposits and world prospects, in Drilling and production, Seventh World Petroleum Congress, Mexico, 1967, Proceedings, v. 3: London, Elsevier Publishing Co., p. 659-667.

Three general categories of oil shale are carbonate-rich shale, siliceous shale, and cannel shale. The principal environments in which oil shale is deposited are (1) large lake basins; (2) shallow seas on continental platforms and shelves; and (3) small lakes, bogs, and lagoons associated with coal-forming swamps. The age and world distribution of oil shale deposits are discussed and illustrated on world maps. The geologic settings favorable for prospecting are described. Some of the largest deposits of oil shale include the Green River Formation of the western U.S., the Devonian black shales of the eastern and central U.S., the Permian Irati Shale of Brazil, and Cambrian deposits of northern Asia.

______1976, Geologic setting of oil-shale deposits and world prospects, in Yen, T.F., and Chilingarian, G.V., eds., Oil shale: New York, Elsevier Scientific Publishing Co., p. 13-26.

This is the same paper by Duncan (1967).

Duncan, D.C., and Swanson, V.E., 1965, Organic-rich shale of the United States and world land areas: U.S. Geological Survey Circular 523, 30 p.

This is the basic reference on oil shales. Report includes definitions, types of deposits, status of the oil shale industry, classification of resources, and resource estimates for the U.S. and abroad. Oil yields for many different oil shale deposits are given. Outline maps of the world, the United States, and the area covered by the Green River Formation showing location of oil shale deposits are included. Organic-rich shale deposits of the world have a potential yield of more than 2×10^{15} barrels (0.3×10^{15} cubic meters) of oil.

Dyni, J.R., and Schell, E.M., 1982, Tertiary coals in Medicine Lodge Creek Valley, Beaverhead County, Montana: Montana Bureau of Mines and Geology Geologic Map 29, 18 p.

"This report presents the results of the exploratory drilling and laboratory analyses of core and outcrop samples of coal and associated rocks in the Medicine Lodge Creek Valley, southwestern Montana. Destructive distillation tests of coal and carbonaceous shale from prospects and outcrops produced trace amounts to 14.9 gallons of oil per ton; most samples yielded a trace to about 5 gal/ton."

Ertl, Tell, 1961, Shale oil--a competative fuel in the 1960's: Journal of Petroleum Technology, v. 13, p. 983-986.

Report starts with a description of oil shale and covers oil shale resources, industrial development, production techniques, and economics. China and Russia both have active oil shale industries, proving that oil shale can be commercial under the right circumstances. Author concludes that oil shale can be a viable resource in the U.S. and Brazil.

Evans, T.J., 1975, Native bituminous materials in Texas: University of Texas, Austin, Bureau of Economic Geology Mineral Resource Circular No. 57, 18 p.

Report includes the oil shales of the Barnett Formation of central Texas which is exposed across Lampasas, San Saba, and McCulloch Counties in a 60-mile (97-kilometer) discontinuous band varying from 100 to 400 feet (30 to 122 meters) in width. Insufficient data are available to make a reliable oil shale resource estimate of the Barnett.

Feth, J.H., 1964, Review and annotated bibliography of ancient lake deposits (Precambrian to Pleistocene) in the western states: U.S. Geological Survey Bulletin 1080, 119 p.

Report includes the lacustrine oil shale deposits such as the Green River Formation and the Tatman Formation of Wyoming. It contains maps of lake deposits at 1:2,500,000 scale.

Foster, R.W., Luce, P.B., Culver, L.G., and Maras, B.B., 1966, Preliminary investigations of the oil shale potential in New Mexico: New Mexico Bureau of Mines and Mineral Resources Circular 87, 22 p.

Various shales in New Mexico were tested for their oil shale potential, but no high-grade deposits were found. As much as 5 gallons of oil per ton (21 liters per metric ton) was obtained from samples of highly carbonaceous shale containing thin coal seams in the Sandia Formation of Pennsylvanian age near Lamy, New Mexico. As much as 10 gallons of oil per ton (42 liters per metric ton) was distilled from samples of carbonaceous, coaly shales in the Crevasse Canyon Formation (probably the Gibson Coal Member) of Cretaceous age located east of Pinedale, New Mexico. As much as 5 gallons of oil per ton (21 liters per metric ton) was obtained from the lower part of the Mancos Shale 13 miles (21 kilometers) west of Shiprock, New Mexico. From 4.2 to 8.6 gallons of oil per ton (17.5 to 35.9 liters per metric ton) was obtained from carbonaceous shales in the Raton Formation of Tertiary age near Raton, New Mexico.

Gavin, M.J., 1922, Oil-shale: an historical, technical, and economic study: U.S. Bureau of Mines Bulletin 210, 201 p.

This is a general report on various aspects of the oil shale industry in 1921 including U.S. and foreign deposits. The oil shale industry of Scotland is perhaps the best developed anywhere and serves as a model for the development of a U.S. industry. Report covers the workings of several different types of oil shale retorts that have been used to distill oil from rock.

Gaylord, E.G., and Hanna, G.D., 1925, Correlation of organic shales in the southern end of the San Joaquin Valley, California: American Association of Petroleum Geologists Bulletin, v. 9, no. 2, p. 228-234.

On the basis of paleontologic evidence, the organic shales at the southern end of the San Joaquin Valley, California are correlated with the Monterey Formation. Much of the oil produced from the area is believed to have originated in these shales.

Gill, J.R., Cobban, W.A., and Schultz, L.G., 1972, Stratigraphy and composition of the Sharon Springs Member of the Pierre Shale in western Kansas: U.S. Geological Survey Professional Paper 728, 50 p.

The stratigraphy and mineralogy of the Sharon Springs Member of the Pierre Shale in western Kansas, locally containing low grade oil shale, is described. The Sharon Springs Member is recognized in Kansas, Nebraska, North and South Dakota, and parts of Colorado, Wyoming, Montana, and eastern Utah. Several measured surface stratigraphic sections and two well log descriptions from Kansas are given.

Gore, F.D., 1924, Oil shale in Santa Barbara County, California: American Association of Petroleum Geologists Bulletin, v. 8, no. 4, p. 459-472.

The oil shales of the Monterey Formation of Miocene age located in Santa Barbara County, California, are briefly described. Some of the oil can be removed from the shales by treatment with organic solvents, and some can be removed only by destructive distillation. The average oil yield is about 30 gallons per ton (125 liters per metric ton). The crude oil obtained by distillation is particularly well suited for use as flotation oil in the recovery of sulfide minerals in ores.

Granger, A.E., Bell, M.M., Simmons, G.C., and Lee, Florence, 1957, Geology and mineral resources of Elko County, Nevada: Nevada Bureau of Mines Bulletin 54, p. 171-172.

The oil shales near Elko, Nevada occur in the lower part of the Humboldt Formation. [The lower part of the Humboldt Formation was reassigned to the Elko Formation by Smith and Ketner in 1976.]

Gries, J.P., 1942, Economic possibilities of the Pierre shale: South Dakota Geological Survey Report of Investigations No. 43, 79 p.

The Pierre Formation is described and its distribution is shown for South Dakota. The oil shale potential of the Sharon Springs Member of the Pierre is indicated, but it is very low grade.

Hoots, H.W., 1929, Oil shale in a producing oil field in California, in Shorter contributions to general geology, 1928: U.S. Geological Survey Professional Paper 154, p. 171-173.

Oil shale of probable Miocene age encountered in a well drilled at the south end of San Joaquin Valley, California is described. The oil shale zone in the well correlates strongly with the zone of oil production in the area.

Hoots, H.W., Blount, A.L., and Jones, P.H., 1935, Marine oil shale, source of oil in Playa Del Rey field, California: American Association of Petroleum Geologists Bulletin, v. 19, no. 2, p. 172-205.

Marine oil shale that constitutes the middle unit of the Modelo (or Monterey) Formation of late Miocene age is indicated as the source of oil in the Playa del Rey oil field located about 15 miles (24 kilometers) west of Los Angeles, California. The oil shale contains both free oil and pyrobituminous material. The authors contend that free oil can be obtained from organic sediment when subjected to appropriate temperatures and pressures during the metamorphosis of the sediment to oil shale. The geology of the area is discussed in some detail.

Hundemann, A.S., 1975, Oil shale--a bibliography with abstracts: Available from National Technical Information Service as report NTIS/PS-75/362, 136 p.

This bibliography covers the period 1964 to April, 1975 and contains 136 entries with abstracts covering exploration, mining, retorting, chemistry, environmental impacts, and policies relating to oil shale research.

Hunt, J.M., and Jamieson, G.W., 1958, Oil and organic matter in source rocks of petroleum, in Weeks, L.G., ed., Habitat of oil: American Association of Petroleum Geologists Symposium, p. 735-746.

The distribution of organic matter in potential petroleum source rocks of various lithologic character is investigated. Hydrocarbon, asphalt, and kerogen were analyzed separately and results tabulated. Small but significant amounts of hydrocarbon were found in nearly all samples, while the amount of kerogen dominated in all samples. The Niobrara Formation and the Woodford Shale yielded large amounts of kerogen, a result consistent with their oil shale potential.

Jaffé, F.C., 1962, Oil shale, Part I, Nomenclature, uses, reserves and production: Colorado School of Mines Mineral Industries Bulletin, v. 5, no. 2, 11 p.

Author discusses the terminology, classification, uses, resources, and production of oil shale. Several classifications of oil shales have been devised, but none have met with general acceptance. The principal oil shale resources of the world are tabulated with accompanying pertinent information.

Janka, J.C., and Dennison, J.M., 1980, Devonian oil shale, in Synthetic fuels from oil shale: Symposium sponsored by Institute of Gas Technology, 1979, p. 21-116.

The Devonian oil shales of the eastern and central United States are discussed. "The Woodford shale in Murray County, Oklahoma shows Fischer Assay oil yields up to 15.3 gal/ton and averaging 11.5 gal/ton. The areal extent of the Woodford shale outcrop in Oklahoma, however, is limited."

Jones, J.C., 1923, Suggestive evidence on the origin of petroleum and oil shale: American Association of Petroleum Geologists Bulletin, v. 7, no. 1, p. 67-72.

"The chief difference in the origin of oil shales and sediments giving rise to petroleum lies in the degree of bacterial decomposition of the organic matter which in turn depends on the saline content of the waters in which the decay takes place." Evidence supporting this observation comes from Lake Lahontan in northwestern Nevada.

Keefer, W.R., 1961, Waltman Shale and Shotgun Members of Fort Union Formation (Paleocene) in Wind River Basin, Wyoming: American Association of Petroleum Geologists Bulletin, v. 45, no. 8, p. 1310-1323.

The Waltman Shale Member of the Fort Union Formation of Paleocene age in the Wind River Basin of central Wyoming contains significant amounts of organic material, some of which converts to oil during distillation. Some of the shale contains as much as 6.5 percent organic matter and yields the equivalent of about 4 gallons of oil per ton (17 liters per metric ton).

______1965, Stratigraphy and geologic history of the uppermost Cretaceous, Paleocene, and lower Eocene rocks in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-A, p. A23-A28.

The Waltman Shale Member of the Fort Union Formation of Paleocene age in Wyoming may be considered a very low grade oil shale. The retorted shale yields about 2.5-4 gallons of oil per ton of rock (10.4-17 liters per metric ton).

Ketner, K.B., 1970, Geology and mineral potential of the Adobe Range, Elko Hills, and adjacent areas, Elko County, Nevada: U.S. Geological Survey Professional Paper 700-B, p. B105-B108.

The lower part of the Tertiary sequence exposed along the east side of the Adobe Range and around the Elko Hills in central Elko County, Nevada contains extensive beds of oil shale. The stratigraphy, structure, mineral potential, and suggestions for prospecting in the area are discussed.

Knutson, C.F., and Dana, G.F., 1983, Developments in oil shale in 1982: American Association of Petroleum Geologists Bulletin, v. 67, no. 10, p. 2009-2030.

Oil shale developments in 1982 in Montana, Nevada, Texas, and elsewhere are presented. Oil shale potential exists in Nevada in the Elko Formation, Sheep Pass Formation, Newark Canyon Formation, Vinini Formation, Woodruff

Formation, and Wyemaha Formation. Outline maps of Nevada and Texas showing potential oil shales are included.

Landis, E.R., 1958, Radioactivity and uranium content of Devonian and Mississippian black shales in the central midcontinent area, in Geologic investigations of radioactive deposits--Semiannual progress report, December 1, 1957 to May 31, 1958: U.S. Geological Survey TEI-740, p. 202-208, issued by U.S. Atomic Energy Commission Technical Information Service, Oak Ridge, Tenn.

The specific gravity of oil and oil yield are plotted versus uranium content for six samples of Woodford Shale from Oklahoma. The oil yields for samples that gave a large enough yield for specific gravity determinations range from 11 to 16 gallons per ton (46 to 67 liters per metric ton).

Lincoln, F.C., 1923, Mining districts and mineral resources of Nevada: Reno, Nevada Newsletter Publishing Co., p. 38-39, 43-44.

Oil shale is mentioned at Carlin and Elko, Nevada. The Catlin Shale Products Co. has produced shale oil at Elko. Elko oil shales yield as high as 50-75 gallons of oil per ton (209-313 liters per metric ton).

Love, J.D., 1964, Uraniferous phosphatic lake beds of Eocene age in intermountane basins of Wyoming and Utah: U.S. Geological Survey Professional Paper 474-E, p. E1-E66.

In the Lysite Mountain area, in north-central Wyoming along the southeast margin of the Bighorn Basin, the Aycross(?) equivalent strata of Eocene age include oil shale, coal, and finely tuffaceous lacustrine beds. [The Aycross(?) equivalent strata at Lysite Mountain are mapped as the Wagon Bed Formation on the 1985 state geologic map of Wyoming.] "Oil content of the oil shale beds reaches a known maximum of 38 gallons per ton, with as much as 23 gallons per ton for a thickness of 7 feet."

"The Tatman Formation along the southwest margin of the Bighorn basin contains as much as 14 gallons of oil per ton."

Lucas, E.L., 1953, Oil shale distillation techniques on Oklahoma shales: Oklahoma Academy of Science Proceedings, v. 34, p. 143-146.

Oil shale assay retort apparatus and methods used on shales from Oklahoma are briefly described. Samples of shale from the Woodford Chert of southern Oklahoma yielded approximately 9.34 gallons of oil per ton of rock (38.95 liters per metric ton).

Lyttle, R.B., 1982, Shale oil and tar sands, the promises and pitfalls: New York, Franklin Watts, 86 p.

Many facts and figures on the oil shale and tar sand industries are presented. The author optimistically contends that the timing may finally be right for the development of a commercial domestic oil shale industry. However, the development of a domestic oil shale industry is no substitute for prudent energy conservation measures.

Maughan, E.K., 1975, Organic carbon in shale beds of the Permian Phosphoria Formation of eastern Idaho and adjacent states--a summary report, in Wyoming Geological Association Guidebook, 27th Annual Field Conference, p. 107-115.

Parts of the Permian Phosphoria Formation are source beds for petroleum in Idaho, Montana, Utah, and Wyoming. The areal distribution of organic carbon in the Meade Peak Member and the Retort Member of the Phosphoria Formation is illustrated and described.

______1976, Organic carbon and selected element distribution in the phosphatic shale members of the Permian Phosphoria Formation, eastern Idaho and parts of adjacent states: U.S. Geological Survey Open-File Report 76-577, 92 p.

The Meade Peak Member of the Phosphoria Formation contains as much as 8.8 weight percent organic carbon, and the Retort Member of the Phosphoria Formation contains as much as 9.7 weight percent organic carbon. The trace elements silver, barium, chromium, copper, lanthanum, molybdenum, neodymium, nickel, lead, strontium, titanium, vanadium, yttrium, ytterbium, and zinc are found in high concentrations in these units. In some areas petroleum has been generated within the Retort and Meade Peak Members and has either migrated or been metamorphosed.

McAuslan, E.R., 1959, In the Niobrara, oil may yield to special methods: Oil and Gas Journal, v. 57, no. 38, p. 158-160, 162-164, 166.

The Niobrara Formation of Cretaceous age is probably a source rock for petroleum and a low-grade oil shale locally. Oil yields of 10-12 gallons per ton (42-50 liters per metric ton) are reported, but sample locations are not given.

McKee, R.H., and Goodwin, R.T., 1923, A chemical examination of the organic matter in oil shales: Colorado School of Mines Quarterly, v. 18, no. 1, supplement A., 41 p.

In this study four procedures were used to determine the nature of kerogen: (1) chemical analysis, (2) the effect of heat, (3) the action of solvents and reagents, and (4) microscopic examination. Chemical analysis of oil shales shows that there is considerable variation in organic constituents depending on geographic locality and geologic formation. The thermal decomposition of kerogen does not take place directly, but an intermediate product forms that decomposes to form oil. Solvents and reagents have only minor effects on oil shale while pyrolysis is the only effective means of releasing oil from oil shale. All of the organic matter identifiable under the microscope consists of plant material and its degradation products.

McKelvey, V.E., Williams, J.S., Sheldon, R.P., Cressman, E.R., Cheney, T.M., and Swanson, R.W., 1956, Summary description of Phosphoria, Park City, and Shedhorn Formations in western phosphate field: American Association of Petroleum Geologists Bulletin, v. 40, no. 12, p. 2826-2863.

The lithologic and stratigraphic features of the Permian Phosphoria Formation in the western U.S. are discussed in detail. The distribution of the Retort and Meade Peak Phosphatic Shale Members of the Phosphoria, both containing oil shale locally, is described.

Mertie, J.B., Jr., 1929, Preliminary report on the Sheenjek River district, in Smith, P.S., and others, Mineral resources of Alaska, report on progress of investigations in 1926: U.S. Geological Survey Bulletin 797, p. 122.

A sample of oil shale from the Christian River, located about 75 miles (121 kilometers) north of Fort Yukon in northeastern Alaska, was submitted to the U.S. Geological Survey in 1926 and yielded 122 gallons of oil to the ton (509 liters per metric ton). The age and extent of the oil shale are undetermined. Oil shale from along the Yukon River just above Nation River comes from Upper Triassic rocks and yielded 28 gallons of oil per ton (117 liters per metric ton).

Miller, R.N., 1953, Oil shales in Montana: Butte, Mont., Montana School of Mines, B.S. thesis, 78 p.

Oil shales have been found in five different stratigraphic units in Montana: (1) Tertiary lignites(?) in the southwestern part of the state; (2) parts of the Colorado Shale in northwestern Montana; (3) parts of the Phosphoria Formation in southwestern Montana; (4) the Heath Formation in central Montana; and (5) the basal part of the Lodgepole Formation, or Paine Shale, in central Montana. Of these units the Phosphoria appears to have the best potential with oil yields up to 21 gallons per ton (88 liters per metric ton). The middle and upper parts of the Heath Shale, the Colorado Shale, and black shale at the base of the Lodgepole Formation are only slightly petroliferous. Some of the Tertiary lignites(?) have high oil yields, but they are thin and localized.

Moore S.W., Madrid, H.B., and Server, G.T., Jr., 1983, Results of oil-shale investigations in northeastern Nevada: U.S. Geological Survey Open-File Report 83-586, 103 p.

The oil shale resource potential of Nevada is small compared to that of the Green River Formation in Colorado, Utah, and Wyoming. Nevertheless, the Elko Formation in northeastern Nevada has significant oil shale potential that was evaluated by shallow core-drilling near Elko, Nevada. Oil shale resource estimates in the Elko area were calculated at 228 million barrels (36 million cubic meters) of oil from beds averaging at least 15 gal/ton (63 l/mt) over a thickness of 15 feet (5 meters). The Vinini and Woodruff Formations are considered petroleum source rocks in Nevada, and they are also potential oil shales. Locally, these units have high concentrations of heavy metals such as vanadium, selenium, and zinc.

An annotated bibliography for oil shales in northeastern Nevada and Fischer assays of oil yields are appended.

Newton, V.C., Jr., and Lawson, P.F., 1974, Oil shale: Ore Bin, v. 36, no. 8, p. 129-143.

Authors briefly discuss the nature of oil shale, its distribution, its history of commercial development, the status of U.S. oil shale development, the effects of development on the environment, and the outlook for the industry. "A small deposit of oil shale occurs in the Western Cascades of Oregon 10 miles northeast of Ashland. The deposit is interbedded with tuff of the Little Butte Volcanics of Oligocene age and represents a local fresh-water lake environment where organic material and volcanic ash accumulated. Assays by the U.S. Bureau of Mines yielded 35 to 37 gallons of oil per ton of shale. The extent of the deposit is not known but is probably small and is estimated to contain less than a million tons of kerogen shale."

Noble, L.F., 1917, Report on an investigation of oil shale in the vicinity of Schuman, Calif. : U.S. Geological Survey Open-File Report 581, 11 p.

Bituminous brown shales of the Monterey Formation were sampled from the Santa Maria oil district near Schuman, California. The report deals mostly with a description of the sampling.

Nolan, T.B., Merriam, C.W., and Williams, J.S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geological Survey Professional Paper 276, p. 34-36.

The Vinini Formation of Ordovician age is exposed on the eastern slope of Roberts Creek Mountain 25 miles (40 kilometers) northwest of Eureka, Nevada. Samples from the upper part of the Vinini are reported to yield on distillation, values greater than 25 gallons of oil per ton (104 liters per metric ton).

Plummer, F.B., 1940, Summary of progress on geology and oil shale investigations in San Saba County, Texas: Texas University Bureau of Economic Geology Mineral Resource Circular 13, 4 p.

The geology of the Llano region in central Texas was investigated, and a preliminary geologic map of the area was prepared. The Barnett Formation of Mississippian age averages about 20 feet (6 meters) thick and consists of black and brownish-black, extremely thin-bedded, soft, petroliferous, fossiliferous shale with a few layers of limestone. The Barnett is an oil shale that yields as much as 42.2 gallons of oil per ton (176.0 liters per metric ton).

Plummer, F.B., and Grant, Bruce, 1944, Oil shale of central Texas: Oil and Gas Journal, v. 43, no. 22, p. 66, 69-70.

"The oil shales of the Llano region of central Texas are confined to the Barnett Formation of upper Mississippian age. The most characteristic features of the Barnett shale are large, flattened, spherical, calcareous concretions which, when broken, give a strong odor of petroleum and contain cavities which in some instances are filled with a light crude oil." Of 63 samples of shale tested, the average oil yield was 13.61 gallons per ton (56.75 liters per metric ton).

Poole, F.G., and Desborough, G.A., 1980, Oil and metals in Ordovician and Devonian kerogenous marine strata of central Nevada: American Association of Petroleum Geologists Bulletin, v. 64, no. 5, p. 767.

Kerogenous strata in the Vinini Formation of Ordovician age and the Woodruff Formation of Devonian age in central Nevada contain potential resources of syncrude oil, V, Zn, Mo, Se, Ag, and Cr. Low-grade oil shales in these units often yield less than 40 liters of oil per metric ton (10 gallons per ton), but some local layers yield as much as 125 liters per metric ton (30 gallons per ton).

Prien, C.H., 1951, Oil shale and shale oil, in Sell, George, ed., Oil shale and cannel coal, vol. 2: Proceedings of Second Oil Shale and Cannel Coal Conference, Glasgow, Institute of Petroleum, p. 76-111.

The history, occurrence, geologic origin, chemical constitution, recovery, mining, crushing, and refining of oil shale are discussed. Emphasis is on the oil shales of the Green River Formation, but other oil shales are mentioned as well. Author points out the similarity between oil shale and coal. The chemical composition of oil shale is inadequately known, and the organic constituents are complex.

Rogers, M.P., [compiler], 1969, List of Bureau of Mines publications on oil shale and shale oil, 1917-1968: U.S. Bureau of Mines Information Circular 8429, 61 p.

Compiler lists 430 entries on oil shale.

______[compiler], 1977, A bibliography of publications dealing with oil shale and shale oil from U.S. Bureau of Mines, 1917-1974, and the ERDA Laramie Energy Research Center, 1975-1976: U.S. Energy Research and Development Administration, Laramie Energy Research Center, Laramie, Wyo., 50 p.

Compiler lists 663 publications by year of publication.

Rohrer, W.L., and Smith, J.W., 1969, Tatman Formation, in Wyoming Geologic Association Guidebook, 21st Annual Field Conference: p. 49-54.

Geologic relations from two measured sections and other outcrops of the Tatman Formation of Eocene age in the southern part of the Bighorn basin in Wyoming are discussed. Oil yields from the Tatman were determined to be as much as 13.8 gallons per ton (57.5 liters per metric ton).

Rubel, A.C., 1955, Shale oil--as a future energy resource: Mines Magazine, v. 45, no. 10, p. 72-76.

Author describes what he believes is the future of the oil shale industry, especially that of the Green River Formation. Report includes a map of the conterminous U.S. and Alaska showing the principal oil shale resources. A tabulation of the known oil shale formations of the U.S. with information on oil yield and references are also included.

Rühl, Walter, 1982, Tar (extra heavy oil) sands and oil shales, in Beckmann, Heinz, ed., Geology of Petroleum, Vol. 6: Stuttgart, Ferdinand Enke Publishers, p. 74-149.

Report covers the history, geology, geochemistry, recovery, above-ground processing, refining and upgrading, world occurrences, environmental aspects, and resources of oil shale. Oil shales in California, Alaska, Wyoming, Colorado, Nebraska, South Dakota, and Nevada are briefly mentioned. The chemical composition of oil shale kerogen is discussed in some detail.

Runnels, R.T., Kulstad, R.O., McDuffee, Clinton, and Schleicher, J.A., 1952, Oil shale in Kansas: Kansas Geological Survey Bulletin 96, Part 3, p. 157-184.

Several black shales in Kansas have potential as oil shales. Samples from the Sharon Springs Member of the Pierre Shale of Late Cretaceous age located in western Kansas and from several different Pennsylvanian shales in eastern Kansas yield an average of 6 to 12 gallons of oil per ton (25 to 50 liters per metric ton) by Fischer assay. Thirteen localities have oil shales with yields of at least 5 gallons of oil per ton (21 liters per metric ton).

"The quantity of recoverable shale oil known to occur in Kansas, calculated by using only shales that yield 5 or more gallons per ton and using the area of those shales lying under 100 feet or less of overburden, is about 3 billion barrels."

Russell, P.L., 1980, History of western oil shale: New Jersey, Center for Professional Advancement, 152 p.

Author traces the historical development of the oil shale industry in the western United States with emphasis on the companies that tried to produce shale oil. "The Catlin Shale Products Company's operation at Elko, Nevada represented the largest, best technically oriented and best financed effort to develop the western oil shales during the 1917-1930 period." Most of the more recent oil shale activity has been in Colorado.

Schramm, L.W., 1970, Oil shale, in Mineral facts and problems: U.S. Bureau of Mines Bulletin 650, p. 183-202.

This is a general treatment of oil shales including mining, retorting, resources, byproduct and coproduct relationships, economics, and technology. The supply of water may be a major limiting factor on the development of western U.S. oil shales.

Server, G.T., Jr., and Soloman, B.J., 1983, Geology and oil shale deposits of the Elko Formation, Pinon Range, Elko County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1546, scale 1:24,000.

The Elko Formation was mapped over a small area in the Pinon Range of northeastern Nevada. It is divided into four informal members: (1) a tuff and dolomitic shale member, (2) an oil shale, limestone and dolomitic shale member, (3) a limestone and shale member, and (4) a cherty limestone member. The richest bed of oil shale in the Elko Formation yields 20.7 gal/ton (86.3 l/mt).

Sharp, R.P., 1939, The Miocene Humboldt formation in northeastern Nevada: Journal of Geology, v. 47, no. 2, p. 133-160.

The Tertiary basin deposits of the Elko, Nevada region are herein called the Humboldt Formation. "The oil shale of the Humboldt formation is a thin-bedded, dark-colored, petroliferous shale exposed near the base of the formation in the Elko Range south of Elko." Information on the lithology, structure, and age of the Humboldt Formation is given.

Sladek, T.A., 1974, Recent trends in oil shale--Part 1--History, nature, and reserves: Colorado School of Mines Mineral Industries Bulletin, v. 17, no. 6, 20 p.

A brief history, the composition, and resources of oil shale are presented with emphasis on the Green River Formation.

Smith, J.F., Jr., and Howard, K.A., 1977, Geologic map of the Lee 15-minute quadrangle, Elko County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1393, scale 1:62,500.

Map shows limited outcrop of the Eocene and Oligocene(?) Elko(?) Formation, a stratigraphic unit containing oil shale in some localities.

Smith, J.F., Jr., and Ketner, K.B., 1976, Stratigraphy of post-Paleozoic rocks and summary of resources in the Carlin-Pinon Range area, Nevada: U.S. Geological Survey Professional Paper 867-B, p. B1-B48.

The Elko Formation of Eocene and Oligocene(?) age is formally introduced in this report and includes the oil shales south of Elko, Nevada. A stratigraphic type section and upper and lower contacts are described. The Elko Formation is somewhat younger than the Green River Formation of Colorado, Utah, and Wyoming.

The exact extent of the oil shale is unknown, but it occurs scattered over a north-south area of at least 100 km (60 mi) and an east-west area of about 33 km (20 mi).

The oil shales of the Elko Formation could have been a source rock of petroleum.

______1978, Geologic map of the Carlin-Pinon Range area, Elko and Eureka Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-1028, scale 1:62,500.

Map shows outcrops of the Elko Formation, which contains oil shale. This map covers the same area as the geologic map in Smith and Ketner (1976) but at a different scale and with Paleozoic rocks included.

Smith, J.W., 1980, Oil shale resources of the United States: Mineral and Energy Resources, Colorado School of Mines, v. 23, no. 6, 20 p.

Deposits of oil shale are described for the Green River Formation in Colorado, Utah, and Wyoming, the Devonian black shales in the central and eastern U.S., the Phosphoria Formation of Montana, Idaho, and Wyoming, and various other formations throughout the United States. This reference served as a primary source for nearly all the smaller potential oil shales in the U.S. Resource estimates are presented for several of the larger oil shale deposits. A map showing the oil shale deposits of the United States is included.

Solomon, B.J., 1979, Geology and oil shale resources near Elko, Nevada: San Jose, Calif., San Jose State University, M.S. thesis, 142 p.

"Oil shale from the Elko Formation yields up to 358 l/metric ton (85.5 gal/short ton) and contains at least 30 million m^3 (191 million barrels) of oil.

"Deposits similar to the oil shale near Elko are extant over a wide area of northeast Nevada in a region extending about 155 km in a north-south direction and about 125 km in an east-west direction. It is still uncertain whether all these rocks were deposited in a single large basin or whether irregular topography created several lakes.

"Two periods of Tertiary deformation and subsequent erosion have left only isolated remnants of Eocene and Oligocene lacustrine deposits."

Report includes a 1:12,000 scale geologic map of the Elko Formation near Elko, Nevada.

______ 1981, Geology and oil shale resources near Elko, Nevada: U.S. Geological Survey Open-File Report 81-709, 146 p.

This is the same report as Solomon (1979).

Solomon, B.J., McKee, E.H., and Anderson, D.W., 1979, Stratigraphy and depositional environments of Paleogene rocks near Elko, Nevada, *in* Armentrout, J.M., Cole, M.R., and TerBest, Harry, Jr., eds., Cenozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 75-88.

The Elko Formation of Eocene and Oligocene(?) age is subdivided into five informal members near Elko, Nevada. One of the members contains rich oil shale that was mined for oil in the past. The Elko Formation and adjacent stratigraphic units are described.

Solomon, B.J., and Moore, S.W., 1982a, Geologic map and oil shale deposits of the Elko West Quadrangle, Elko County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1410, scale 1:24,000.

The Elko Formation is divided into four informal members that are mapped south of Elko, Nevada. Two of the members contain oil shale that was mined during 1916-1924. Oil yields as high as 34.9 gallons of oil per ton (145.5 liters per metric ton) were obtained from weathered samples. "Much more oil shale may be present in downdropped structural basins than is indicated by the much faulted and eroded oil shale outcrops exposed in the Elko area."

_____1982b, Geologic map and oil shale deposits of the Elko East Quadrangle, Elko County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1421, scale 1:24,000.

Authors divide the Elko Formation into six informal members and map them southeast and east of Elko, Nevada. This is a continuation of the geology of the Elko West Quadrangle of Solomon and Moore (1982a). "The richest bed of oil shale, which is about 7 in. thick, yields 85.5 gallons of oil per ton."

Stanfield, K.E., and Frost, I.C., 1949, Method of assaying oil shale by a modified Fischer retort: U.S. Bureau of Mines Report of Investigations 4477, 13 p.

"A method of assaying oil shale is presented that utilizes a modification of the Fischer cast-aluminum retort used commonly for low-temperature coal carbonizations. The proposed method has several immediate advantages over the former Bureau of Mines oil-shale assay method and is recommended for oil-shale assays until a better method is developed. The report shows the effects of different experimental conditions upon oil yields by the modified Fischer retort and a comparison of oil yields by this method with those obtained by the former Bureau of Mines assay method."

Swanson, V.E., 1960, Oil yield and uranium content of black shales: U.S. Geological Survey Professional Paper 356-A, 44 p.

"Some black shales contain as much as one hundred times more uranium than other common sedimentary rocks, and they also contain organic matter that will yield oil when subjected to destructive distillation. Such shales may be referred to as uraniferous oil shales and have been considered as a potential source of both oil and uranium; oil yield and uranium determinations on more than five hundred samples of these shales are recorded in this report.

"The fraction of the total organic matter in a shale genetically responsible for most of the uranium is of the humic type. Though this same fraction contributes a small part, it is the sapropelic type of organic matter that is the source of most of the oil extractable from a shale."

Tailleur, I.L., 1964, Rich oil shale from northern Alaska, in Geological Survey research 1963: U.S. Geological Survey Professional Paper 475-D, p. D131-D133.

Samples of oil shale of Jurassic(?) age taken from the northern part of the Brooks Range in northern Alaska assay 26-146 gallons of oil per ton of rock (108-609 liters per metric ton), significantly more than most assays of the Green River Formation in the Rocky Mountain region. Insufficient information is available to evaluate the economic potential of these oil shales.

Tissot, B.P., and Welte, D.H., 1984, Petroleum formation and occurrence, 2nd ed.: New York, Springer-Verlag, p. 254-266.

An oil shale is virtually any rock that will yield oil in commercial quantities by pyrolysis, a heat treatment to about 500 °C. Generally speaking, a petroleum source rock contains less organic carbon than oil shale, but an oil shale, if sufficiently buried, can be a petroleum source rock. Some properties of oil shales and related shale oil are tabulated for various countries. Sulfur and nitrogen are abundant in shale oil.

Tourtelot, H.A., Donnell, J.R., and Tailleur, I.L., 1967, Oil yield and chemical composition of shale from northern Alaska, in Drilling and production, Seventh World Petroleum Congress, Mexico, 1967, Proceedings, v. 3: London, Elsevier Publishing Co., p. 707-711.

Oil shale from along the north flank of the Brooks Range in northern Alaska is part of a complexly folded rock sequence that is Late Jurassic to Early Cretaceous in age. It includes (1) tasmanite, (2) a peculiar rubbery shaly coal, (3) a kind of cannel coal, (4) another impure coal of different nature, and (5) black shale. The purer tasmanite yields 75 to 144 gallons of oil per ton (313 to 600 liters per metric ton) and the other oil shales yield lesser but significant amounts of oil. Certain metal concentrations are larger than normal for these rocks.

Tourtelot, H.A., and Tailleur, I.L., 1965, Oil yield and chemical composition of shale from northern Alaska: U.S. Geological Survey Open-File Report 824, 17 p.

Oil yields and geochemistry of samples of oil shale taken from the central and western Brooks Range of northern Alaska are discussed. Oil yields of samples taken from the central Brooks Range are from about 3 to 144 gallons per ton (13 to 600 liters per metric ton). The amounts of zinc, molybdenum, vanadium, and other metals in these rocks are anomalously high compared to other oil shales. Oil yields of samples taken from the western Brooks Range are relatively low with a maximum of 24 gallons per ton (100 liters per metric ton).

U.S. Geological Survey, Oil shale; a potential source of energy: 15 p.

"In the United States alone shale oil resources probably exceed 2,000 billion barrels of petroleum (42 U.S. gallons per barrel). Oil shale is a very fine-grained sedimentary rock that contains enough organic matter (hydrocarbon) to yield 10 gallons or more oil per ton when properly processed. The burnable portion of oil shale is mostly solid organic matter composed of carbon, hydrogen, oxygen, and usually small amounts of nitrogen and sulphur. The shale also contains large amounts of incombustible minerals such as calcite, dolomite, clay, quartz, and feldspar which generally make up more than half the rock. Oil shale accumulated as layers of organic ooze and mud on the bottoms of ancient lakes, ponds, lagoons, and shallow seas, in places where plant or animal life was abundant."

This is a good general introduction to oil shale.

Van Houten, F.B., 1944, Stratigraphy of the Willwood and Tatman Formations in northwestern Wyoming: Geological Society of America Bulletin, v. 55, no. 2, p. 165-210.

The Tatman Formation contains low-grade oil shale in the Squaw Buttes area of the Big Horn Basin, Wyoming. In its type locality on Tatman Mountain, the Tatman Formation contains no oil shale. The Tatman Formation and the shore facies of the Green River Formation were probably deposited under similar conditions.

Van Tuyl, F.M., and Blackburn, C.O., 1925, The relation of oil shale to petroleum: American Association of Petroleum Geologists Bulletin, v. 9, no. 8, p. 1127-1142.

The hypothesis that oil shale can form petroleum under conditions of burial was tested by flowage experiments on oil shale at elevated pressures and temperatures. Significant amounts of free oil were not formed by these experiments. It is concluded that oil shale and petroleum originate under different conditions, and except in the vicinity of igneous intrusions, oil shales do not form petroleum.

Winchester, D.E., 1923, Oil shale of the Rocky Mountain region: U.S. Geological Survey Bulletin 729, 204 p.

This is a general treatment of oil shales in the states of Colorado, Idaho, Montana, Nevada, Utah, and Wyoming. Oil shales are present in northwestern Colorado in the Green River Formation in the Piceance Creek basin, Battlement Mesa, and Grand Mesa. In Idaho black shales of the Phosphoria Formation are locally oil shales. In Montana the Quadrant Formation, the Three Forks Formation, the Phosphoria Formation, and certain Tertiary beds were examined for oil shale potential. In Utah there are oil shales of the Green River Formation in the Uinta basin. In southwestern Wyoming oil shales occur in the Green River Formation in the Green River basin and the Red Desert basin. There is also some oil shale potential in the Phosphoria Formation in parts of Wyoming.

Results of distillation tests for the various stratigraphic units are given.

Yen, T.F., 1976, Oil shales of United States--a review, <u>in</u> Yen, T.F., ed., Science and technology of oil shale: Ann Arbor, Ann Arbor Science Publishers, Inc., p. 1-17.

Author gives composition and oil yield for oil shales from Kiligwa River, Alaska, Ione, California, and Shale City, Oregon in addition to other localities. Colored photomicrographs of oil shales and coal are included to illustrate similarities between the two. Oil shale retorting technologies are briefly discussed.

Yen, T.F., and Chilingarian, G.V., 1976, Introduction to oil shales. <u>in</u> Yen, T.F., and Chilingarian, G.V., eds., Oil shale: New York, Elsevier Scientific Publishing Co., p. 1-12.

This is a general introduction to the subject of oil shale including origin, types of oil shale, potential resources, surface retorting, <u>in-situ</u> processing, and biochemical recovery. Biochemical recovery involves the degradation of inorganic components of oil shale so that the organic components can be separated. Unfortunately bioleaching requires large amounts of water, a commodity in short supply in some areas.