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GEOLOGICAL SURVEY

Results of Oil-Shale Investigations in Northeastern Nevada

By

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This report is preliminary and has not been
edited for conformity with U.S. Geological
Survey editorial standards and stratigraphic
nomenclature.

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UNITS OF MEASUREMENT

U.S. customary units of measurement are used throughout most of this report because of the wide range of the intended audience. Also, U.S. customary units are used by convention in the drilling industry and, in general, are used in most reporting of U.S. oil-shale research and development. Therefore, the following table of factors is given for conversion to SI metric units.

Factors for converting U.S. customary units to SI metric units

To convert from	To	Multiply by
Foot (ft)	Meter (m)	0.3048
Gallon (gal)	Liter (L)	3.785
Ton (U.S. short)	Ton (t)	0.9072
Gallon/ton (gal/ton)	Liter/ton (L/t)	4.172

EXECUTIVE SUMMARY

This report is the result of an investigation done through a cooperative agreement made in August 1981 between the U.S. Geological Survey, Conservation Division (now part of the Bureau of Land Management) and the Nevada Department of Energy. The purpose of this agreement was to provide funding to investigate and to analyze occurrences of oil-shale resources and their development potential in the state of Nevada. Because the U.S. Geological Survey was already involved in oil-shale studies in northeastern Nevada, the additional funding was applied primarily to a shallow exploratory drilling program used to better delineate oil-shale deposits near Elko, Nevada. The original source of the funding, in the amount of $70,000, was the U.S. Department of Energy.

The United States is heavily dependent on oil and natural gas as a primary source of energy and associated products. Despite intermittent fluctuations in petroleum supplies, oil is a finite resource. In the future, as domestic petroleum supplies dwindle and recovery increases in cost, other alternative energy sources such as oil shale may become increasingly more attractive. Although oil shale has not yet achieved successful commercial production in the United States, oil shale should be considered as a future energy resource.

Oil shale is a fine-grained sedimentary rock that yields substantial quantities of oil when heated to high temperatures in a closed retort (destructive distillation). Kerogen is the solid, insoluble, organic material in the shale that can be converted to oil and other petroleum products by pyrolysis and distillation.

Major resources of oil shale occur in ancient lake beds of the Green River Formation in Colorado, Utah, and Wyoming. Although the resource potential of Nevada oil shale is comparatively minor, relatively little detailed geologic study has previously been devoted to Nevada's oil shale. This report surveys potential oil-shale resources located in northeastern Nevada.

Oil shale in Nevada is primarily associated with rocks now designated as the Elko Formation. Other rock units in Nevada also contain organic-rich deposits that have some minor potential for oil-shale resources; however, they have been discussed in this report mostly because of their significance as conventional oil and gas source rocks for petroleum reservoirs in Nevada. Of these rocks with minor interest for oil shale, the most promising formations include the Vinini and the Woodruff Formations.

The Vinini and Woodruff Formations locally contain kerogen-rich, marine-deposited shales that have high concentrations of heavy metals such as vanadium, selenium, and zinc. Although the Vinini and Woodruff Formations locally have shales that yield from a few gallons to as much as 15 to 30 gallons of oil per ton, oil yields are lower on the average. However, the possibility of metal extraction as a byproduct of oil-shale development may make these formations attractive for development in the future.

The Elko Formation contains oil-shale deposits of primary significance in the state of Nevada. A minimum geologic age determined for the Elko Formation is latest Eocene and earliest Oligocene, or about 37 million years old. Oil shale in the Elko Formation was derived from the accumulation and preservation of mineral sediments and organic materials deposited in an ancient lake or lakes. Subsequent erosion and faulting have disrupted the original lateral continuity of these oil-shale bearing deposits and left only scattered remnants exposed in mountain ranges, or deeply buried in sedimentary basins in northeastern Nevada. Scattered remnants of the Elko Formation occur over a north-south elongated area about 100 miles long and 30 miles in wide, confined to Elko County.

Detailed surface geologic studies and sampling of the Elko Formation have been conducted at three localities in Elko County: near Elko; in the Pinon Range; and in Coal Mine Canyon. Of these three areas, the richest oil-shale deposits occur in the Elko area. Informally designated members 2, 3, and 4 of the Elko Formation near Elko contain oil shale. On the basis of Fischer-assay determinations of oil yield on continuous core samples from the Elko area, total in-place shale oil in members 2 and 3 has been calculated as 600 million barrels. Of this total, 228 million barrels are from beds averaging at least 15 gal/ton over a 15-ft thickness, the minimum classifiable standard for prospectively valuable oil-shale deposits. The remaining approximately 373 million barrels of in-place shale oil has been calculated for low-grade shale of member 3 that averages only 5 gal/ton over a thickness of 260 to 280 ft. Because of high energy demands in mining and processing of oil shale, shales yielding less than 10 gal/ton are not of sufficient richness to be considered for present economic development. Therefore, the 228 million barrels of shale oil in member 2 of the Elko Formation are considered to be the present shale-oil resource for the Elko area.

Despite the richness of oil-shale deposits of member 2 of the Elko Formation in the Elko area, the present economic development potential of this deposit is low. Present economic conditions of tight money, high interest rates, and escalating costs of construction have plagued commercial development of all oil shale in the United States, including rich deposits of the Green River Formation. In addition, lower world crude oil prices and decreased domestic crude oil consumption have decreased the present potential for shale oil to compete economically with conventional petroleum sources.

Aside from economic conditions, the stratigraphic and structural complexity of the Elko Formation would be another major disadvantage to development. The close proximity of the town of Elko to the oil-shale deposit puts other serious constraints on the development of that resource. Environmental problems, conflicts with present land use and water availability, and development of technologically and socially acceptable mining and retorting methods are all factors that would have to be weighed if this oil-shale deposit were to be economically developed on a commercial scale. Although there are notable quantities of shale oil in the Elko Formation near Elko, and more resources may be discovered buried within sedimentary basins in northeastern Nevada, the commercial development of these resources is not likely in the forseeable future.

INTRODUCTION

Background, Purpose, and Scope

In August 1981, a cooperative agreement was made between the U.S. Geological Survey (USGS), Conservation Division (now part of the Bureau of Land Management) and the state of Nevada Department of Energy (NDOE). The purpose of this agreement was to provide information on occurrences of oil-shale resources and their development potential in the state of Nevada. The agreement involved a grant provided to the USGS through NDOE to defray costs of an oil-shale investigation in northeastern Nevada. The original source of the funding, in the amount of $70,000, was the U.S. Department of Energy. This report is a result of that investigation.

Oil shale is generally defined as an organic-rich sedimentary rock that yields substantial quantities of oil by conventional methods of destructive distillation in a closed retort (Stanfield and Frost, 1949). Oil shale is synonomous with "kerogen shale," kerogen being the fossilized, insoluble, solid, organic material that can be converted by pyrolysis and distillation to petroleum products.

Oil shale has been the subject of increasing interest as an alternative energy resource because of diminishing supplies and increasing costs of conventional petroleum resources. Increased dependence by the United States on foreign sources of energy, as was generally recognized in the 1970's, has also spurred renewed interest in domestic oil shale.

The U.S. has large volumes of oil shale in the Green River Formation in Colorado, Utah, and Wyoming. Estimated identified resources in those three states total about 1.8 trillion barrels of oil in oil shale of 15 or more gallons per ton (Culbertson and Pitman, 1973, p. 500). Because of these tremendous resources, most of the U.S. oil shale research and development in past years has centered on the Green River Formation deposits. In contrast, oil-shale deposits in Nevada are relatively unknown. This report consolidates information relating to the potential for oil-shale resources in the state of Nevada.

The major focus of this oil-shale investigation has been on specific localities of oil-shale resource potential. Past and present involvement of the U.S. Geological Survey in geologic studies related to oil-shale deposits in Nevada has targeted the Elko Formation of Eocene and Oligocene(?) age in northeastern Nevada as having potential for oil-shale resources. Three main areas of oil-shale occurrence have been studied in detail: the Elko area, Pinon Range area, and Coal Mine Canyon (fig. 1). Geologic mapping, stratigraphic studies, and sampling to delimit the lateral extent of the oil shale deposits were in progress prior to the cooperative agreement with NDOE. These surface geologic studies have been summarized in this report. The results of surface geologic studies conducted near Elko suggested that the Elko area represented the best and most accessible oil-shale deposits; therefore, the Elko area was selected as the site of a shallow exploratory drilling program. Most of the NDOE funding was applied towards completion of this drilling program.

Essential to this study was the obtaining of fresh, unweathered oil-shale samples from the Elko area. The samples were obtained from the core-drilling

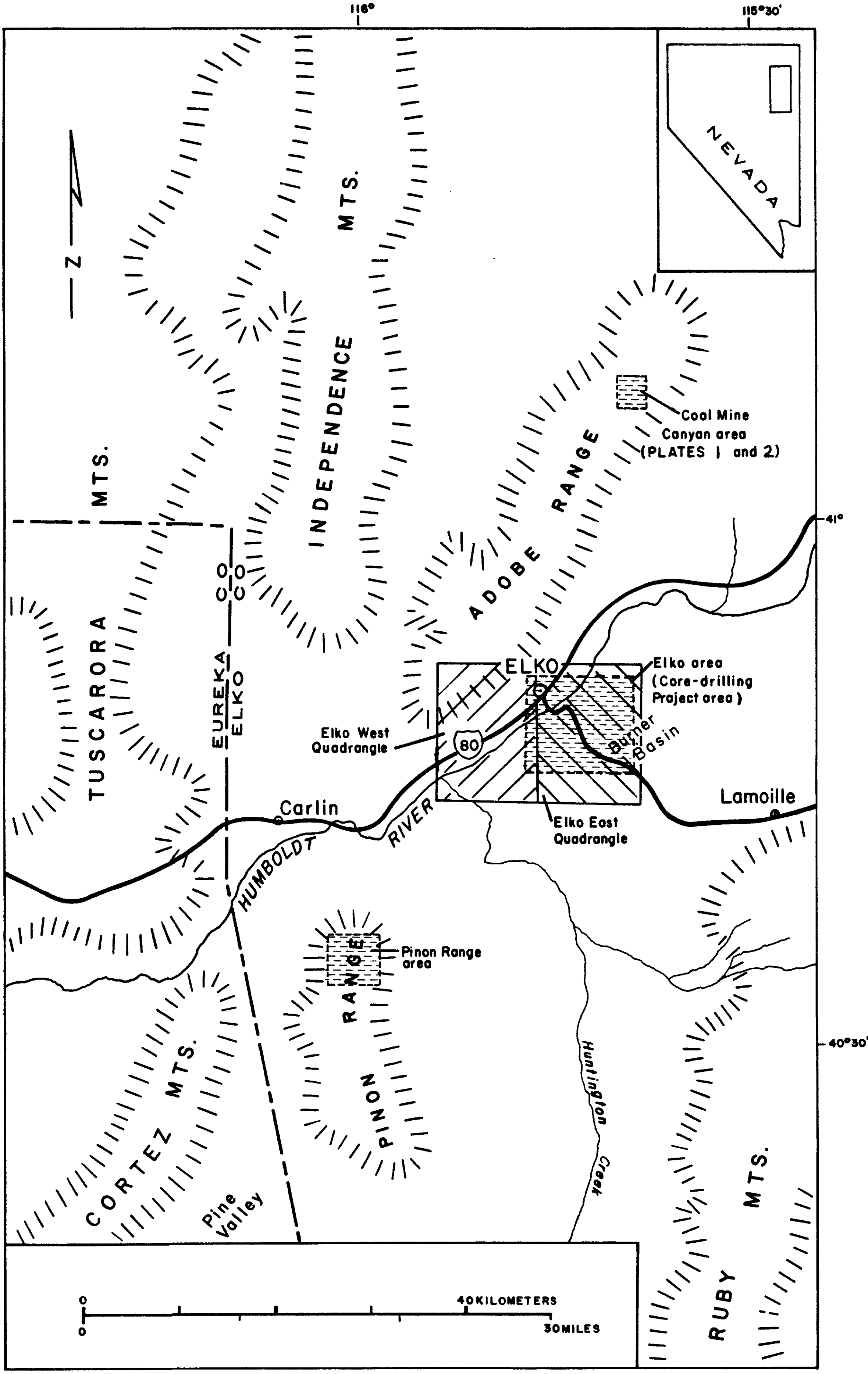

Figure 1.--Index map showing locations of oil-shale study areas in northeastern Nevada.

program and tested for oil yield by Fischer assays. The oil yields determined from these samples, together with the geology have provided an improved basis for resource estimates for the oil-shale deposit at Elko.

In addition to the more detailed field studies, a literature survey was conducted to develop a bibliography related to oil shale in Nevada and to use as a basis for identifying other oil-shale occurrences. The literature search was also extended to include information on petroleum source rocks that contain organic-rich shales with possible potential as additional oil-shale resources.

This report is the product of three principal authors. S. W. Moore, the principal investigator, was responsible for sections and plates related to the geology, oil-shale resources, and development potential of the Elko area, and also for the general section on oil shale and organic-rich deposits of northeastern Nevada. H. B. Madrid was author of the sections and plates on the Coal Mine Canyon area, and co-author of the annotated bibliography (Appendix A). G. T. Server, Jr., wrote the section on the geology and oil-shale deposits of the Pinon Range area.

Acknowledgments

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The manuscript was reviewed by Susan T. Miller and Michael L. Throckmorton, both of BLM, Menlo Park, and by Laurence G. Trudell of Laramie Energy Technology Center. Forrest G. Poole, USGS, Denver, Colorado also reviewed several sections of the manuscript.

1/ On January 19, 1982 the Secretary of the Interior formed the Minerals Management Service from the Conservation Division of the U.S. Geological Survey. On December 3, 1982, the Associate Directorate for Onshore Minerals Management was transferred from the Minerals Management Service to the Bureau of Land Management.

OIL-SHALE AND RELATED ORGANIC-RICH DEPOSITS IN NORTHEASTERN NEVADA

Results of Literature Search

A literature search was conducted in order to identify areas of potential oil-shale resources in Nevada. Many of the literature references were found during the course of preparation for surface mapping investigations at known oil-shale occurrences at Elko, Coal Mine Canyon, and Pinon Range study areas. To extend the range of the literature search to include other areas of oil-shale resource potential, a computer literature search was done through the USGS library on the "GEOREF" system. A compilation of pertinent selected references obtained is given in Appendix A--Annotated bibliography for oil shale and related organic-rich deposits of northeastern Nevada. Annotations in Appendix A highlight the location, name, and age of pertinent rock unit or formation, correlations, and any available oil yields of oil shale or organic-rich shale.

From a review of the literature, oil shale and related organic-rich rocks in Nevada occur in three general categories or types of deposits: (1) the lacustrine Elko Formation; (2) other lacustrine and related nonmarine deposits; and (3) organic-rich marine shale. Of the three categories, the Elko Formation is most well known for its oil-shale deposits. The latter two categories also contain organic-rich deposits with possible potential for oil-shale resources. However, because of the comparatively low-organic carbon concentrations, the rocks in the latter two categories are primarily of interest as possible petroleum source rocks for oil and gas reservoirs in Nevada. The general distribution of oil shale and related organic-rich deposits in eastern Nevada is shown in figure 2.

Elko Formation

Geology

At present, the Elko Formation appears to have the most favorable prospects for oil-shale resources in Nevada. Oil-shale deposits were recognized in the Elko area and described in early reports by King (1876; 1878) and Hague and Emmons (1877). Those reports referred to the oil shale and associated rocks near Elko as the Eocene Green River Formation on the basis of lithologic similarities to that unit in Utah. J. P. Buwalda (*in* Winchester, 1923) described the geology and oil-shale deposits near Elko and initially agreed with the assignment of the oil shale of the Elko area to the Green River Formation, but subsequently suggested a Miocene age on the basis of fossil evidence. Sharp (1939) formally named all Tertiary rocks of northeastern Nevada as the Miocene Humboldt Formation. Van Houten (1956) later suggested correlations of oil-shale deposits near Elko with Eocene and Oligocene rocks, but many subsequent studies still referred to these rocks as the Miocene Humboldt Formation (Granger and others, 1957; Dickinson, 1959; Dickinson and Swain, 1967; Becker, 1969; and Swain and others, 1971). Smith and Ketner (1976) finally assigned the oil-shale bearing deposits to the Elko Formation and described the type section at a locality along the northeast flank of the Pinon Range approximately 40 mi south of Elko (Pinon Range area; fig. 1).

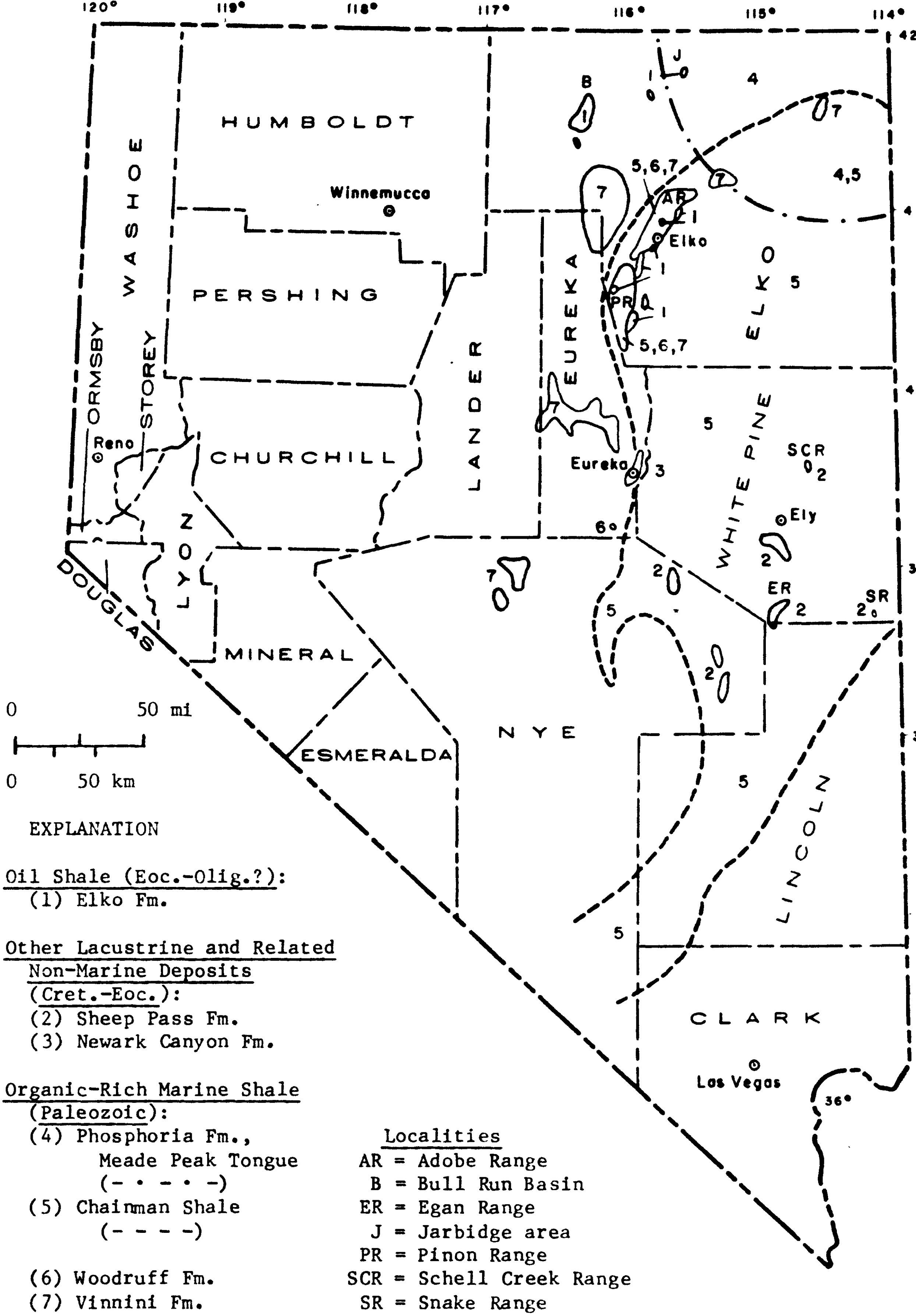

Figure 2.--Distribution of oil shale and other related organic-rich deposits (petroleum source rocks) of eastern Nevada. (Modified from Stewart, 1980, figs. 3, 16, 24, and 41; Maughan, 1979, fig. 2; and Fouch, 1979, figs. 1 and 7).

Beds belonging to the Elko Formation are distributed over a north-south elongated area of approximately 100 mi in length and 30 mi in width. Tertiary faulting and erosion, however, have left only isolated, exposed remnants of these deposits. Three main exposures of the Elko Formation have been examined and are described in detail in this report: the Elko area; the Pinon Range area; and Coal Mine Canyon (fig. 1).

Oil shale probably correlative with the Elko Formation also exists about 55 mi northwest of Elko in Bull Run Basin along the west side of the northern Independence Mountains (Smith and Ketner, 1976, p. 22). Decker (1962, p. 27-28) noted that oil shale beds were encountered in an exploratory oil well drilled by Richfield in 1959 (No. 1 Scott-Government well) in Bull Run Basin. The Elko Formation has been mapped in the Carlin-Pinon Range area (Smith and Ketner, 1976) and south of Elko near Huntington Creek (Smith and Howard, 1977). Exposures of Elko Formation in the Pinon Range and at Elko have at least locally thick sedimentary accumulations of approximately 2,500 ft (Smith and Ketner, 1976, p. 22) and 1,750 ft, respectively.

The Elko Formation consists mostly of laminated shale, claystone, siltstone, and oil shale, with minor tuff and limestone. Minor, thin, lignite beds are also interbedded with the commonly paper-thin-weathering oil shale. The Elko Formation has been described in detail in the Elko area by Solomon and others (1979a, b), and Solomon (1981) and is summarized in the "Elko area" section of this report.

Oil shale and associated deposits of the Elko Formation have long been interpreted as having been deposited in a mostly lacustrine environment. Finely laminated oil shale and other fine-grained beds near Elko suggest open-lacustrine, quiet-water deposition in a low-salinity, alkaline lake under reducing conditions (Solomon and others, 1979a, b). Because the Elko Formation now occurs only as scattered and faulted erosional remnants, the original lateral depositional continuity between the outcrop areas is difficult to prove. In particular, it is uncertain whether oil shale was deposited in one large lake on the scale of about 100 mi by 30 mi or in several smaller, isolated lake basins (Smith and Ketner, 1976; Solomon, 1981). The relatively large thicknesses of the Elko Formation in the Pinon Range and at Elko suggest that the basin of deposition must have been reasonably large (Smith and Ketner, 1976, p. 22). The presence of extremely rich, although thin oil-shale beds also suggests concentration of organic matter from a relatively large basin (Moore and Solomon, 1982).

The Elko Formation is assigned an Eocene and Oligocene(?) age on the basis of radiometric ages of tuffaceous material within the formation. Radiometric ages of about 37 to 38 m.y. have been obtained at the Pinon Range area (Smith and Ketner, 1976) and at Elko (Solomon and others, 1979a, b). The stratigraphic sequence at Bull Run Basin is dated by potassium-argon ages of 35 m.y. on a tuff within the unit, and 42 m.y. on volcanic rocks below the unit (Axelrod, 1966).

Paleogene lacustrine units similar to the Elko Formation are common over much of the western interior of the United States and represent a wide range of ages (Fouch and others, 1979; and fig. 3). The Elko Formation appears to be slightly younger than the Paleocene and Eocene Green River Formation in the western Uinta Basin (Fouch, 1979). The Elko Formation may be temporally

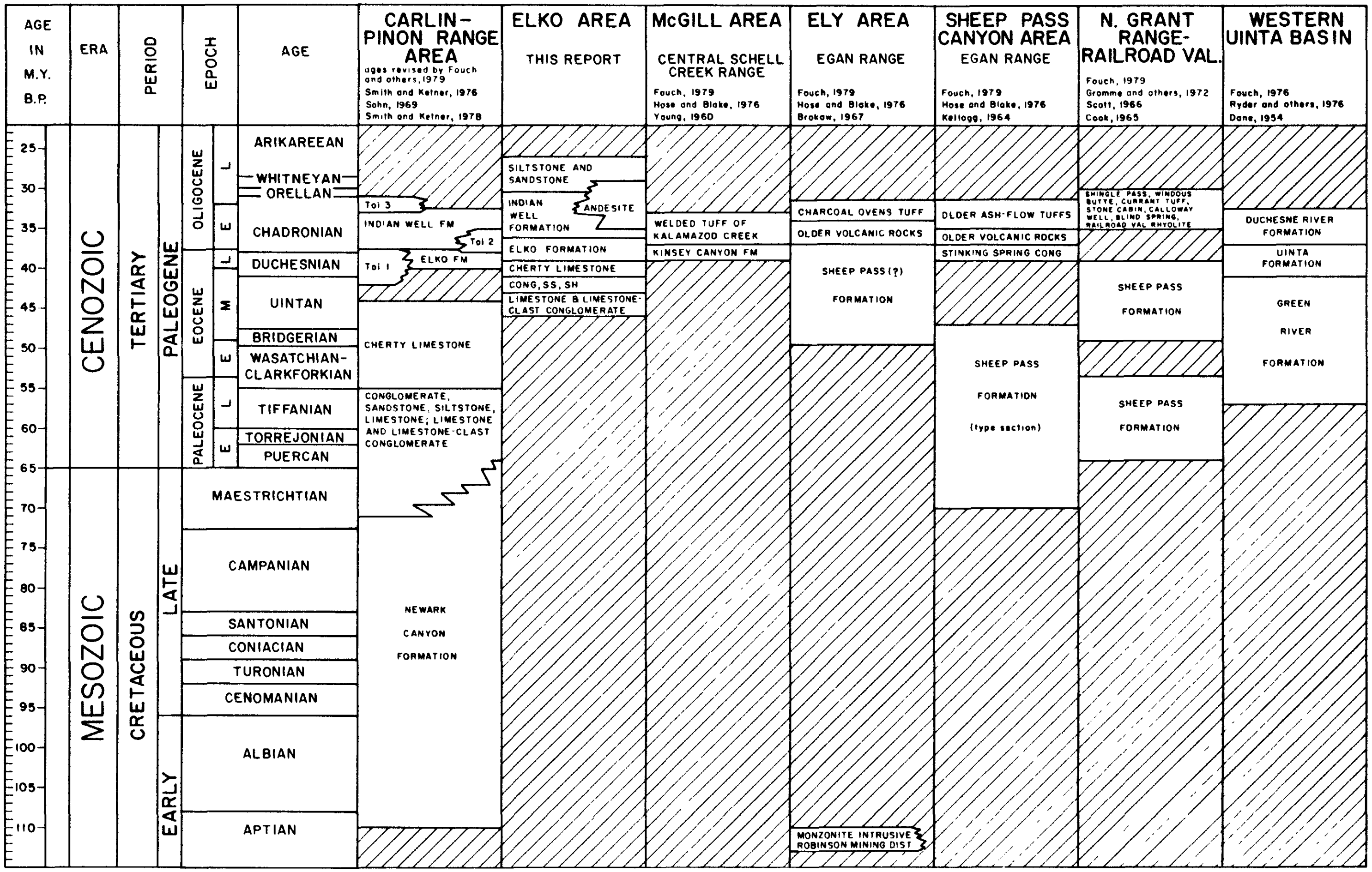

Figure 3.--Correlation chart of Cretaceous and Paleogene units in northeastern Nevada, east-central Nevada, and the western Uinta Basin, Utah. (Modified from Fouch and others, 1979, fig. 2; and Solomon, 1981, fig. 5.) In the Carlin-Pinon Range area, Toi 1 indicates the older intermediate volcanics of Smith and Ketner (1976); Toi 2 indicates the silicic intrusive rocks of Smith and Ketner (1976); Toi 3 indicates the mafic to intermediate plugs and dikes of Smith and Ketner (1976).

equivalent to the sandstone and limestone facies of the Eocene Uinta Formation and overlying units in the western Uinta Basin (Dane, 1954; Ryder and others, 1976; Fouch, 1979). The Elko Formation may also be slightly younger than the Sheep Pass Formation south of Ely (Kellogg, 1964) and near Railroad Valley (Cook, 1965), but may be coeval with the uppermost part of a unit tentatively mapped as the Sheep Pass Formation near Ely (Brokaw, 1967; Fouch, 1979; Fouch and others, 1979). The Elko Formation is temporally equivalent to the Kinsey Canyon Formation of Young (1960), near McGill, Nevada (Fouch, 1979; Fouch and others, 1979).

Early Oil-Shale Mining Activities near Elko. The occurrence of oil shale at Elko has been of interest since the early 1870's when an attempt was made to use darker shales as coal for the railroad (Winchester, 1923, p. 91-102; Granger and others, 1957). The apparent richness of the thin oil-shale beds spurred additional interest in the Elko area. As early as 1890, R. M. Catlin had determined an oil yield of 53.5 gal/ton from surface shale (Russell, 1980, p. 75). Other early reports gave oil yields ranging from a few gallons per ton to as much as 87 gal/ton (Lincoln, 1923; Winchester, 1917, 1923; and Gavin, 1924, p. 23).

During the period from about 1917 to 1924 an early attempt was made to mine and develop oil-shale resources near Elko, as reported in Lincoln (1923), Couch and Carpenter (1943), Granger and others (1957), and Russell (1980). The rock unit mined was shale now considered as part of member 2, or the oil-shale member, of the Eocene and Oligocene(?) Elko Formation (Solomon and others, 1979a, b; Solomon, 1981; Solomon and Moore, 1982a, b). Oil shale was mined by Catlin Shale Products Company and by the Southern Pacific Railroad.

The Catlin Shale Products Company operated retorts at their main plant site south of Elko in section 27, T. 34 N., R. 55 E., M.D.M. The Catlin Shale Products Company represented the first pioneer effort in the United States to work out methods to try to produce marketable products from western oil shale to compete with conventional petroleum products (Russell, 1980, p. 80). Russell (1980) considers the Catlin operation as a unique occurrence in the oil-shale history of this country. As well as being a well-financed venture, the capital was provided entirely by R. M. Catlin, and the project was an integrated operation that included experimentation on and performance of mining, crushing, conveying, retorting, spent shale disposal, and marketing of the shale-oil products (Russell, 1980, p. 80). From 1917 to 1918, 46 short tons of oil shale was mined, with a production value of about $1,920 (Couch and Carpenter, 1943, p. 42). Three oil-shale retorts were constructed by the Catlin Oil Shale Products Company. The second retort, constructed in 1919, produced about 15,000 gallons of shale oil, through January 1, 1920, but was regarded only as an experimental retort (Winchester, 1923, p. 101). The third and largest retort operated intermittently during 1921-1924. According to Mull (1968, in Russell, 1980, p. 78-79), during the final 10 months of operations, 9,095 barrels of shale oil were produced averaging 46 barrels of oil per day from 77 tons of shale per operating day. Using a 42-gallon/barrel capacity, this shale oil was produced from shales with an average yield of approximately 25 gal/ton.

Products from the Catlin operation plant included wax, distillate fuel oil, gasoline or naptha, and lubricating oil. According to Russell (1980), unfortunately none of these products were totally satisfactory: the gasoline recovery was low and the product of poor quality; kerosene produced would not meet Government specifications and was mixed with the overall distillate product; the lubricating oil was of too low viscosity to meet specifications and had mixed, often unacceptable performance in automobile engines (Mull, 1968, in Russell, 1980, p. 80). Sibley (1925) also reported on the less than satisfactory properties of lubricating oil made from Elko oil shale.

According to Russell (1980, p. 80), Catlin concluded from actual market tests that lubricating oil from Elko shale could not be sold in quantity in competition with eastern lubricating oils and that economically the price of the Elko oil could not be reduced to make it more attractive (presumably due to the high cost of production).

The other attempt at early mining of oil shale near Elko was undertaken by the Southern Pacific Railroad Company. The plant was constructed in 1919 in section 13, T. 34 N., R. 55 E., M.D.M., and employed an experimental Pumpherston Scotch retort. The U.S. Bureau of Mines supervised construction and operation of this plant. The plant did not operate after 1921 and reportedly produced only a few barrels of shale oil. According to C. L. Jones, who inspected the operation in 1920 (Russell, 1980, p. 82), the plant had three main problems contributing to the poor results of the retorting experiment: 1) poor regulation of fires in the retorts caused damage to all four retorts; 2) poor location of the plant, about 1 mile from the nearest source of oil shale to be processed and 1 mile's distance from the railroad; and 3) the shale tested was of low yield, only about 8 gal/ton.

Other Lacustrine and Related Non-Marine deposits

This second category of petroleum-bearing deposits includes Cretaceous and Paleogene age lacustrine and related non-marine deposits, which are, in part, correlative with the Elko Formation. Significant rock units in this category include the Sheep Pass Formation and the Newark Canyon Formation of east-central Nevada (fig. 2). These rocks, although not prime targets for oil shale development, locally have pyrolitic oil yields of several gallons/ton (Fouch, 1977, 1979; and Fouch and others, 1979). These rocks were largely deposited in lake basins, as was the Elko Formation, and are rich in organic matter (Fouch and others, 1979). These organic-rich beds are considered to be a source of hydrocarbons where buried at depths adequate to convert kerogen into oil or gas (Fouch and others, 1979).

Sheep Pass Formation. The Cretaceous and Paleogene Sheep Pass Formation is perhaps the most extensive of these largely lacustrine units and occurs at scattered localities in east-central Nevada mostly in White Pine, Lincoln, Eureka, and Nye Counties (fig. 2). The type section occurs in the Sheep Pass Canyon area in the southern Egan Range, White Pine County, Nevada (T. 10-11 N., R. 62-63 E., M.D.M.) and is described by Winfrey (1960) and Kellogg (1964). This type section has been correlated with similar rocks cropping out in the northern Grant Range, the Pancake Range, and with stratigraphic sections encountered in exploratory oil wells in the White River and Railroad Valleys (Winfrey, 1960). Correlations have been expanded to even a larger area by Gustafson (1977). The majority of the Sheep Pass Formation is older than the Elko Formation as indicated by the absence of tuffaceous material suggesting mostly "pre-volcanic" deposition, in contrast to the tuffaceous Elko Formation. Correlations of the Sheep Pass Formation in east-central Nevada are summarized in Fouch (1977, 1979) and Fouch and others (1979).

The petroleum potential of the Sheep Pass Formation is indicated by many authors (Winfrey, 1960; Fouch, 1977; Bortz and Murray, 1978; Fouch and others, 1979; Claypool and others, 1979; and Foster and Dolly, 1980). Some oil production in the Eagle Springs field, the first oil field in Nevada, is from carbonate reservoir rocks of the Sheep Pass Formation (Bortz and Murray, 1978). Strong evidence favors the Sheep Pass Formation as the source rock for petroleum in the Eagle Springs Field (Claypool and others, 1979).

Newark Canyon Formation. The Newark Canyon Formation is of mostly Early and Late Cretaceous age and is named for the type section in the Diamond Mountains, near Eureka, Nevada (Nolan and others, 1956). The Newark Canyon Formation has also been mapped in the Fish Creek Range, and in the Carlin-Pinon Range area of Elko County where it ranges to as young as Paleocene (Fouch and others, 1979; Smith and Ketner, 1976, 1978). At the type section of the Newark Canyon Formation, lipid-rich "oil shale" is reported to have pyrolitic oil yields greater than 10 gal/ton (Fouch and others, 1979, p. 311).

Organic-Rich Marine Shales

Paleozoic marine shales, rich in organic matter, are common in northeastern and east-central Nevada. Principal rock units in this category include the Vinini Formation, the Chainman Shale, the Woodruff Formation (fig. 2). In general, these rocks have been considered as petroleum source rocks, and in some cases pyrolytic oil yields of selected beds are high enough to be considered as oil shale.

Vinini Formation. The Ordovician Vinini Formation was named by Merriam and Anderson (1942, p. 1693-1698) for exposures on the east side of the Roberts Mountains, south of the Carlin-Pinon Range area (Smith and Ketner, 1975, p. 9). The Vinini Formation is primarily composed of chert, shale, siltstone, and mudstone and is structurally complex. The Vinini Formation is distributed over much of north-central Nevada, primarily in Eureka and Elko Counties (Stewart, 1980, p. 27). This formation locally contains shale which yields 10 to 25 gallons of oil per ton (Duncan and Swanson, 1965, p. 15). Results from recent solid state ^{13}C nuclear magnetic resonance (NMR) techniques used on samples provided by F. G. Poole (written commun., 1982) from the Vinini Formation indicate high aliphatic carbon fractions of 0.54 to 0.58 (Mikinis and Smith, 1982, p. 51-53). These aliphatic carbon fractions correlate with carbon-converted-to-oil fractions of 0.39 to 0.30, suggesting reasonable capabilities for obtaining shale oil from the Vinini Formation.

The Vinini Formation is reported to contain potential resources of syncrude oil in shales that range from 10 to 30 gal/ton and that also contain metals of possible economic significance including vanadium, zinc, selenium, silver, and chromium (Poole and Desborough, 1980). The presence of these metals might make the Vinini Formation oil shale a more attractive economic prospect, where shale oil might be considered as a byproduct. Because of the high organic-content of the Vinini Formation, it also is considered as a possible oil and gas source rock in Nevada (Foster and Dolly, 1980).

Woodruff Formation. The Devonian Woodruff Formation is included in the western siliceous assemblage in the upper plate of the Roberts Mountains thrust (Smith and Ketner, 1976, p. 27). Major rock types that comprise the Woodruff Formation include siliceous mudstone and chert, and lesser shale, dolomitic siltstone, and dolomite. The Woodruff Formation primarily crops out in the

Carlin-Pinon range area of southwestern Elko County (Smith and Ketner, 1978), in southern Eureka County (Desborough and others, 1979; fig. 2).

Brooks and Potter (1974) report on a shale locality of Woodruff Formation in southwestern Elko County that is rich in vanadium and contains up to 10 percent organic carbon. Desborough and others (1981) describe the same locality and report an oil yield of 13.9 gal/ton. Poole and Desborough (1980) point out the similarity of these organic-rich shales to those of the Vinini Formation. Desborough and others (1979) report an oil yield of 12.4 gal/ton from a metalliferous shale in the Woodruff Formation, southern Fish Creek Range, Eureka County. As with the Vinini Formation, low-grade oil shales of the Woodruff Formation could be considered more economically attractive considering the potential for extraction of contained vanadium and other metals.

Chainman Shale. The Mississippian Chainman Shale is locally rich in organic matter. It occurs extensively in east-central Nevada and is considered to be a hydrocarbon source rock (Smith, 1976, p. 90; Foster and Dolly, 1980). On the basis of comparison of chemical compositions of organic matter from the Chainman Shale and of crude oil from the Trap Spring oil field, the Chainman Shale is interpreted as the principal source rock (Claypool and others, 1979).

Phosphoria Formation. The relatively high organic content, regional extent, and volume of shale in the Meade Peak Phosphatic Shale Member of the Phosphoria Formation suggest that this unit is a possible petroleum source rock (Claypool and others, 1978; Maughan, 1978a, b, 1979). The Meade Peak, which is noted for rich phosphorite deposits (McKelvey and others, 1959), occurs within a large area including southwestern Montana, western Wyoming, northern Utah, southeastern Idaho, and into northeastern Nevada. The Meade Peak attains a maximum thickness in the Terrace Mountains of northwestern Utah and apparently thins and wedges out westward into Elko County, northeastern Nevada (Maughan, 1979; general extent shown in fig. 2). In northeastern Nevada, phosphate-bearing strata of the Meade Peak and correlative units occur in the Leach Mountains, northern Snake Mountains, Goose Creek Mountains, southern Pequop Mountains, and in the Peko Hills (Hope and Coats, 1976; Maughan, 1979).

Most strata within the Meade Peak contain in excess of the 0.5-weight-percent carbon considered necessary for adequate source rock (Maughan, 1979, p. 528). Maughan (1979, p. 526-527) reports average organic contents as high as 9.0 weight percent for Meade Peak shale beds northeast of Soda Springs, Idaho. In northeastern Nevada, at Murdock Mountain in the Leach Range, 92 ft of shale averages 1.0 weight-percent organic carbon (Maughan, 1979, p. 526).

ELKO AREA

Introduction

The major focus of this study was on oil shale and related deposits located immediately south and southeast of Elko, Nevada (fig. 1). The geology near Elko was examined in detail through geologic mapping and stratigraphic study by Solomon and others (1979a, b) and Solomon (1981). The geology and stratigraphy of the Elko area is shown in detail on the Elko West and Elko East quadrangles by Solomon and Moore (1982a, b). The geologic framework of the oil-shale deposits near Elko is summarized in this section.

Geology

The stratigraphic section in the Elko area is composed of rocks ranging in age from Mississippian to middle Tertiary (fig. 4). The lower Tertiary (Eocene through Oligocene) sequence unconformably overlies the dominantly conglomeratic Diamond Peak Formation of Late Mississippian and Early Pennsylvanian age. The lower Tertiary sequence is divided, in ascending order, into the following units: limestone and limestone-clast conglomerate unit; conglomerate, sandstone, and shale unit; cherty limestone; the Elko Formation, which is subdivided into five informal members; the Indian Well Formation; andesite; and a siltstone and sandstone unit. Figure 5 shows correlations between mapped rock units from the Elko study area to the other two study areas in the Pinon Range (Server and Solomon, 1982) and in Coal Mine Canyon (plate 1).

Tertiary Rocks Underlying the Elko Formation

The oldest Tertiary rocks in the Elko area are represented by the limestone and limestone-clast conglomerate. This unit is about 50 ft thick and is characterized by angular to subangular, pebble- to boulder-size, bluish-gray limestone clasts. An Eocene(?) age is suggested on the basis of the unit's stratigraphic position below rocks of known Eocene age and on the correlation with similar rocks in the Carlin-Pinon Range area that were assigned an Eocene age by Smith and Ketner (1976). The informally designated conglomerate, sandstone, and shale unit lies unconformably above the Mississippian and Pennsylvanian Diamond Peak Formation.

The conglomerate, sandstone, and shale unit may be in part laterally equivalent to the limestone and limestone-clast conglomerate although this relationship is not clear. The lower part of the conglomerate, sandstone, and shale unit is predominantly composed of fine-grained rocks, most notably light-brown to gray claystone with interbeds of siltstone and minor limestone and tuff. Conglomerate and sandstone dominate the upper part of this unit. Prominent medium-scale cross-stratification is displayed in conglomerate and sandstone beds up to 10 ft thick. The minimum thickness of the conglomerate, sandstone, and shale unit is approximately 105 ft. This unit greatly thickens to the northeast as suggested by geologic mapping (Solomon and Moore, 1982b).

The age of the conglomerate, sandstone, and shale unit is Eocene on the basis of stratigraphic relationships and on a potassium-argon age of 43.3 ± 0.4 m.y. (million years) obtained from a tuff near the base of the unit (Solomon and others, 1979a). This radiometric age is significant since the tuff records one of the earliest events of Tertiary volcanism in northeastern Nevada (McKee

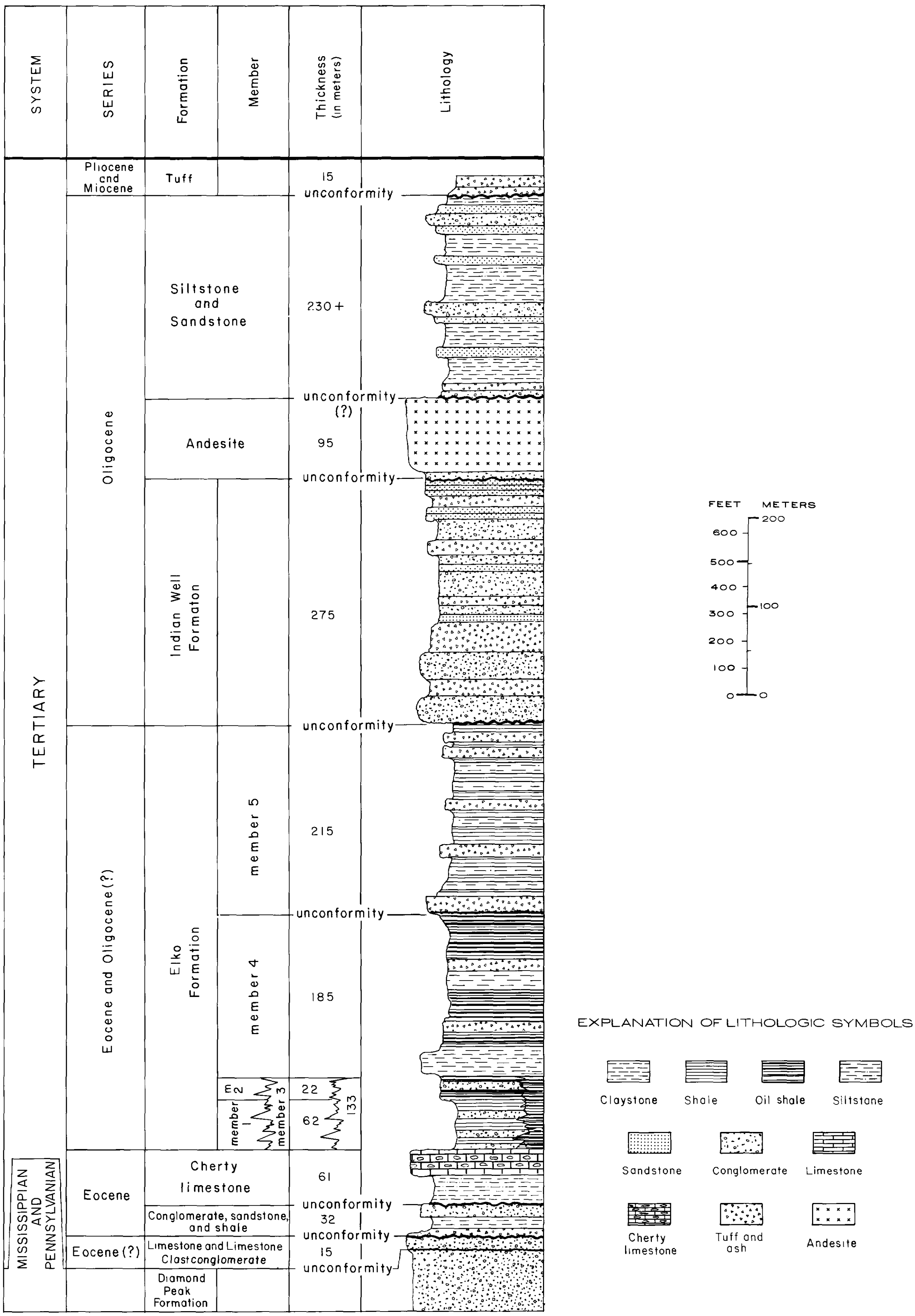

Figure 4.--Generalized stratigraphic section near Elko, Nevada (modified from Solomon, 1981).

Age		Pinon Range Area (Server and Solomon, 1983, and Smith and Ketner, 1976)	Elko Area (Solomon and Moore, 1982a, b)	Coal Mine Canyon Area (This report, plates 1 and 2)
Eocene and Oligocene(?)	Elko Formation	Elko Formation: Tuff and dolomitic shale member (Tets)	Elko Formation: Member 5--Tuff, shale, and siltstone member (Tet)	Elko Formation: Limestone and tuffaceous siltstone and claystone member (Tel); Tuffaceous claystone member (Tetc)
		Oil shale, limestone, and dolomitic shale member (Tesl)	Member 4--Siltstone and oil shale member (Tes)	
			Member 2--Oil shale member (Teos)	Oil-shale member (Teo)
		Limestone and shale member (Tels)	Member 1--Claystone and conglomerate (Tec) / Member 3--Dolomite and oil-shale member (Ted), (Teb*)	Claystone member (Tec)
Eocene		Cherty limestone member (Tecl)	Cherty limestone (Tcl)	//////////////////////////
Eocene and Paleocene(?)		Conglomerate, sandstone, siltstone, and limestone	Conglomerate, sandstone, and shale (Tcs)	Conglomerate (Tcs)
		Limestone and limestone-clast conglomerate	Limestone and limestone-clast conglomerate (Tlc)	//////////////////////////

Figure 5.--Correlation chart of Paleocene through Oligocene age rock units between the Pinon Range, Elko, and Coal Mine Canyon study areas. Map unit symbols are shown in parentheses ( ) following the unit name.

*(Also included with member 3 is the correlative oil shale and siltstone of Burner Basin member of the Elko Formation of Solomon and Moore, 1982b.)

and others, 1976). As shown in figure 5, the conglomerate, sandstone, and shale unit is correlative with the conglomerate, sandstone, siltstone, and limestone unit of Smith and Ketner (1976) and Server and Solomon (1983) in the Pinon Range and also with an Eocene conglomerate and sandstone unit described by Silitonga (1974) north of Elko.

The cherty limestone unit is approximately 200 ft thick and lies conformably or slightly disconformably above the conglomerate, sandstone, and shale unit. This informally designated unit is characterized by yellowish-gray, petroliferous limestone locally rich in dark, flat chert nodules (Solomon and others, 1979a, b). Distinctive dark-red claystone beds dominate the lower part of the unit. Calcareous siltstone and minor lignite beds are also present. Silicified ostracodes and fresh-water gastropods are locally abundant fossils in this unit.

The cherty limestone unit is of Eocene age on the basis of bracketing radiometric ages of about 39 m.y. and 43 m.y. on tuffs above and below this unit, respectively (Solomon and others, 1979a, p. 84). The cherty limestone is correlative with rocks of the same unit name in the Carlin-Pinon Range area (Smith and Ketner, 1976; Server and Solomon, 1982) and south of Elko along Huntington Creek (Smith and Howard, 1977; fig. 1). The cherty limestone may be broadly correlative with part of the Sheep Pass Formation near Ely, and Railroad Valley, Nevada (Cook, 1965; Scott, 1966; Gromme and others, 1972; Fouch, 1979; Fouch and others, 1979). The cherty limestone also may be temporally equivalent to part of the Green River Formation in the western Uinta Basin (Fouch, 1979).

Elko Formation

The rock unit of major interest in this report is the oil-shale bearing Elko Formation. The Elko Formation conformably overlies the cherty limestone unit. The Elko Formation near Elko has been subdivided into five informally designated members. For simplicity, these members have been numbered 1 through 5, in ascending order, except for member 3, which is the lateral stratigraphic equivalent of member 1 (Solomon, and others, 1979a, b; Solomon, 1981). The members are: (1) claystone, chert-pebble conglomerate, and minor sandstone; (2) rich oil shale, carbonaceous shale, bituminous siltstone, lignite, and tuff; (3) shale, oil shale and minor, thin beds of silty limestone and dolomite (corrlative with the oil shale and siltstone member of Burner Basin in Elko East quadrangle, Solomon and Moore, 1982b); (4) siltstone, mudstone, and lean oil shale with minor tuff, lignite, and limestone; and (5) tuff, shale, and siltstone. Members of the Elko Formation were given lithologic names in Solomon and Moore (1982a, b); the correspondence of member numbers with lithologic names is shown on figure 5.

The conglomerate and sandstone of member 1 contrast markedly with the predominantly fine-grained rocks in members 2 through 5. The conglomerate of member 1 is composed of mostly well-rounded, poorly sorted granules and pebbles of dark chert in a sandy, noncalcareous matrix. Conglomerate and sandstone commonly have irregular bases that truncate underlying beds. Small and medium-scale crossbeds are rarely present. Alternating with the conglomerate and sandstone are thin beds of claystone and minor thin beds of silty limestone.

Oil shale occurs in members 2, 3, and 4 with the richest oil shale in members 2 and 3 (Solomon, 1981). The proportion of interbedded tuff and tuffaceous material increases upward, being most abundant in members 4 and 5. Carbonaceous shale and thinly bedded lignite is closely associated with oil shale in members 2 and 3. Fossils identified in member 2 include ostracodes of the genus Candona, the bivalve Sphaerium, and palynomorphs including Ovoidites, Schizosporis, conifer pollen, and algal spores (Solomon and others, 1979a, b; Solomon, 1981).

Geologic mapping by Solomon and others (1979a, b) and by Solomon (1981) suggests that informal members 1 and 2 of the Elko Formation grade laterally into member 3 in an eastward direction. However, detection of rich oil shale of member 2 in core hole EOS-3/3A indicates that this member is laterally continuous at least to the Elko Summit area (fig. 6). If member 2 grades laterally into member 3, then a facies change would probably occur further east or southeast of Elko Summit. Unfortunately, no surface or subsurface data is available to confirm this relationship. Member 1 does appear to grade into the relatively fine-grained rocks of member 3 in an eastward direction on the basis of geologic mapping (Solomon and Moore, 1982a) and core-hole data.

The Elko Formation has a maximum thickness of about 1,750 ft near Elko; approximate thicknesses of individual members are shown on figure 4. The age of the Elko Formation is considered to be Eocene and Oligocene(?) and is supported by potassium-argon ages of 37.1±1.0 m.y. and 38.8±0.3 m.y. obtained from tuffs in member 5 (Solomon and others, 1979a). A tuff near the base of the type section of the Elko Formation in the Carlin-Pinon Range area has a potassium-argon age of 38.6±1.2 m.y. (Smith and Ketner, 1976).

Depositional Setting of the Elko Formation near Elko. Oil shale and associated sedimentary rocks of the Elko Formation are interpreted as being deposited under lacustrine and closely related depositional conditions. Member 1 is interpreted as having been deposited in a marginal-lacustrine environment. The channel-form conglomerate and sandstone with interbedded claystone of member 1 suggest deltaic and interdeltaic depositional conditions. The relatively coarse-grained deposits of member 1 thin out eastward (basinward) and grade laterally into open-lacustrine shale, oil shale, and silty limestone of member 3 (Solomon and Moore, 1982b).

Members 2 through 5 consist of rocks suggestive of deposition in an open-lacustrine environment. Horizontally laminated bedding and the generally fine-grained nature of members 2 through 5 suggest a lack of tractive current activity. Thin beds of rich oil shale alternating with beds of very low organic content in member 2 suggest a fluctuating shoreline and consequent disruption of reducing conditions necessary for preservation of organic matter. The interruption of rich oil-shale deposition between major oil-shale zones in member 2 represented by tuff, tuffaceous shale, and siltstone indicates an increase in volcanic activity. Ostracodes including Candona present in member 2 suggest alkaline, low-salinity water that was at least seasonally cold (R. M. Forester, 1977, written commun.; Solomon, and others, 1979a, b). Member 3 was probably deposited further from shore than the laterally equivalent member 1. This is suggested by the relatively fine-grained, uniform shaly nature of member 3, compared to alternating coarse- and fine-grained rocks of member 1. The thick, vertically continuous, low-yield oil-shale zone of member 3 is also consistent with offshore, open-lacustrine conditions.

Increasing amounts of tuffaceous material in members 4 and 5 reflect a general increase in regional volcanic activity. These members contain notable

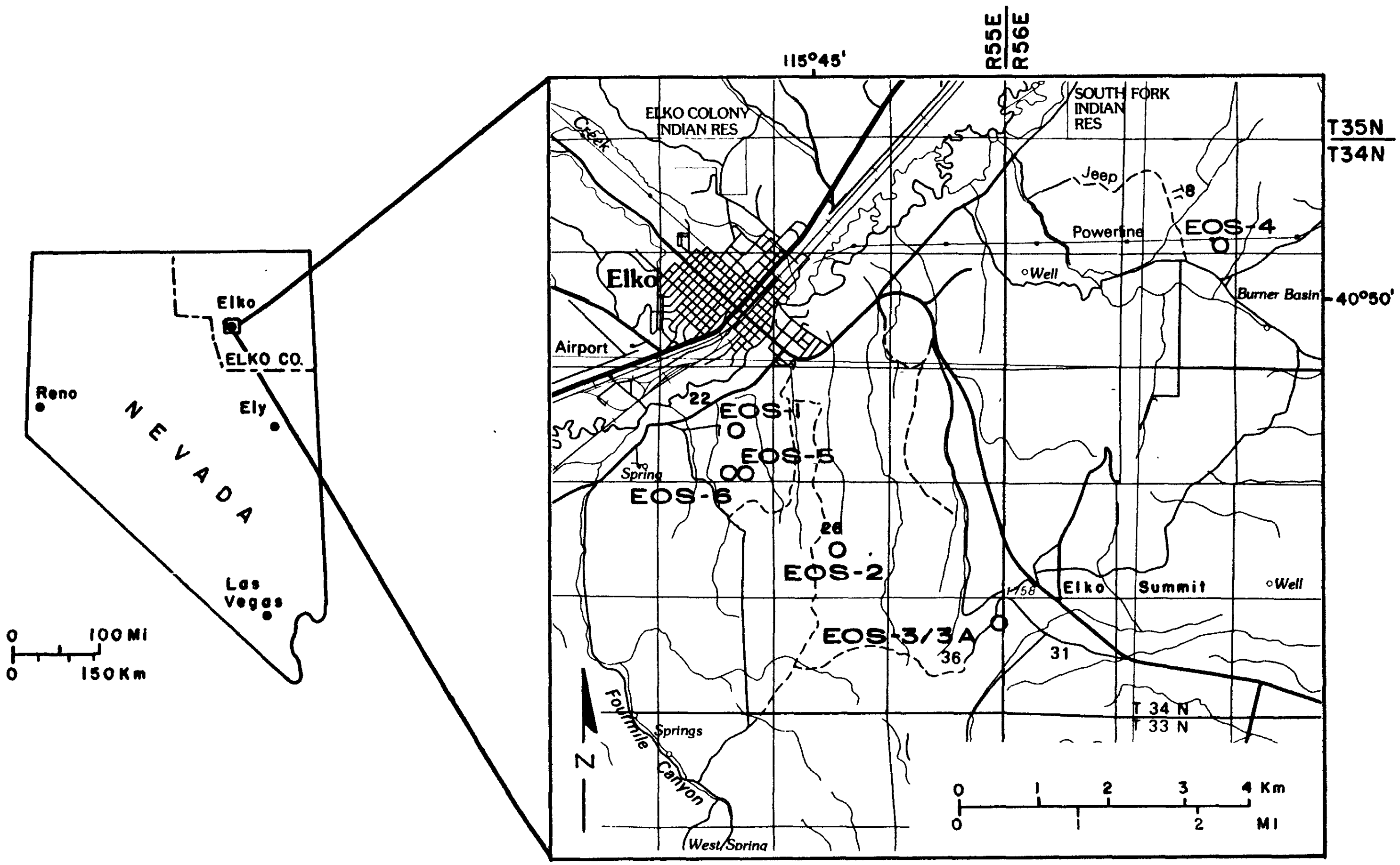

Figure 6.--Map showing the Elko study area and location of core holes drilled by USGS in late 1981.

amounts of opaline material and the zeolite clinoptilolite, which are probably alteration products of siliceous glass (Solomon, 1981).

Tertiary Rocks Overlying the Elko Formation

The Oligocene Indian Well Formation (Smith and Ketner, 1976) unconformably overlies the Elko Formation and has a thickness of approximately 900 ft. This unit consists of tuff and of sandstone and conglomerate and is exposed in the northern part of the Elko study area. Both sandstone and conglomerate contain abundant reworked pyroclastic material.

A 312-ft thick andesite unit, composed of a basal mudflow conglomerate overlain by andesite flows, unconformably overlies the Elko Formation and the cherty limestone unit in the southern part of the study area. This andesite is considered younger than the Indian Well Formation on the basis of stratigraphic and structural relationships. The andesite unit is of Oligocene age as evidenced by potassium-argon ages of 30.9 ± 1.0 and 35.2 ± 1.1 m.y. (Solomon and others, 1979a, b).

An informally designated siltstone and sandstone unit with a minimum thickness of about 755 ft represents the youngest Oligocene unit near Elko. This unit displays indistinct horizontal stratification and is largely calcareous. A fission-track age of 27.01 ± 1.2 m.y. (Solomon and others, 1979a, b) indicates a late Oligocene age.

The youngest Tertiary unit is an unnamed tuff of probable Miocene or Pliocene age. This unit includes rocks assigned to the Humboldt Formation by Solomon and others (1979a, b). The tuff is calcareous, horizontally stratified, and crops out over a relatively small area in the Elko East quadrangle. The tuff lies unconformably over Paleozoic rocks and is approximately 75 ft thick.

Structure

Paleogene rocks near Elko are structurally complex and have undergone at least two episodes of deformation (Solomon and others, 1979a, b). Deformation during the Oligocene resulted in tilting, faulting, and localized folding of the Elko Formation and older units. Subsequently, north- and northeast-trending block faults have been produced as a result of Basin-and-Range extensional tectonics ongoing since middle Miocene.

The Elko Formation and older rocks exposed south of Elko are cut by numerous north-trending faults that have vertical displacements of as much as 660 ft (Solomon and Moore, 1982a, b). These north-trending faults are truncated by a concealed major fault (or faults) parallel to the Humboldt River (Solomon, 1981; Solomon and Moore, 1982a, b). On the basis of the reported occurrence of the Elko Formation at depth in Nevelko-1, a Ladd Petroleum exploratory oil well near the Elko Airport (Nevada Bureau of Mines and Geology well files, Reno, Nevada), a cumulative vertical displacement on the order of 5000 ft has occurred along the northeast fault trend. Most strata within the Elko area have moderate dips of about 15 to 30 degrees.

Oil-Shale Deposits

Oil-shale deposits of primary interest occur in members 2 and 3 of the Elko Formation. Oil-shale beds typically alternate with low-organic-content shale, siltstone, limestone, and minor tuff. Most of the oil shale is finely laminated and yellowish brown to grayish brown in fresh core samples. Carbonaceous shale and thin lignite beds are commonly intercalated with oil-shale beds in member 2. The oil shale and interbedded fine-grained rocks of members 2 and 3 are rich in clay minerals. Minor dolomite also occurs in member 3 (Solomon, 1981). The nature and richness of oil-shale deposits in the Elko area, as determined through a shallow exploratory drilling project, are discussed in detail in the core-drilling and oil-shale resource sections of this report.

PINON RANGE AREA

Introduction

The type section of the Elko Formation is in the Pinon Range, just west of Dixie Flats, in southwestern Elko County, Nevada (Smith and Ketner, 1976). The study area covers approximately 13 square miles and lies in sections 1 to 4, and sections 9 to 16, inclusive, T. 31 N., R. 53 E., and in sections 33 to 36, inclusive, T. 32 N., R. 53 E., M.D.M. (fig. 1).

In 1970, the U.S. Geological Survey cut trench COS-2 through oil shale deposits of the Elko Formation in the study area to collect samples for analysis of oil yield. Exposures near the trench site were designated the type section of the Elko Formation by Smith and Ketner (1976). Server and Solomon (1983) conducted detailed geologic mapping to delineate several members of the Elko Formation in order to gain spatial and temporal control of the oil-shale-rich horizons throughout the deposit. The Paleozoic stratigraphy of the study area follows the desciption of Smith and Ketner (1975).

Geology

Rocks Underlying the Elko Formation

Bay State Dolomite. The oldest rock unit in the mapped area is the Bay State Dolomite, formerly the upper dolomite member of the Nevada Formation, which is Middle Devonian in age (Hose and others, 1982; Nolan and others, 1956). This unit consists of alternating layers of brown and gray dolomite. Much of the brown dolomite emits a strong petroliferous odor when freshly broken. The Bay State Dolomite is part of a carbonate assemblage that was deposited in a miogeosynclinal shallow-water environment. This carbonate assemblage is autochthonous under the Roberts Mountains thrust throughout northeastern Nevada. The Bay State Dolomite is in gradational and interfingering contact with the overlying Devils Gate Limestone.

Devils Gate Limestone. This unit ranges in age from latest Middle Devonian to earliest Late Devonian. The Devils Gate Limestone is composed mostly of medium- and thick-bedded, light- and dark-gray, fine-grained limestone. In the study area, this unit is younger than the Bay State Dolomite and is also part of the autochthonous carbonate assemblage under the Roberts Mountains thrust.

Woodruff Formation. This unit, as mapped in this area, is Late Devonian in age. Rocks composing the Woodruff Formation are principally siliceous mudstone and chert, and lesser amounts of shale, siltstone, dolomitic siltstone, dolomite, and limestone. The Woodruff Formation is part of the allochthonous siliceous assemblage associated with the Roberts Mountains thrust.

Webb Formation. The oldest Mississippian rocks in the mapped area belong to the Webb Formation which is Early Mississippian in age. The unit is composed of gray siliceous mudstone and black to gray, tan-weathering, compact limestone that occurs in lenses near the top. In the Pinon Range area, Mississippian sediments were shed from a rising source area to the west that was uplifted during the Antler orogeny and associated activity of the Roberts Mountains thrust. In general, these deposits grade upward, through several thousand feet, from very fine-grained to very coarse-grained clastic materials, from mudstone and shale to conglomerate. The basal contact of the Webb Formation is an erosional unconformity. The contact with the overlying Chainman Shale is conformable.

Chainman Shale. The Chainman Shale is Early to Late Mississipian in age and is composed mostly of gray and some dark-gray shale and sandstone. The sandstone is composed of quartz and chert grains and is accompanied by conglomerate lenses, thin limestone beds, calcareous sandstone beds, and pebbly mudstone. This unit is a flysch-like sequence of clastic rocks that records part of the depositional history of the region during uplift of the Antler orogenic belt. An erosional unconformity exists between the Chainman Shale and the base of the Elko Formation.

Elko Formation

The name Elko Formation was given by Smith and Ketner (1976) to a group of oil-shale-bearing beds that occur south of Elko in the Pinon Range just west of Dixie Flats (in the study area). The Elko Formation is largely composed of claystone, siltstone, paper-thin carbonaceous shale, oil shale, limestone, and tuff. Server and Solomon (1983) mapped four informal members of the Elko Formation in the study area.

Cherty limestone member. The oldest member mapped in the study area, informally named the cherty limestone member (Tecl), unconformably overlies Paleozoic rocks. This member consists of greenish-gray mottled limestone, which is algal in part, and occurs in beds 1 to 2 ft thick that form prominent outcrops. The limestone contains dark chert nodules and is locally interbedded with platy siltstone. This unit is correlative with the cherty limestone unit at Elko (Solomon and Moore 1982a, b). Thickness of the member is about 220 ft.

Limestone and shale member. Conformably overlying the cherty limestone member is the limestone and shale member (Tels). This member is composed of white to pale-orange and light-brown, compact limestone interbedded with paper-thin shale, minor white calcareous claystone, and is locally interbedded with dense gray and tan limestone, and light-brown and black chert. The base of this member is defined by the lowest exposure of the white to very pale-orange limestone. The limestone and shale member occupies the same stratigraphic position as the claystone and conglomerate member at Elko (Solomon and Moore, 1982a, b). The thickness of this member is about 250 to 275 ft, and the member is conformably overlain by the oil shale, limestone, and dolomitic shale member (Tesl).

Oil shale, limestone, and dolomitic shale member. The oil shale, limestone, and dolomitic shale member (Tesl) consists mostly of dark-brown to black, platy to papery, carbonaceous oil shale interbedded with light-gray to light-reddish-orange limestone and light-brown to light-gray dolomitic shale. Minor amounts of claystone, sandstone, lignite, and tuff are also present. The oil shale weathers light-bluish-gray to white. The base of this member is marked by the lowest tuff bed in the formation. This member is correlative with both the siltstone and oil-shale member, and with the oil-shale member at Elko (Solomon and Moore, 1982a, b; fig. 5). This member is 198 ft thick.

Tuff and dolomitic shale member. A minor angular unconformity separates the tuff and dolomitic shale member (Tets), the youngest mapped member of the

Elko Formation, from the older members. The tuff and dolomitic shale member (Tets) is composed of light-gray quartz-biotite tuff interbedded with light-brown to light-gray dolomitic shale, and minor amounts of limestone and white, compact, porcellaneous claystone. The base of this member, at least in the vicinity of trench COS-2, is considered to be the top of a limestone bed immediately above the highest rich oil-shale bed of the oil shale, limestone, and dolomitic shale member (Teol). Correlative with the tuff, shale, and siltstone member at Elko (Solomon and Moore, 1982a, b), this member appears to thin southward because of erosion that resulted in unconformities separating it from the overlying andesite unit and the underlying oil shale, limestone, and dolomitic shale member. This member ranges in thickness from about 200 to 700 ft.

Oil shale and associated fine-grained rocks of the Elko Formation on the eastern flank of the Pinon Range represent the culmination of Paleogene lacustrine sedimentation. A potassium-argon radiometric age of 38.6$\pm$ 1.2 m.y. has been obtained on biotite from a tuff bed 43.5 ft above the base of the oil shale, limestone, and dolomitic shale member indicating an age of late Eocene to early Oligocene for the Elko Formation (McKee and others, 1971).

Rocks Overlying the Elko Formation

Andesite. Unconformably overlying Elko Formation and Paleozoic rocks are dark gray to black andesite flows of Oligocene age (Server and Solomon, 1983). These flow rocks contain phenocrysts of plagioclase and hypersthene in a cryptocrystalline and glassy groundmass. The andesite unit is unconformably overlain by the Indian Well Formation.

Indian Well Formation. The Indian Well Formation is Oligocene in age (Server and Solomon, 1983) and is composed of light-gray rhyolitic to dacitic, nonwelded and welded ash-flow tuff, and very dark-gray to black vitrophyre. The rhyolite and dacite contain biotite, feldspar, and quartz phenocrysts. This unit is overlain unconformably by Quaternary gravel and alluvium.

Structure

The Elko Formation was deposited prior to the mid-Miocene development of Basin-and-Range topography. Basin-and-Range tectonism produced extensive faulting, especially in the less competent Paleogene rocks, as the Elko Formation. Much of the Elko Formation probably underlies younger sediments in the down-dropped basins. Unfortunately, because of the faulting and differential erosion, only small isolated remnants of the Elko Formation are exposed on the flanks of the ranges. In the study area, the beds of the Elko Formation crop out in two north-northwest trending bands that form the limbs of a south-plunging syncline (Server and Solomon, 1983).

Oil-Shale Deposit

In the study area, oil shale occurs in the oil shale, limestone, and dolomitic shale member of the Elko Formation. Four samples from this member were collected in the vicinity of the type section of Smith and Ketner (1976) from trench COS-2, located in S½S½ Sec. 10, T. 31 N., R. 53 E., M.D.M. Individual beds of oil shale exposed in the trench reach a maximum thickness of 30 in. and are interbedded with dolomitic shales and limestones. Although not sampled, these beds probably also contain a considerable amount of hydrocarbon.

The areal extent of the oil shale, limestone, and dolomitic shale member is just over one-third of a square mile.

Fischer assays to determine oil yield were made on selected samples from trench COS-2 in the oil shale, limestone, and dolomitic shale member (Server and Solomon, 1983). A 28-in.-thick bed of oil shale near the top of the member yields 16.2 gal/ton. Lower in the stratigraphic section, a 22-in.-thick bed yields 14.6 gal/ton. The richest bed sampled, about 30 in. thick, yields 20.7 gal/ton. The fourth bed sampled, about 19 inches thick, yields 12.4 gal/ton.

On the basis of the nature and quality of this deposit, the development potential of the oil shale is low because of the structural complexities, the limited exposures, and the effect of low oil-yield interbeds.

COAL MINE CANYON AREA

Introduction

Coal Mine Canyon is located in the northern Adobe Range about 25 miles northeast of Elko, Nevada (fig. 1). The purpose of this study was to investigate the oil-shale deposits of Coal Mine Canyon to determine the richness, lateral extent, and the stratigraphic and structural framework.

Methods of study

Geology of the area surrounding trench COS-1 was mapped on portions of U.S. Geological Survey 7-1/2 minute Coal Mine Basin and The Buttes quadrangle sheets enlarged to 1:12,000 scale (plate 1). A stratigraphic section of trench COS-1 was measured using a Brunton compass and steel tape (plate 2; Appendix C-1). Oil yields of trench samples were determined by Fischer assay performed by L. G. Trudell, U. S. Department of Energy, Laramie Energy Technology Center, Laramie, Wyoming (plate 2; Appendix C-2). Determination of potassium-argon age data for a hornblende-biotite rhyodacite from an unnamed unit above the Elko Formation was provided by R. W. Kistler, U. S. Geological Survey, Branch of Isotope Geology, Menlo Park, California (Appendix C-3).

Geology

Chainman Formation

The oldest rocks exposed in the study area are included in the Chainman Formation of Early to Late Mississippian age (Ketner, 1975). Elsewhere in Nevada, the commonly used name for this stratigraphic unit is the Chainman "Shale." The designation Chainman "Formation" is used to distinguish rocks dominately coarser than shale that exists in the the "lower member of the Chainman Formation" of Ketner (1975) in Coal Mine Canyon.

Of the two informally named units of the Chainman Formation (Ketner, 1975), only the lower unit occurs in the study area. The lower member consists of siltstone, shale, sandstone composed of chert and quartz grains, and of interbedded conglomerate. The weathered rock is dusky red to dark red. The Chainman Formation is poorly exposed with best exposures occurring along ridges. Bedding trends are indicated by subparallel vegetation patterns that tend to grow along weathered, less resistant interbeds of siltstone and shale.

The Chainman Formation consists of sediments derived from siliceous eugeoclinal rocks located to the west, which were uplifted during an early phase of the Antler orogeny. The lower member of the Chainman Formation is interpreted as submarine turbidite deposits. This unit of the Chainman Formation is estimated by Ketner (1975, p. 81) to be at least 5,000 feet thick.

Tertiary rocks older than the Elko Formation

The next oldest rocks in the study area belong to the Tertiary conglomerate and sandstone unit that unconformably overlies the lower unit of the Chainman Formation. The conglomerate is composed of chert and quartzite clasts ranging in size from pebbles to boulders. The conglomerate and interbedded chert- and quartz-grain sandstone were derived from the Mississippian and Pennsylvanian Diamond Peak Formation. These reworked Paleozoic sediments were deposited under fluvial to alluvial-sheet(?) and alluvial fan conditions as suggested by the generally poor sorting, with localized minor graded bedding, lack of fossils, and reddish to yellowish-brown variegated soils. This unit is probably of Eocene and Paleocene(?) age on the basis of correlations with the conglomerate and sandstone unit in the Pinon Range (Smith and Ketner, 1976) and in the Elko area (Solomon and others, 1979a, b; Solomon, 1981; Solomon and Moore, 1982a, b). Estimated from exposures in the mapped area, this unit is a minimum of 200 feet thick.

Elko Formation

Unconformably overlying the conglomerate and sandstone unit is a lacustrine sequence of claystone, siltstone, mudstone, limestone, paper-thin oil shale, sandstone, and tuff. This sequence is correlative with the Elko Formation on the basis of lithologic similarities to the Elko Formation south of Elko (fig. 5) as first described by Solomon and others (1979a, b). On the basis of a radiometric age, the Elko Formation is assigned an Eocene and Oligocene(?) age (Solomon and others, 1979a, b).

The best exposures of the Elko Formation occur in and around trench COS-1. The Elko Formation in the trench area has been differentiated into three informal members and is described in more detail in the section titled Oil-Shale Deposits and in Appendices C-1, C-2, and plates 1 and 2.

The Elko Formation is poorly exposed in areas outside the vicinity of trench COS-1. In these areas, the rocks are informally designated the limestone and tuffaceous siltstone and claystone member and are interpreted as being, in part, younger than the tuffaceous claystone member (fig. 5). The presence of ostracodes and gastropods indicates a lacustrine to marginal fluvial-lacustrine environment of deposition. The occurrence of petrified wood fragments in fine-grained tuffaceous sediments is also indicative of subaqueous deposition. The limestone and tuffaceous siltstone and claystone member is approximately 600 feet thick in the study area (plate 1).

New radiometric age data indicate the Elko Formation at Coal Mine Canyon is slightly older than the Elko Formation at Elko. Potassium-argon ages were determined for a flat-iron-forming rock from an unnamed unit, consisting of a light-gray, fine to medium-grained hornblende-biotite rhyodacite that unconformably overlies the Elko Formation. The ages range from about 38.3 $\pm$ 0.4 my to 40.7 $\pm$ 0.3 my (R. W. Kistler, written commun.; appendix C-3). These ages indicate deposition of the Elko Formation at Coal Mine Canyon occurred slightly earlier than deposition in the Elko area.

Oil-Shale Deposits

Oil-shale deposits in Coal Mine Canyon are best exposed in a 500 foot-long bladed trench cut extending from section 2 (NE1/4NW1/4NW1/4), T. 37 N., R. 56 E., into section 35 (SE1/4SW1/4SW1/4), T. 38 N., R. 56 E., M.D.M. (plates 1 and 2). This trench, designated COS-1, was cut in 1969 and logged by E. V. Stephens, U.S. Geological Survey. Due to the unavailability of data and subsequent changes in sedimentological nomenclature, the trench was re-logged by H. B. Madrid and is presented as the measured section description of trench COS-1 (Appendix C-1).

Tertiary kerogen-bearing sediments of trench COS-1 are correlative with the Elko Formation exposed south of Elko (fig.5) that were described by Solomon and others (1979a, b). The Elko Formation in Coal Mine Canyon in the area of trench COS-1 is differentiated into three informal units designated the claystone, oil-shale, and tuffaceous claystone members that are the lower, middle and upper members, respectively (plates 1 and 2; Appendices C-1 and C-2).

The claystone member consists of claystone, siltstone, oil shale, lignite, minor limestone, and sandstone and is approximately 230 feet thick in trench COS-1. Ostracodes are abundant in the oil shale and leaf fossils are present in claystones and in some oil-shale beds. The best preserved leaf fossils occur in the upper portion of thes claystone member. The claystone member was deposited under fluvial to marginal-lacustrine conditions. The oil-shale member conformably overlies the claystone member and is composed of paper-thin oil shale, claystone, and siltstone and is approximately 85 ft thick. The tuffaceous claystone member overlies the oil-shale member and consists of abundant claystone, tuff, siltstone, and minor paper-thin oil shale and is about 400 ft thick. The oil-shale and tuffaceous claystone members were deposited in open-lacustrine conditions. The laminae oriented parallel to bedding and pervasive fine grained character of the sediments suggest a lack of current activity. Ostracodes present in the oil-shale and tuffaceous claystone members are indicative of alkaline water of low salinity that was seasonally cold (Solomon and others, 1979a, b). The striking contrast of measured oil yield between interbeds (shown on plate 2 and Appendix C-2) is probably representative of an oscillating shoreline that varied the influx of organic material and disrupted the reducing conditions necessary for preserving organic matter. This fluctuation in oil yield could also have resulted from climatic variations that affected the density of algal blooms as has been interpreted for similar fluctuations in the Green River Formation (L. G. Trudell, 1982, written commun.).

Oil shale of Coal Mine Canyon is estimated to have a cumulative thickness of at least 135 ft in the lower three members of the Elko Formation. Of the three members, the oil-shale member is the "richest" oil-shale-bearing interval. Fischer assays of samples indicate oil yields ranging from trace amounts up to 26.9 gal/ton (plate 2; Appendix C-2).

The oil yields represent analyses of weathered individual-bed surface samples from trench COS-1. Since the extent to which measured oil-yield values have been decreased by weathering processes is unknown, the assay results are minimum oil-yield values (plate 2; Appendix C-2). Sample collection based on selected individual beds may have biased the estimate of cumulative oil-shale thicknesses to a minimum value.

Conclusions

The surficial extent of the oil shale is located at, and to the west of, trench COS-1. Relatively steeply dipping beds of up to 44 degrees in the trench are truncated by an east-west-trending normal fault (plate 1). Oil shale may occur at depth to the south and east of the trench area. Since the areal extent of the oil shale has been affected by normal faulting, the lateral and subsurface extent of the oil shale in Coal Mine Canyon cannot be determined without subsurface data. On the basis of the relatively small quantity of low-oil-yield oil shale at Coal Mine Canyon and the significant extent of the structural disruption, the development of oil-shale resources at Coal Mine Canyon is not likely at this time nor in the forseeable future.

CORE-DRILLING INVESTIGATION OF OIL-SHALE DEPOSITS AT ELKO

Purpose and Procedures

A drilling project was conducted between September and December 1981 to investigate oil-shale deposits in the Elko Formation near Elko, Nevada. The purpose of the drilling was to obtain fresh, unweathered oil-shale samples for Fischer assay as well as to obtain a more complete stratigraphic section of the Elko Formation. Previously, only limited trench samples and weathered surface oil-shale samples were available. Members 2 and 3, containing most of the oil shale in the Elko Formation were the primary targets of the drilling.

The drilling was primarily continuous-core drilling done by Toly Exploration of Salt Lake City, Utah under USGS contract. Surface to core point was rotary drilled using a conventional drag bit. The core rig was wire-line equipped and was fitted with an NQ-size, diamond-core bit for obtaining core with a diameter of approximately 1.875 in. Where possible, wire-line geophysical well logs were run in each core hole by White Dog Exploration of Salt Lake City.

Six core holes and one relatively deep rotary drilled hole were completed within a few miles south and east of Elko (fig. 6). Total depths of the core holes range from 117 ft to 488 ft. The one rotary-drilled hole, EOS-3A, located adjacent to EOS-3, was drilled to a total depth of 800 ft. Drilling statistics including core recovery percentages are summarized in table 1.

Oil-shale assays of the core were completed under the direction of L. G. Trudell at the U.S. Department of Energy's Laramie Energy Technology Center in Laramie, Wyoming. Oil-shale assays were done using the modified Fischer retort method (ASTM method D-3904-80: "Standard test method for oil from oil shale, resource evaluation by the U.S. Bureau of Mines Fischer Assay Procedure"). Assays were done on continuous samples of various length, based on lithologic uniformity. Samples were crushed and air-dried at room temperature to constant weight. Oil-shale assays were completed for all six core holes and on cuttings from a selected interval of rotary-drilled core hole EOS-3A.

Wire-Line Well Logs

Geophysical logs were run in core holes EOS-2, -4, and -6, and in rotary drilled EOS-3A (plates 4-7). The suite of bore-hole geophysical logs includes gamma-gamma density, natural gamma, resistance, and caliper logs. Study of the wire-line well logs suggests a good correlation of rich oil-shale beds with relatively low-density deflections on the gamma-gamma density log. This relationship was noted by geophysical logging of the oil shale of the Green River Formation by Bardsley and Algermissen (1963). The density log may be used for predicting higher oil-yield zones from future drill holes at the well site prior to Fischer assaying. Oil-shale beds also appear to correlate qualitatively with a combination of a normal shale response on the gamma log and a relatively high resistance log deflection; however, this correlation is probably only indirectly related to the organic content of the oil shale.

Results of Drilling and Fischer Assays

Plates 3 through 7 summarize the data obtained from each core hole including Fischer assay oil-yield histograms, wire-line geophysical well logs,

EOS-No.	DEPTH TO COREPOINT (ft)	TOTAL DEPTH (ft)	% CORE RECOVERY	DATE OF COMPLETION	APPROXIMATE ELEVATION (ft)	LOCATION
1	20.0	117.0	88%	09/30/81	5160	NE¼NW¼SE¼ sec. 22, 34N, 55E; from SE sec. corner, approx. 2050 ft N. and 1500 ft W.
2	19.3	180.1	77%	10/11/81	5600	NW¼NW¼SE¼ sec. 26, 34N, 55E; from SE sec. corner, approx 2500 ft N. and 2450 ft W.
3	59.0	488.0	88%	11/19/81	5820	SE¼NE¼NE¼ sec. 36, 34N, 55E; from NE sec. corner, approx. 800 ft S. and 250 ft W.
3A (Rotary drilled)	400.0 1/	800.0	(cuttings)	12/10/81	" "	" " " " " " " " "
4	20.0	292.8	96%	09/27/81	5660	SW¼SE¼ SE¼ sec. 8, 34N, 56E; from SE sec. corner, approx. 450 ft N. and 800 ft W.
5	20.0	53.0	32%	10/22/81	5240	SE¼SW¼SE¼ sec. 22, 34N, 55E; from SE sec. corner, 550 ft N. and 1650 ft W.
6	112.5	192.0	74%	11/24/81	5260	NE¼SW¼SE¼ sec. 22, 34N, 55E; from SE corner 800 ft N. and 1850 ft W.

1/ Collection of cuttings began at a depth of 400 ft.
--Total footage: 1,072.1 ft cored; 1,050.8 ft rotary drilled
--Wire-line well logs were completed on EOS-2, -3a, -4, and -6. Suite of logs includes gamma-gamma density, resistance, natural gamma ray, and caliper logs.

Table 1.--Summary of drilling statistics of USGS Elko oil-shale drilling project--1981.

general lithologic column and description, location, and other details and specifications of the drilling. "Oil shale" indicated on the lithologic logs for each core hole are those organic shales that had Fischer assay oil yields in excess of 3 gal/ton. Fischer-assay oil yields for core samples and cuttings in Appendix B and trench samples in Appendix C and throughout this report are reported in gallons of oil per ton of sample (gal/ton).

Fischer assay results, shown graphically in histograms on plates 3 through 7 and on figure 7, indicate significant variations between oil yields of interbeds. Maximum individual-bed oil yields range up to 60 to 85 gal/ton in member 2; however, these high oil-yield beds alternate with low-yield beds with only a few gal/ton or trace oil yields. In member 3, maximum individual-bed oil yields range from about 15 to 18 gal/ton in core hole EOS-3/3A, and rich beds also alternate with relatively low-yield beds. In member 3 in core hole EOS-4, maximum-individual-bed oil yields range up to about 28 gal/ton. Because of large differences in oil yield of intercalated beds, average oil yields were calculated for selected oil-shale zones.

Oil shale in member 4 was penetrated only in core hole EOS-1 (plate 3). Oil yields range up to about 13 gal/ton over a drilled interval of 80 ft in core hole EOS 1.

Calculation of Average Oil Yields

Average oil yields were calculated for oil-shale zones in members 2 and 3 from Fischer-assay determinations of oil yield for individual samples. For the purpose of correlation, selected "oil-shale zones" are designated the "upper" and "lower" zones of member 2, and zones "A through G" of member 3 (fig. 7). Since Fischer-assay oil yields are determined on a weight basis (in gallons of oil per ton of sample) it was necessary to consider the specific gravities of individual samples. Using the specific gravities, the average oil yield of core sections made up of samples composited on a volume basis (such as would be the case in a mining situation) can be determined.

At present, the specific gravity for oil shale of the Elko Formation has not been directly measured; therefore, for the purpose of resource calculations, the specific gravity-oil yield relationship is assumed to be similar to that of oil shale of the Green River Formation. The organic content and oil yield of oil shales is considered to be inversely related to specific gravity. In other words, the less dense (lower specific gravity) oil shales have higher organic content and thus higher oil yields. Therefore, the specific gravity-oil yield relationships and methodology of Smith (1956) and Stanfield and others (1957) were used to determine approximate specific gravity and average oil yields of oil shale in members 2 and 3 of the Elko Formation.

To calculate the average oil yield for a selected oil-shale zone the following steps were used, given:

SG = Specific gravity
62.3 lb = Weight of 1 cubic foot (1 ft^3) of water at 60°F

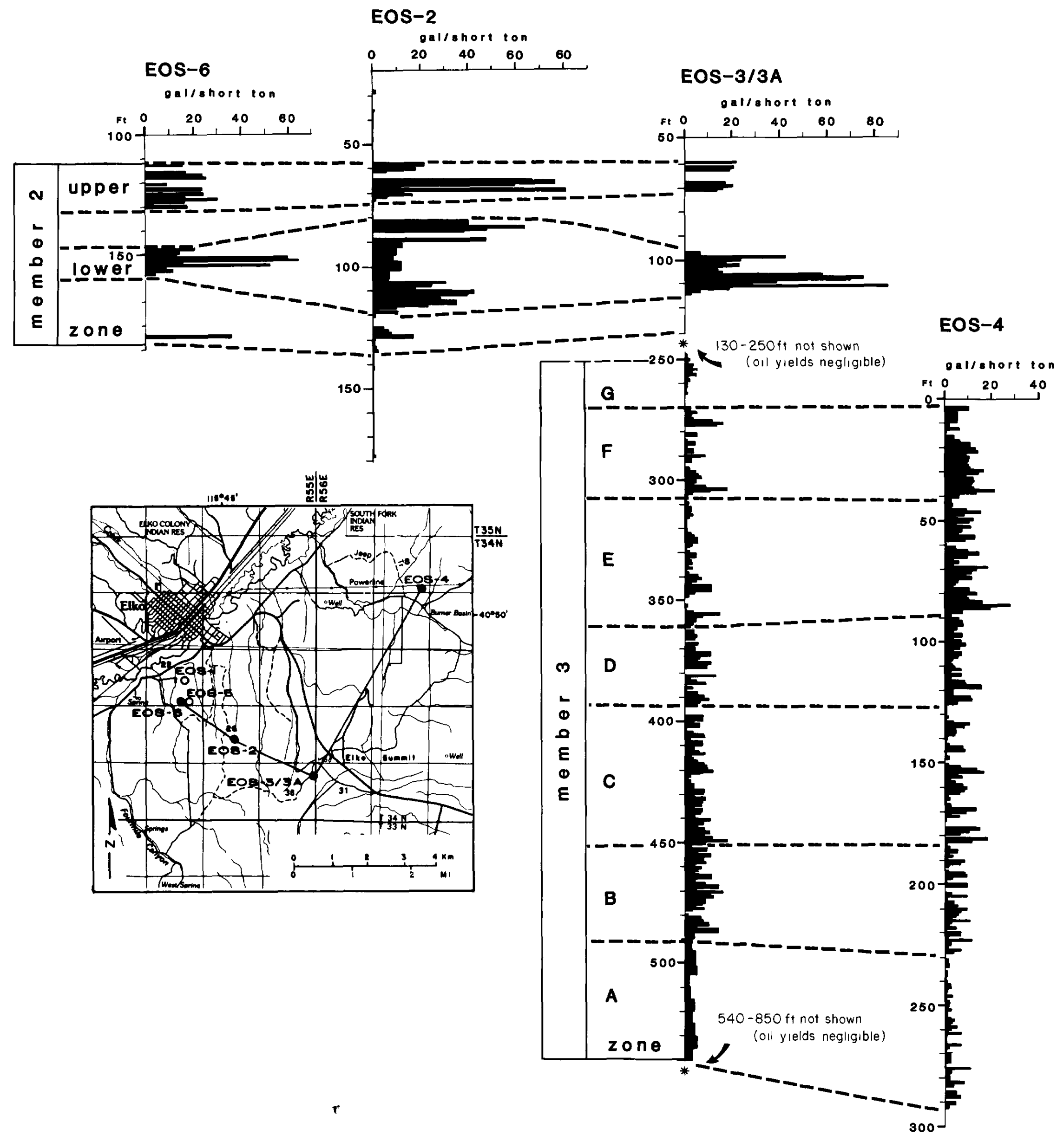

Figure 7.--Preliminary correlation of oil-shale zones in members 2 and 3 of the Elko Formation near Elko using Fischer assay oil-yield histograms from core holes EOS-6, -2, -3/3A, and -4.

Conversion factors used to convert oil shale per unit weight to oil shale per unit volume:

$$32.10 = \frac{2{,}000 \text{ lb/ton}}{62.3 \text{ lb/ft}^3} = \text{ft}^3 \text{ of water per ton}$$

$$0.0312 = \frac{1}{32.10} = \text{tons of water per ft}^3$$

Steps: 1. For each sample interval,

a) Determine SG--Estimate SG (from figure 1 or table 1 of Stanfield and others, 1957, p. 3-6).

b) Convert assayed oil yield per unit weight (gal/ton) to oil yield per unit volume (gal/ft^3):

$$\begin{array}{c}\text{Fischer assay}\\ \text{oil yield}\\ \text{(in gal/ton)}\end{array} \times \text{SG} \times 0.0312 = \begin{array}{c}\text{Oil yield per}\\ \text{unit volume}\\ \text{(in gal/ft}^3\text{)}\end{array}$$

2. Find total of assayed intervals.

3. Determine average SG for oil-shale zone:

$$\text{Average SG} = \frac{\text{total of [intervals (in ft) x SG]}}{\text{total of assayed intervals (in ft)}}$$

4. Calculate average oil yield per unit volume for oil-shale zone (using oil yields determined for each interval):

$$\begin{array}{l}\text{Average oil yield}\\ \text{per unit volume}\\ \text{for zone}\\ \text{(gal/ft}^3\text{)}\end{array} = \frac{\text{Total of all [interval (in ft)} \times \text{interval oil yield (in gal/ft}^3\text{)]}}{\text{Total of intervals in zone (ft)}}$$

5. Convert average oil yield per unit volume (gal/ft^3) back to yield per unit weight (gal/ton):

$$\begin{array}{l}\text{Average oil yield}\\ \text{per unit volume}\\ \text{(in gal/ft}^3\text{)}\end{array} \times 32.10 = \begin{array}{l}\text{Average oil yield}\\ \text{per unit weight}\\ \text{(in gal/ton)}\end{array}$$

To illustrate the calculation of average oil yields, the calculations for the lower oil-shale zone of member 2 in core hole EOS-6 are shown below and results summarized in table 2. (Numbers correspond to steps stated previously.)

1. For sample interval: 147.5-148.8 ft; Interval = 1.3 ft.

a) SG = 2.29

b) Oil yield per unit volume:

$$20.7 \text{ gal/ton} \times 2.29 \times 0.0312 = 1.479 \text{ gal/ft}^3$$

Depth of assayed sample (feet)			Assayed oil yield		Specific gravity of shale (SG)	Interval x (gal/ft^3)	Interval x SG
From	To	Interval	(gal/ton)	(gal/ft^3)			
147.5	148.8	1.3	20.7	1.479	2.29	1.923	2.98
148.8	150.1	1.3	14.0	1.048	2.40	1.362	3.12
150.1	151.1	1.0	1.0	0.971	2.43	0.971	2.43
151.1	152.1	1.0	59.6	3.329	1.79	3.329	1.79
152.1	153.2	1.1	64.6	3.487	1.73	3.826	1.91
153.3	154.5	1.2	15.3	1.127	2.36	1.352	2.83
154.5	155.6	1.1	51.9	3.028	1.87	3.330	2.06
155.6	156.6	1.0	8.7	0.681	2.51	0.681	2.51
156.6	157.8	1.2	11.8	0.902	2.45	1.082	2.94
157.8	159.0	1.2	4.5	0.365	2.60	0.438	3.12
	Totals	11.4				18.304	25.69

Table 2.--Example of values calculated for determination of average oil yield in the lower oil-shale zone of member 2 in core hole EOS-6.

Similar calculations were performed for each sample interval.

2. Total of assayed intervals = 11.4 ft

3. Average SG $= \dfrac{25.69}{11.4 \text{ ft}} = 2.25$

4. Average oil yield per unit volume for zone $= \dfrac{18.304 \text{ gal/ft}^3}{11.4} = \underline{1.606 \text{ gal/ft}^3}$

5. Average oil yield per unit weight $= \dfrac{1.606 \text{ gal/ft}^3}{2.25} \times 32.10 = \underline{23.0 \text{ gal/ton}}$

Average oil yields are calculated using the assayed interval total (instead of the oil-shale zone drilled interval). In each core hole, a proportion of core was not recovered; in the oil-shale zone from 147.5 to 159.0 ft, only 0.1 ft was not recovered. Because of the relatively insignificant missing sample, the calculated average oil yields are assumed to be representative of the entire zone for this and other core holes. Therefore, the 23.0 gal/ton average oil yield is assumed to be representative of the entire oil-shale zone. Calculation of average oil yields for selected oil-shale zones of members 2 and 3 in core holes EOS-6, -2, -3/3A, and -4 were performed in a similar manner to the example and are summarized in table 3. In table 3, a "composite" thickness, average specific gravity, and oil yield were determined for the cumulative oil-shale zones in each core hole. The composite values were determined for the purpose of calculation of the total in-place shale-oil resources, disregarding barren or low-yield intervals between the upper and lower zones in member 2.

Since bedding was not horizontal in any of the core holes (plates 3 through 7), it was necessary to calculate the true thickness of the oil-shale zones using the following formula:

$$\text{True thickness (in ft)} = \text{Drilled interval (apparent thickness, in ft)} \times \sin(90° - \text{dip})$$

For example, for the upper oil-shale zone of member 2, which lies between 113.0 and 131.0 ft depth in core hole EOS-6, has an apparent thickness of 18.0 ft. Since the bedding dips an average of 10° in core hole EOS-6,

$$\text{True thickness} = 18.0 \text{ ft} \times \sin(90° - 10°)$$

$$= 18.0 \times 0.9848 = 17.7 \text{ ft}$$

In core holes EOS-2, -3/3A, and -4, bedding has average dips of 20°, 26°, and 15°, respectively. True thickness of oil-shale zones and the composite thicknesses are also shown in table 3.

Correlation of Oil-Shale Zones

Oil-shale zones from four core holes, EOS-6, -2, -3/3A, and -4, have been tentatively correlated on the basis of general lithology and Fischer assay

Core Hole EOS-	Elko Formation member	Oil-Shale Zone	Depth (feet) From	to	Thickness	True Thickness (feet)	Average Specific Gravity	Average oil yield (gal/ft³)	(gal/ton)
6	2	upper	113.0	131.0	18.0	17.7	2.30	1.428	19.9
		lower	147.5	159.0	11.5	11.4	2.25	1.6125	23.0
		Composite*	113.0	159.0	29.5	29.1	2.27	1.519	21.5
2	2	upper	57.5	73.0	15.5	14.6	2.21	1.747	25.4
		lower	80.8	135.0	54.2	50.9	2.41	1.102	14.7
		Composite*	57.5	135.0	69.7	65.5	2.39	1.1369	16.8
3/3A	2	upper	59.0	71.5	12.5	11.2	2.41	0.7517	10.0
		lower	96.9	114.8	17.9	16.1	2.23	1.753	25.2
		Composite*	59.0	114.8	30.4	27.3	2.31	1.3345	18.5
		G	249.4	270.5	21.1	19.0	2.63	0.1004	1.2
	3	F	270.5	307.0	36.5	32.8	2.59	0.3880	4.8
		E	307.0	360.1	53.1	47.7	2.63	0.2457	3.0
		D	360.1	392.4	32.3	29.0	2.42	0.3998	5.3
		C	392.4	450.9	58.5	52.6	2.56	0.4828	6.1
		B	450.9	490.0	39.1	35.1	2.53	0.6020	7.6
		A	490.0	540.0	50.0	44.9	2.62	0.2795	3.4
		Composite (A-G)	249.4	540.0	290.6	261.1	2.57	0.3740	4.7
4	3	F	3.0	40.8	37.8	36.5	2.50	0.6981	9.0
		E	40.8	88.5	47.7	46.1	2.50	0.6695	9.0
		D	88.5	125.5	37.0	35.7	2.56	0.4770	6.0
		C	125.5	182.5	57.0	55.1	2.45	0.3900	5.1
		B	182.5	228.7	46.2	44.6	2.61	0.3067	3.8
		A	228.7	292.8	64.1	61.9	2.66	0.1371	1.7
		Composite (A-F)	3.0	292.8	289.8	279.9	2.55	0.4202	5.3
		Selected interval	18.0	39.0	21.0	20.3	2.43	0.9335	12.3
		Selected interval	68.6	86.7	18.1	17.5	2.44	0.9017	11.9

Composite = Cumulative thickness, specific gravity, and average oil-yield of oil-shale zones.

* In member 2, barren or low oil-yield interval between upper and lower zones is disregarded for the purpose of in-place shale-oil resource calculation.

Table 3.--Summary of average oil yields calculated for selected oil-shale zones in core holes EOS-6, -2, -3/3A, and -4.

results (fig. 7; plates 4-7). Two relatively rich oil-shale zones in member 2 correlate reasonably well between core holes EOS-6 and EOS-3/3A. The two oil-shale zones in member 2 occur over a maximum drilled interval of about 56 ft between EOS-6 and EOS-3/3A. The oil-shale zonation in EOS-2, which lies between EOS-6 and -3/3A, is less distinctly concentrated in two zones and rich oil shale occurs over a drilled interval of approximately 77.5 ft that averages 15.3 gal/ton. Member 3 contains a relatively thick, although substantially leaner, oil-shale sequence that overall averages 4.7 gal/ton over a drilled interval of 290.6 ft in EOS-3/3A and 5.3 gal/ton over a drilled interval of 289.8 ft in EOS-4 (table 3). Member 3 is subdivided into zones A through G for determination of average oil yields for specific drilled intervals.

Oil-shale-zone correlations, particularly between zones A through G of member 3 as shown in figure 4, are presently considered preliminary. Significant variations in the oil yield between tentatively correlative zones may be attributable to one or more factors that may have affected the vertical stratigraphic section as sampled by each core hole. As noted in table 1 and on plates 3-7, less than complete core recovery was achieved in each core hole. Core recovery was particularly poor in core holes EOS-2, -5, and -6 becauses of difficult drilling conditions. In fact, the drill site was relocated from EOS-5 to EOS-6 because of the extremely poor core recovery (32%). Possible fault displacements, undetected in the missing core intervals, would significantly alter the vertical stratigraphic sequence as sampled in each core hole. In addition, abrupt lateral facies changes between the relatively near-shore lacustrine deposits of members 1 and 2 and more offshore deposits of member 3 could account for oil-yield discrepancies between core holes EOS-3/3A and -4.

Because of these factors, the oil-shale-zone correlations shown on figure 7, particularly for member 3, are considered preliminary. Extremely detailed lithologic examination of the core samples, beyond the immediate goals of this project, is required to strengthen the validity of the oil-shale-zone correlations. Detailed core examination can hopefully be accomplished in the near future.

OIL-SHALE RESOURCES IN THE ELKO AREA

The study area at Elko has the best prospects for oil-shale resources of the three study areas (Elko, Pinon Range, and Coal Mine Canyon). On the basis of Fischer assays and calculated average oil yields for sections penetrated by core holes EOS-6, -2, -3/3A, and -4, total in-place oil-shale resources of members 2 and 3 of the Elko Formation have been calculated for the estimated area of outcrop/subcrop near Elko (fig. 8). Subareas V through Z were designated for the purposes of resource calculations in order to account for structural complexities and variations in average oil yield as sampled by associated core holes. Boundaries for the area of outcrop/subcrop and the subareas are straight lines and were approximated to the nearest quarter-quarter section to simplify area determination. Subareas were defined on proximity to the nearest core hole, distribution of surface outcrops, and inferred presence of oil-shale-bearing units in the subsurface based on geologic mapping by Solomon and Moore, 1982a, b. Table 4 summarizes oil-shale resources calculated for each subarea in the area of outcrop/subcrop of members 2 and 3 of the Elko Formation.

Calculation of Oil-Shale Resources

The following methodology was used in calculating the in-place oil-shale resources within each subarea. Core holes considered as a representative sampling of each subarea are listed in table 4. In order to calculate the total amount of shale oil in members 2 and 3 in each subarea, the composite (cumulative) true thickness of combined oil-shale zones and the corresponding average oil yield from the associated core hole was determined for each subarea (table 4). For member 2, the upper and lower oil-shale zones were composited, disregarding the intervening barren or low-yield beds between the two zones. For member 3, which consists of more continuous, although low-yield oil shale, the entire sequence including zones A through G was composited.

To calculate the weight of shale per unit volume for a subarea the following formula was used, given:

SG = average specific gravity for the subarea
62.3 lb = weight of 1 ft^3 of water at 60°F

(1) Weight of shale per unit volume (lb/ft^3) = SG x 62.3 lb

Using the weight of shale per unit volume, the weight of oil shale in the subarea can be calculated using the following formula:

(2)

$$\text{Weight of oil shale in subarea (tons)} = \frac{\text{true thickness (ft)} \times \text{weight of shale per unit volume (lb/ft}^3) \times \text{area (ft}^2) \times \text{secant of average dip in subarea}}{2{,}000 \text{ lb/ton}}$$

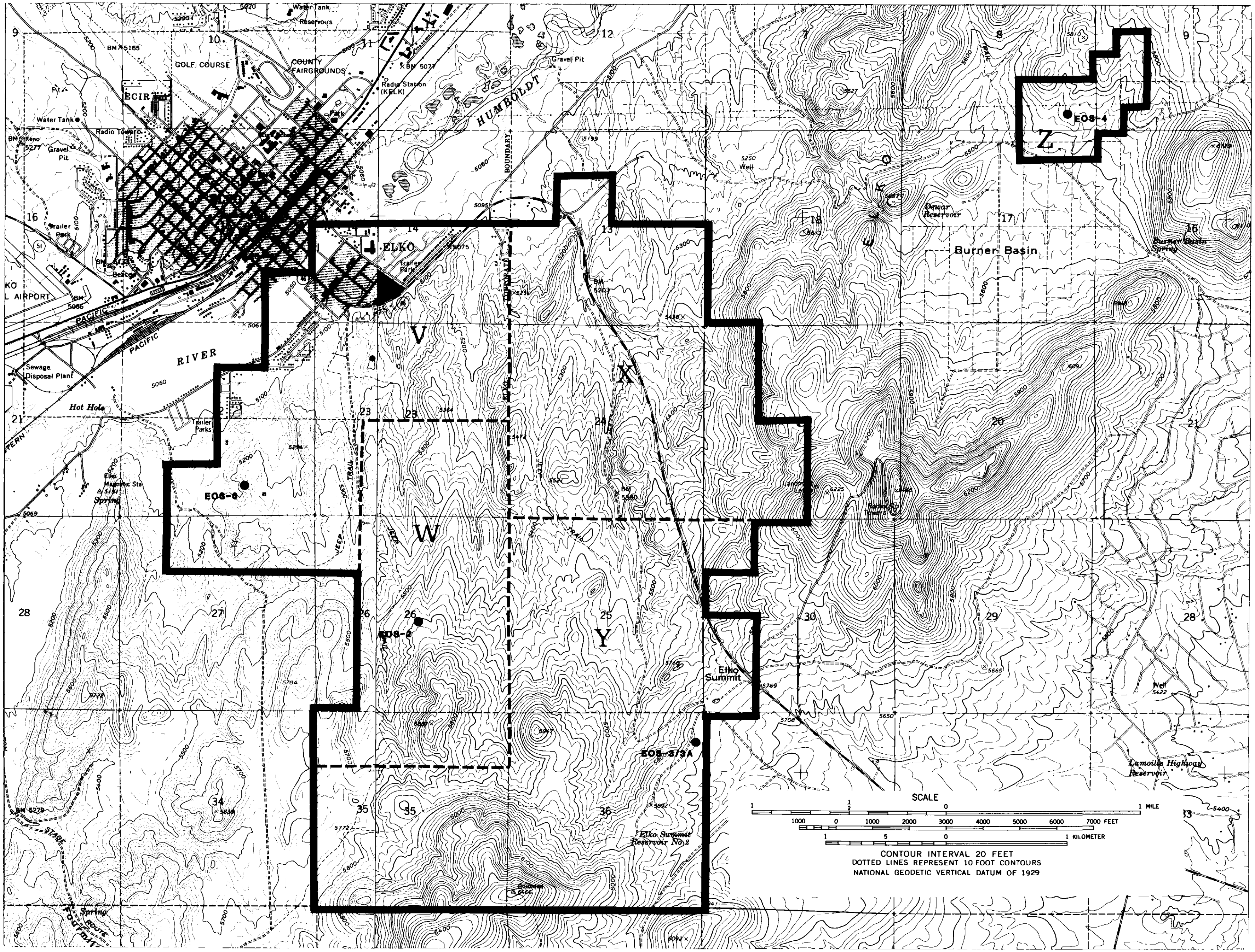

Figure 8.--Estimated area of outcrop/subcrop and designated subareas of members 2 and 3 of the Elko Formation near Elko, Nevada.

Subarea	V	W	X	Y	Y	Z
Member	2	2	3	2	3	3 1/
Sampled by Core hole	EOS-6	EOS-2	EOS-3/3A	EOS-3/3A	EOS-3/3A	EOS-4
Composite true thickness 2/ of oil-shale zones (feet)	29.1	65.5	261.1	27.3	261.1	279.9
Average oil yield per unit weight of composite zones (gallons/ton)	21.5	16.8	4.7	18.5	4.7	5.3
Average specific gravity	2.27	2.39	2.57	2.31	2.57	2.55
Average dip in subarea	28°	26°	26°	28°	26°	15°
Secant of subarea dip	1.133	1.113	1.113	1.133	1.113	1.035
Approximate area of outcrop/subcrop (acres)	1,240	880	1,240	1,880	1,880	150
(ft^2)	54,014,400	38,332,800	54,014,400	81,892,800	81,892,800	6,534,000
Weight of shale per unit volume (lb/ft^3)	141.42	148.90	160.11	143.91	160.11	158.87
Tons of oil shale X 10^6	125.9	208.1	1,257	182.2	1,905	150.4
Barrels of shale oil X 10^6	64.45	83.24	140.6	80.25	213.2	18.98

1/ This member is also referred to as the oil shale and siltstone and of Burner Basin member (Solomon and Moore, 1982b). This member is correlative and essentially equivalent to member 3 to the west.

2/ Calculated true thickness of composite oil-shale zones corrected for dip of bedding in core holes (disregarding intervening barren interval between upper and lower oil-shale zones of member 2).

Table 4.--Estimated oil-shale resources calculated for members 2 and 3 of the Elko Formation near Elko, Nevada. Subareas designated by the letters V, W, X, Y, and Z (fig. 7) for purposes of resource calculations.

Given the weight of oil shale in the subarea, the volume in number of barrels (bbls) of shale oil can be calculated for the subarea:

(3)

$$\text{Volume of shale oil (bbl)} = \frac{\text{weight of oil shale} \times \text{average oil yield (gal/ton)}}{42 \text{ gal/bbl}}$$

Referring to table 4, the calculation of oil-shale resources for member 2 of the Elko Formation in subarea V is shown as an example. (Numbers in parentheses correspond to previously given formulas.):

(1) $$\text{Weight of shale per unit volume} = 2.27 \times 62.3 \text{ lb/ft}^3 = \underline{141.42 \text{ lb/ft}^3}$$

(2) $$\text{Weight of oil shale in subarea V} = \frac{29.1 \text{ ft} \times 141.42 \text{ lb/ft}^3 \times 54{,}014{,}400 \text{ ft}^2 \times 1.133}{2{,}000 \text{ lb/ton}}$$

$$= 125.9 \times 10^6 \text{ tons}$$

(3) $$\text{Volume of shale oil in subarea V} = \frac{(125.9 \times 10^6) \times 21.5 \text{ gal/ton}}{42 \text{ gal/bbl}}$$

$$= 64.45 \times 10^6 \text{ bbls}$$

The oil-shale resources for the other subareas are calculated in a similar manner and the results are summarized in table 4. The total calculated oil-shale resources in the estimated area of outcrop/subcrop for members 2 and 3 are given in table 5.

Results of Resource Calculations

The estimated in-place shale-oil resources of members 2 and 3 of the Elko Formation in the study area at Elko total approximately 600 million barrels (table 5). This estimate, derived from new information from the recent core hole drilling, includes the total amount of shale oil in the indicated area of outcrop/subcrop disregarding minimum oil yield and thickness necessary for the deposit to be considered of economic value.

Oil-shale deposits are considered to be "prospectively valuable" by the Minerals Management Service (MMS) and U.S. Geological Survey (USGS) if the shale is known or inferred to yield at least 15 gal/ton over a minimum thickness of 15 ft (Culbertson and Pitman, 1973, p. 500; USGS Interim Standards for Green River Formation Land Classification, revised 6/29/81). Intervals less than 15 ft thick may also be considered prospectively valuable if oil yields are high enough (above 15 gal/ton) to yield at least the same amount of oil (about 17,300 barrels/acre). Also, on basis of the current MMS/USGS mineral land classification standards, a deposit with a yield of at least 25 gal/ton and a thickness of approximately 25 feet is required for classification as an oil-shale leasing area.

Subarea	V	W	X	Y	Z	Total
Elko Formation member						
Member 2 (Average oil yield of at least 15 gal/ton over a thickness of 15 ft or more)	64.45	83.24	-----	80.25	-----	227.94
Member 3 (Average oil yield of only about 5 gal/ton over a minimum thickness of about 260 ft)	-----	-----	140.6	213.2	18.98	372.78
	TOTAL in-place shale-oil resources (Disregarding minimum thickness and grades to be considered prospectively valuable)					600.72

Table 5.--Total of calculated oil-shale resources in area of outcrop/subcrop (includes subareas V, W, X, Y, and Z of fig. 7) in members 2 and 3 of the Elko Formation, near Elko. Potential resources in millions of barrels of shale oil.

Although there is significant lateral variation, much of the oil shale in member 2 meets or exceeds the minimum 15 gal/ton and 15-ft-thickness standard (table 3). The richest interval is the upper oil-shale zone, as sampled in core hole EOS-2, averaging 25.4 gal/ton over a thickness of 14.6 ft. In fact, the composite 65.5 ft interval in EOS-2 yields an average of 16.8 gal/ton. However, correlation with equivalent member 2 oil-shale zones in core holes EOS-6 and -3/3A within a radius of about 1.5 miles to the northwest and southeast suggests that this relatively thick 16.8-gal/ton-shale interval is more locally concentrated (fig. 6). Another rich interval of oil shale yielding 25.2 gal/ton over 16.1 ft in the lower zone of core hole EOS-3/3A also exceeds the minimum classification standard.

About 373 million barrels or 62 percent of the calculated 600 million barrels of shale-oil resources are from low-yield oil shale of member 3. Member 3 oil shale, although possessing a composite thickness of about 280 ft, has an average oil yield of only 4.7 to 5.3 gal/ton. The richest selected interval in member 3, as sampled in core hole EOS-4, yields 12.3 gal/ton over 20.3 ft (table 3), still below the standard for prospectively valuable oil-shale lands.

Accuracy of Estimates

Several factors affect the accuracy of these estimates of shale-oil resources near Elko. The core-drilling and new Fischer assays on continuous cores greatly improved the range and accuracy of sampling of the oil-shale deposits in the Elko Formation over past collections of weathered surface samples and trench samples (Solomon, 1981). Because of improved subsurface sampling, preliminary estimates of about 191 million barrels (Solomon, 1981) of shale-oil resources of members 2 and 3 of the Elko Formation near Elko have been revised to about 600 million barrels.

While the selected core-hole locations (figs. 6 and 8) provided a reasonable testing of the area of outcrop/subcrop of Elko Formation members 2 and 3, data from additional drill holes would probably increase the accuracy of the estimates. In particular, the presence of member 3 in subarea X is largely inferred, on the basis of scattered outcrops and geologic interpretation of subcrop using cross sections (Solomon and Moore, 1982b). Another core hole in subarea X would significantly increase the confidence level of the revised resource estimates. However, owing to the structural and stratigraphic geologic complexity of the Elko area and to the complex land ownership, more core holes would have been difficult to site and costly to drill. Additional drilling would yield more subsurface control and would probably modify the extent of the estimated area of subcrop of members 2 and 3 located in subareas V through Z (fig. 8).

A consideration that affects the calculated oil-shale resources is attributable to missing (unrecovered) core. In particular, relatively large proportions of core are missing in the richest parts of oil-shale zones in core holes. EOS-6 and EOS-2. The missing core in those zones probably has reduced the average oil yields; therefore, member 2 oil-shale resources may still be somewhat low.

Another consideration that affects the calculated resources is the inaccuracy introduced when oil yields assayed on a weight basis were converted to oil yield on a volume basis. The specific gravities of the shale must be used for this conversion. Since specific gravities of the Elko shale have not been measured, specific gravities were assigned to the Elko oil-shale samples on the basis of the specific gravity-oil yield relationships of the Green River Formation oil shales (Smith, 1956; Stanfield and others, 1957). The use of specific gravities of shale from the Green River Formation is considered to be a close approximation because of the similarities of the specific gravity of oil and the density of organic matter in the shales of the Elko and Green River Formations (Solomon, 1981, p. 135). In addition, similar proportions of oil can be converted from organic matter in oil shales of the Elko and Green River Formations. The conversion fractions are 58 and 66 percent, respectively, for oil shale from the Elko Formation and for the Mahogany Zone in the Green River Formation (Smith, 1969, p. 7). Differences in the mineralogical composition of shale between the two formations could also affect the shale's specific gravity. However, the effect is considered small, since minerals such as pyrite and analcime, which substantially alter the specific gravity of shale (Smith, 1966, p. 168), are not present in signficant quantity in the Elko shales.

ECONOMIC DEVELOPMENT POTENTIAL OF OIL-SHALE RESOURCES AT ELKO

The economic viability of a mineral deposit can be determined only after a detailed examination of the geology and resources. Physical parameters of the an oil-shale deposit including oil yield, thickness, volume of resource, depth, stratigraphic and structural characteristics, and chemical nature of the oil shale are important factors to be considered. Beyond the physical parameters of the deposit, a diverse range of factors become involved in determining the potential for economic development of the deposit. For oil shale, a fossil energy resource that has not yet achieved commercial production in the United States, the list of factors is particularly long and complex. Although a detailed economic analysis is beyond the scope of this report, a consideration of the economic viability of the oil-shale resource at Elko is given in terms of quality of the resource and of other economic, environmental, and technological considerations.

Quality of the Oil-Shale Resource at Elko

An area of approximately 5,390 acres at Elko has been defined as containing in-place shale-oil resources of approximately 600 million barrels, determined as a result of geologic mapping, stratigraphic study and limited core-drilling and analyses (fig. 8; table 5). However, of these shale-oil resources, only about 228 million barrels in member 2 of the Elko Formation meet or approach the 15-gal/ton and 15-ft thickness standard to be considered as a valuable oil shale deposit (table 5). Oil shale in member 3 of the Elko Formation, although possessing individual-bed-yields of up to 28 gal/ton, in a continuous vertical sequence of up to 280 ft, only has an average oil yield of about 5 gal/ ton, too low to be of present economic interest. In fact, shales of less than 10 gal/ton might more correctly be defined as "organic-rich shales" rather than oil shales. According to Duncan and Swanson (1965, p. 3), "the 10 gal/ton figure represents the approximate minimum oil yield of deposits that have been mined and processed on a commercial scale by the world oil-shale industries, and which thus may be considered as possible sources of oil for future development by demonstrated recovery methods". In addition, results of experimental retorting of oil shales at the Laramie Energy Technology Center indicate that more energy is required to retort oil shale that contains less than 8 gal/ton than is recovered from the process (Donnell, 1977, p. 9). In view of this energy required for retorting, it is difficult to consider the low-yield member 3 oil shale as a valuable economic resource either at present or in the distant future.

Eliminating the forseeable economic potential of member 3 oil shale, the effective resource at Elko is reduced to a maximum of 228 million barrels in member 2. Of member 2 oil shale, probably only the richest intervals would be of initial economic interest. As detected in core-hole EOS-3/3A, the richest oil-shale zone is approximately 16 ft thick and averages 25.4 gal/ton (table 3). Selection of this and other rich-oil-shale intervals, accurately defined over a given area within the area of outcrop/subcrop of member 2 (fig. 8), would probably be the initial target of future oil-shale development near Elko, given favorable economic, environmental, and other factors.

Comparison of Oil Shale From the Elko and Green River Formations

To put the oil shale resources near Elko into proper perspective, a brief comparison of the oil shale of the Elko Formation to that of the Green River Formation seems appropriate. The Green River Formation, which occurs in Colorado, Utah, and Wyoming, contains the largest known oil-shale deposits in the United States. The Green River Formation has been estimated to contain identified resources of about 1.8 trillion barrels of shale oil in oil shale that yields a minimum average of 15 gallons/ton (Culbertson and Pitman, 1973, p. 500). Of these Green River Formation identified resources, about 418 billion barrels of shale oil are from shales yielding more than 30 gal/ton (Culbertson and Pitman, 1973, p. 500). The majority of the rich oil-shale deposits are located in western Colorado, in the Piceance Creek Basin.

Most of the oil-shale resources in the Piceance Creek Basin are contained in the Parachute Creek Member of the Green River Formation. The Parachute Creek Member ranges in thickness from about 900 to 1900 ft and in the center of the basin contains oil shale averaging as much as 30 gal/ton over an 800 ft-thickness (Trudell and others, 1974, p. 68).

As a comparison to an area of about the same size as the Elko study area, oil-shale resources including grades and thicknesses of oil shale are given for Colorado tract C-a of the Piceance Creek Basin. Federal tract C-a, developed by Rio Blanco Oil Shale Co. (Gulf Oil Co. and Standard Oil Co. of Indiana), consists of 5,090 acres and contains total in-place oil shale resources of approximately 5.1 billion barrels (U.S. Department of Interior, 1973, v. III, p. II-46 to II-48). The richest oil-shale zones of the Parachute Creek Member in tract C-a include: the Mahogany-rich interval, which averages 41 gal/ton over an average thickness of 58 ft; the R-5 interval, which averages 29 gal/ton over an average thickness of 180 ft; and the R-4 interval, which averages 32 gal/ton over an average thickness of 130 ft (Gulf Oil Co. and Standard Oil Co. of Indiana, 1974, p. 53; Murray, 1974, p. 132).

Although the oil shales at Elko, Nevada are less in quantity and quality than oil shales of the Piceance Creek Basin, the relatively rich oil shale in member 2 of the Elko Formation near Elko represents a potential oil-shale resource. The calculated total of 228 million barrels of shale-oil for member 2 must be considered as a potential future resource for the State of Nevada.

Other Geologic Constraints

In addition to grade, thickness, and volume of the resource, other geologic constraints affect the economic value of the oil-shale deposit at Elko. These constraints include complex structure and stratigraphy, and depth. In general, most of the Green River Formation oil shale in the Piceance Creek Basin, Colorado, is continuous, horizontal-lying, and structurally simple. In contrast, geologic mapping near Elko has shown considerable structural and stratigraphic complexity (Solomon and Moore, 1982a, b; plates 1 and 2). Most of the oil-shale bearing strata are tilted 15 to 30 degrees from horizontal, and in addition are traversed by numerous faults and are locally folded. The relatively near-shore nature of the oil-shale deposits near Elko is reflected in complex lateral facies changes and local fluctuations in the amount and oil-yield of shale. This stratigraphic complexity makes the prediction of the presence of rich oil-shale zones over an area a difficult task.

While some of the oil-shale bearing strata of member 2 are exposed at the surface, the dip of the bedding projects the oil shale in some parts of the map area to as deep as 2,500 ft (plates 1 and 2, cross-sections). Although oil-shale of the Elko Formation is inferred to be present in adjacent down-faulted basins (Solomon, 1981; Solomon and Moore, 1982; plates 1 and 2; Ketner, 1970), the deep burial under a few thousands of feet of younger sediments puts these deposits beyond economic recovery.

Oil-Shale Chemistry

Limited analytical data on oil shale from the Elko Formation suggests that this oil shale may have some inherent advantages in terms of processing. Fischer assay data (Appendix B) indicates that even the richest shale does not tend to coke (Smith, 1980, p. 17). This non-coking characteristic is an advantage, since the formation of coke would tend to reduce the total amount of oil recoverable from Fischer assay.

Other favorable factors of the Elko oil shale are the shale's high organic content, high conversion fraction to oil, and a generally siliceous mineral character. In addition to possessing a generally high organic content, the proportion of organic content that can be converted to oil is of vital importance in the consideration of the development potential of an oil-shale deposit (Mikinis and Smith, 1982, p. 50). According to Smith (1969, p. 7), approximately 58 percent of the organic matter in the Elko oil shale can be converted to oil. This figure compares relatively well with an average conversion fraction of 66 percent for the Green River Formation oil shale (Smith, 1969, p. 7). More recent studies suggest that an even larger fraction of organic matter in the Elko oil shales converts to oil than in Green River Formation shales (Smith, 1980, p. 7). Mikinis and Smith (1982) suggest that the conversion efficiency of an oil shale is directly related to the amount of aliphatic carbon present. Of the total carbon in a sample of oil shale from the Elko Formation, the aliphatic carbon fraction is 0.77 (77 percent), and the conversion efficiency was 52 percent (Mikinis and Smith, 1982, p. 52). Mikinis and Smith (1982, p. 61) state that the 52 percent conversion efficiency is considered anomalously low in comparison with other Tertiary samples, but offer no explanation. Other samples should be tested to further establish the conversion efficiency of the oil shales from the Elko Formation.

The siliceous mineralogical composition of shales in the Elko Formation may also be a positive advantage to shale processing. The mineral content as reported in Solomon (1981, p. 26-27) is largely dominated by quartz, feldspar, smectite clays, and minor carbonates. This composition contrasts markedly with the more dominant carbonate character of the Green River Formation. Since removal of the carbonate minerals is one of the primary considerations in isolating the kerogen and processing the shale,the relative absence of carbonates in the Elko oil shales could be an advantage.

Development Problems

Beyond the physical parameters of the oil-shale deposit at Elko, a number of other related factors are intricately involved in determining the economic viability. Some of these major problems, also plaguing all U.S. oil-shale development, involve, but are not limited to: economics, environment, land and water availability, and technological problems.

Economics

One of the primary motivations for shale-oil development in the U.S. has been the increasing cost of crude oil from domestic and foreign sources. However, because of the high costs of shale-oil production involved in mining, plant construction, developing retorting technology, land acquisition, and environmental compliance, the general feeling in the U.S. is that oil shale cannot yet compete economically with conventional sources of oil. The economic instability is particularly susceptible to current fluctuations in inflation and a tight availability of funding in the United States (Russell, 1981, p. 30).

Recent oil-shale development stoppages and slow-downs have not been encouraging in 1981-82. The abrupt announcement of Exxon's shelving of the large Colony Project in the Piceance Creek Basin of western Colorado in early May 1982 is considered a severe set-back for the oil-shale industry. Prior to Exxon's retreat, Multi-Minerals and Cathedral Bluffs Oil Shale Company had also recently stopped Colorado oil-shale development operations. According to Gary (1982, p. vii) the reasons given for these stoppages were a soft crude oil market and lower world crude prices, a greater than expected decline in crude oil consumption, escalating costs, and high interest rates. In view of current unfavorable economic conditions affecting high-grade oil-shale developments in Colorado, it is doubtful that the oil shale at Elko would be commercially attractive at the present time.

Environment

Oil-shale development poses serious problems in regard to environmental quality. Water quality can be affected seriously by mining operations, discharges from the retorting plant, and by drainage from spent shale piles. Dust and emitted gases require abatement to insure air quality. Any oil-shale mining and retorting operation constructed to develop the oil-shale deposits near Elko would require strict monitoring and control of potential hazardous by-products because of the close proximity to the town.

Land Use and Water Availability

Acquisition of land and availability of relatively large quantities of water are necessary for an oil-shale development. The land ownership in the vicinity of Elko is a mixture of mostly alternating sections of private and Federal lands. The acquisition of sufficient land for mining, processing, and waste disposal probably would be a difficult task considering the recent expansion of the town of Elko and the present demand for residential, agricultural and commercial land uses. Public acceptance of an oil-shale mine in close proximity to Elko would also be a major consideration. Oil-shale development is a waterintensive industry and adequate water supplies in the relatively dry climate near Elko are already under a high demand. Water supplies would have to be carefully studied and water rights obtained before any oil-shale development could occur at Elko or elsewhere in northeastern Nevada.

Mining and Retorting Technology

Aside from the general types of problems with oil-shale development already mentioned, technological problems of mining and retorting are a major consideration. Although many types of mining and retorting technologies are being tested and developed on a small scale, no current technology has been successfully demonstrated on a commercial level (Russell, 1981, p. 31). Experimental, small-scale in-situ retorting operations hold promise for future oil-shale development in the United States. In-situ methods for steeply dipping beds as in the Elko Formation have not yet been developed; however, for in-situ cool gasification, steep dips are a definite advantage (L.G. Trudell, written commun., 1982). Many of the problems associated with open-pit and underground mining, such as handling and disposal of huge quantities of spent shale could be avoided with a true in-situ process. A wide variability of experimental mining and retorting technologies is being considered by various oil-shale projects in the Piceance Creek Basin. Technological success of producing shale oil from Green River Formation oil shales will doubtlessly affect the chances and suitability of development of oil shale in the Elko Formation.

CONCLUSIONS

Rock units containing potential oil-shale resources are restricted mostly to northeastern and east-central Nevada. Of primary interest are the locally rich oil-shale deposits of the lacustrine Eocene and Oligocene(?) Elko Formation in Elko County. Other rock units, presently considered as petroleum source rocks, that may have limited potential for oil-shale resources, can be classified in two other categories: other lacustrine and related non-marine deposits; and organic-rich marine shale. Other lacustrine and related non-marine rocks include the Upper Cretaceous and Paleogene Sheep Pass Formation and the Cretaceous to lower Paloecene Newark Canyon Formation. The organic-rich marine shale category includes: the Ordovician Vinini Formation; the Devonian Woodruff Formation; the Mississippian Chainman Shale; and the Permian Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation. Other than the Elko Formation, the marine shales of the Vinini and Woodruff Formations appear to have the most potential for being developed for oil shale, because of locally high kerogen content and associated byproducts of vanadium and other metals.

Present data suggests that the best potential for oil shale in Nevada is in the Elko Formation. The Elko Formation is distributed over a north-south elongated area of approximately 100 miles in length and at least 30 miles in width. Tertiary faulting and erosion have left only isolated exposed remnants or deeply buried stratigraphic sections. Geologic mapping and stratigraphic studies at three main areas of exposed Elko Formation, at Elko, the Pinon Range, and in Coal Mine Canyon suggest that the Elko Formation represents a geologic interval of late Eocene and earliest Oligocene continental sedimentation.

Oil shale and related mostly fine-grained deposits of the Elko Formation were deposited in an open-lacustrine, low-salinity, alkaline water environment. Reducing conditions in the lake provided for the preservation of organic matter to form oil shale. Abundant tuffaceous material in the Elko Formation indicates concurrent volcanic activity in the region during the interval of lacustrine deposition. Whether the Elko Formation was deposited in a single large lake, or in several smaller basins is uncertain because of the lateral discontinuity of the deposits. However, the relatively large thicknesses of the Elko Formation at Elko and in the Pinon Range, and the extremely rich oil-shale beds suggests concentration of organic matter and deposition in a relatively large basin.

The best defined oil-shale deposits in the Elko Formation are near Elko and have been investigated by a shallow exploratory core-drilling project. The richest oil-shale deposits near Elko are in member 2 of the Elko Formation. Individual oil-shale beds in member 2 locally yield as much as 85 gallons of oil per ton. The best oil-shale zone in member 2 has an average oil-yield of 25.4 gal/ton over a thickness of about 16 feet. In-place shale-oil resources in member 2 near Elko have been calculated to be about 228 million barrels from beds meeting or approaching a standard classifiable grade of 15 gal/ton over a minimum thickness of 15 feet.

Member 3 of the Elko Formation near Elko is estimated to have an additional 373 million barrels of in-place shale oil. However, this shale-oil is from relatively low-oil-yield beds in member 3. Over a thickness of 260 to 280 feet, member 3 has an average oil yield of only about 5 gal/ton. Because of the high energy demands of mining and processing of oil shale, shales yielding less oil than 10 gal/ton are not presently considered economic resources. The richest interval in member 3, has an average oil yield of 12.3 gal/ton over a thickness of 20 ft, but still does not meet the minimum classifiable standards for valuable oil-shale lands. Because of the low average oil yields of member 3, the economic development of this member is likely.

On the basis of grade, thickness, and volume, member 2 oil shale of the Elko Formation near Elko should be considered the initial target of future oil-shale development in Nevada. In the state of Nevada, the Elko Formation is an important oil-shale resource, however these resources are quite meager compared to the large identified oil-shale resources of the Green River Formation in Colorado, Utah, and Wyoming. Structural and stratigraphic complexity, and a laterally discontinuous nature of the oil-shale deposits are major problems limiting the economic development potential of the Elko Formation.

The large costs involved in development of an oil-shale resource, relative to conventional petroleum resources, are a major deterrent to development of Elko Formation oil shale. Current economic problems including the availability of funding, fluctuations in inflation, high interest rates, and escalating costs of construction have made development of oil shale in the United States, including the rich deposits of the Green River Formation, a formidable task. Lower world crude-oil prices and a decline in domestic consumption of crude oil is further delaying the economic feasibility of oil shale. Other practical, environmental, and technological obstacles present problems to oil-shale development. Although shale oil is present in notable quantities in the Elko Formation, and more resources may be discovered buried within large sedimentary basins in northeastern Nevada, the commercial development of these resources is not likely in the near future.

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Winfrey, W. M., Jr., 1960, Stratigraphy, correlation, and oil potential of the Sheep Pass Formation, east-central Nevada, in Boettcher, J. S., and Sloan, W. W., eds., Guidebook to the geology of east-central Nevada: Intermountain Association of Petroleum Geologists and Eastern Nevada Geological Society 11th Annual Field Conference Salt Lake City, Utah, p. 126-133.

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APPENDIX A

ANNOTATED BIBLIOGRAPHY FOR OIL SHALE AND RELATED ORGANIC-RICH ROCKS OF NORTHEASTERN NEVADA

By

Steven W. Moore, Helen B. Madrid, and Catherine L. Helseth

APPENDIX A--Annotated Bibliography for Oil Shale and Related Organic-Rich Deposits of Northeastern Nevada

By Steven W. Moore, Helen B. Madrid, and Catherine L. Helseth

Alderson, V.C., 1920, The oil shale industry: Frederick A. Stokes Company, New York, p. 31-32; p. 42-44.
Mentions the two experimental oil shale plants in the vicinity of Elko, Nevada: a Pumpherston (Scotch) retort operated by Southern Pacific Company under the supervision of the U.S. Bureau of Mines; and the plant of the Catlin Shale Products Company. Reports the mining and processing methods of the Catlin plant that produces oil with a high content of paraffin. Oil yields of 50 gal/ton are reported. (See Brooks and Potter, 1974; Desborough and others, 1981; and Russell, 1980.)

American Institute of Mining Engineers, 1914, The oil shales of Elko, Nevada: Bulletin of the American Institute of Mining Engineers, no. 90, p. 1402-1404.
A discussion of some early observations about the oil shale exposed at Elko. "Oil shale" at Elko was compared and contrasted to oil shale in Elko Scotland. R. M. Catlin observed a high paraffin-wax content in the Elko shales and noted the association of abundant volcanic materials.

Axelrod, D. I., 1966, The Eocene Copper Basin flora of northeastern Nevada: University of California Publications in the Geological Sciences, v. 59, 125 p.
Describes a previously unreported conifer-deciduous hardwood forest flora from an Eocene stratigraphic section in the Copper Mountain area, in the southern part of the Jarbidge quadrangle, northern Elko County. Also describes Bull Run flora and gives a K/Ar age of 35 m.y. (p. 48) for this section. (The Tertiary sedimentary sequence in Bull Run Basin may be correlative with the Elko Formation near Elko based on lithologic similarities. See Smith and Ketner, 1976, p. 22.)

Bortz, L. C., and Murray, D. K., 1978, Eagle Springs oil field, Nye County, Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 62, p. 881.
Eagle Springs oil field, first oil field in Nevada, was discovered by Shell Oil Co. in 1954. Production from reservoir in carbonate rocks of the Sheep Pass Formation (Cretaceous? to Eocene) and welded tuffs of the Garrett Ranch Group (Oligocene). Production for 1978 was 400 bbl/day.

Brooks, P. T., and Potter, G. M., 1974, Recovering vanadium from dolomitic Nevada shale: U.S. Bureau of Mines Report of Investigation 7932, 20 p.
Discusses recovery methods for extraction of vanadium from shale in the Woodruff Formation of Devonian age. Vanadiferous shale contains up to 10% organic carbon. (According to mapping of Smith and Ketner, 1975, the Woodruff Formation is approximately located in southwestern Elko County in T. 31 N., R. 52 E., M.D.M.)

Claypool, G. E., Fouch, T. D., and Poole, F. G., 1979, Chemical correlation of oils and source rocks in Railroad Valley, Nevada [abs.]: Geological Society of America Abstracts with Programs, v. 11, p. 403.
Comparison of composition of organic matter (hydrocarbon distributions and carbon isotope ratios) from extracts of the Mississippian Chainman Shale and the composition of crude oil from the Trap Spring field suggests that the Chainman Shale is the source rock. Although geochemical evidence is inconclusive, strong circumstantial evidence favors the Sheep Pass Formation as the source rock for oil in the Eagle Springs field.

Coats, R. R., 1964, Geology of the Jarbidge quadrangle, Nevada-Idaho: U.S. Geological Survey Bulletin 1141-M, 24 p.
p. 7-8: Describes the Meadow Fork Formation in northern Elko County, which consists mostly of conglomerate, shale, and tuff. Age is regarded as Eocene.

Couch, B. F., and Carpenter, J. A., 1943, Nevada's metal and mineral production (1859-1940, inclusive): University of Nevada Bulletin, v. 37, 159 p.
Reports oil shale production from the Elko district in 1917 and 1918 of 46 tons of oil shale with a commercial production of $1,920.

Decker, R. W., 1962, Geology of the Bull Run quadrangle, Elko County, Nevada: Nevada Bureau of Mines Bulletin 60, p. 27-28, 57-58.
Oil shale beds were detected in the "Lower member of the Humboldt Formation" in an exploratory oil well drilled by Richfield in 1959 (No. 1 Scott Government well), in SW¼ sec. 22, T. 43 N., R. 52 E., M.D.M., Bull Run Basin area of northwestern Elko County. Oil shows were also present in the lower part of the well. (The Tertiary sedimentary sequence at Bull Run basin is correlative with the Elko Formation. See Osmond and Elias, 1971; and Smith and Ketner, 1976, p. 22.)

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.
Discusses metalliferous oil shales in the Devonian Woodruff Formation. Reports an oil yield of 13.9 gallons/ton for this shale. (For locality, see Brooks and Potter, 1974.)

Desborough, G. A., Poole, F. G., Hose, R. K., and Radtke, A. S., 1979, Metals in Devonian kerogenous marine strata at Gibellini and Bisoni properties in southern Fish Creek Range, Eureka County, Nevada: U.S. Geological Survey Open-File Report 79-530, 31 p.
Reports on a vanadium and kerogen-rich marine shale in the Devonian Woodruff Formation. This shale contains up to 3.6 weight percent oil and bulk rock analyses yielded 12.4 gallons of oil/ton. Located in T. 15-16 N., R. 52 E., M.D.M., Eureka County, Nevada.

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Desborough, G. A., and Poole, F. G., 1983, Metal concentrations in marine black shales of the Western United States: in review, scheduled for publication in Journal: Economic Geology (volume dedicated to G. Cameron).

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.
Mentions thin, high-grade oil-shale deposits near Elko considered part of the Humboldt Formation of Miocene and Pliocene(?) age by Winchester (1928, p. 13) contain a potential of 6 million barrels of oil. (These rocks are now assigned to the Elko Formation. See Smith and Ketner, 1972, 1976; Solomon 1981; Solomon and others, 1979 a,b) p. 15: Mentions organic-rich marine shales in the Ordovician Vinini Formation of Nevada. Locally, shales from the Vinini Formation yield 10 to 25 gallons of oil per ton. The oil potential of this formation is presumably large.

Engineering and Mining Journal, 1890, v. 49, p. 392.
Reports a belt of oil shale cropping out over a distance of more than one mile, near Patterson, Lincoln County, Nevada. (Unable to determine the exact area; however this occurrence may be an outcrop of Sheep Pass Formation or other petroliferous shale unit in the southern Schell Creek Range, northeast Lincoln County.)

Feth, J. H., 1963, Tertiary lake deposits in western coterminous United States: Science, v. 139, no. 3550, p. 107-110.
A compilation of Tertiary lacustrine deposits west of the Rocky Mountains with references of general localities. Mentions these deposits are of economic interest due to potential resources of petroleum and natural gas or other industrial minerals. Sharp (1939) is cited for the vicinity of Elko, Nevada.

Foster, W. H., and Dolly, E. D., 1980, Petroleum potential of the Great Basin [abs.]: American Association of Petroleum Geologists Bulletin, v. 64, p. 442.
Summarizes oil fields and petroleum source rocks in the Basin and Range Province. Eagle Springs, Trap Spring, and Currant fields in east-central Nevada are noted. Accumulations in these fields occur in truncation-fault traps or in drape-over faulted structures. Reservoirs are in fractured Oligocene ignimbrites or Eocene lacustrine rocks. Lists the following as oil source rocks: shale of the Ordovician Vinini Formation (Fm.); the Devonian Pilot Shale, and Mississippian Chainman Shale Formations; and Cretaceous to Tertiary lake deposits (Sheep Pass Fm., Elko Fm., Kinsey Canyon Fm., Newark Canyon Fm., and King Lear Fm.).

Fouch, T. D., 1977, Sheep Pass (Cretaceous? to Eocene) and associated closed-basin deposits (Eocene and Oligocene?) in east-central Nevada: Implications for petroleum exploration [abs.]: American Association of Petroleum Geologists Bulletin, v. 61, p. 1378.
Reports pyrolytic oil yields in excess of 4 gallons/ton (17 liters/metric ton) from the Cretaceous and Eocene Sheep Pass Formation of east-central Nevada. Proposes a model with two periods of closed-basin lacustrine sedimentation from Cretaceous(?) through Eocene. Rocks including the "Sheep Pass Fm.," near Ely, and the Kinsey Canyon Fm., are considered as potential hydrocarbon source and reservoir rocks.

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Relates several localities of Late Cretaceous through Paleogene rocks in

east-central Nevada to a general paleogeographic model. Deposition of sediments occurred in warm, alkaline, shallow, vegetated, permanent lakes and in alluvial fan settings adjacent to mountain fronts. Rock units discussed include: Sheep Pass Fm., Kinsey Canyon Fm., and various informally named units. Correlations with the Elko Fm., near Elko are suggested.

Fouch, T. D., Hanley, J. H., and Forester, R. M., 1979, Preliminary correlation of Cretaceous and Paleogene lacustrine and related nonmarine sedimentary and volcanic rocks in parts of the eastern Great Basin of Nevada and Utah, in Newman, G. W., and Goode, H. D., eds., Basin and Range symposium and Great Basin field conference: Rocky Mountain Association of Geologists and Utah Geological Association, p. 305-312.
Correlates scattered localities of Cretaceous and Paleogene stratigraphic units in eastern Nevada and Utah. The Elko Fm. is correlative with: the Kinsey Canyon Fm., central Schell Creek Range, Nev.; rocks mapped as the "Sheep Pass Formation" near Ely, Nev; and with units in the western Uinta Basin, Utah. Notes the possible petroleum source rock potential of the Elko and Newark Canyon Formations. At the type section of the Kinsey Canyon Formation in the Diamond Range, near Eureka, Nevada, analyses of lipid-rich "oil shales" have pyrolitic oil yields greater than 10 gal/ton.

Garside, L. J., 1973, Radioactive mineral occurrences in Nevada: Nevada Bureau of Mines and Geology Bulletin 81, p. 46.
Report on occurrence of asphaltic pyrobitumen at localities between Trout Creek and Willow Creek, near the Eureka County line. Vanadium and uranium are also present. Location: N½N½ sec. 1, T. 29 N., R. 52 E., M.D.M. (See Vanderburg, 1938.)

Gavin, M. J., 1924, Oil shales in the United States: U.S. Bureau of Mines Bulletin 210, p. 23.
Reports on Nevada oil shales near Elko and Carlin. Notes physical and chemical differences of these Nevada oil shales from oil shales of the Green River Formation. The Nevada oil shales are probably correlative with the Eocene Green River Formation. Reports that a rich 2-ft-seam of Nevada oil shale yields 60 gal/ton.

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.
Summarizes early interest in oil shale near Elko, including efforts at mining and retorting of shale by Catlin Shale Products Co. (from 1916 through the early 1920's) and by the Southern Pacific Co./U.S. Bureau of Mines. Considered oil shale to be part of the Humboldt Formation of Miocene and Pliocene age. Reported oil shale yields up to 86.8 gal/ton. Notes high contrast of oil yields in adjacent interbeds.

Gustafson, F. V., 1977, Regional reconnaissance of the Sheep Pass Formation [M.S. thesis]: Reno, University of Nevada, MacKay School of Mines, 86 p.
Discusses Cretaceous and lower Tertiary Sheep Pass Formation and its relationship and correlation to similar deposits in east-central Nevada. Notes the distinctive lack of tuffaceous material in deposits of, and correlative with the Sheep Pass Formation. (Later studies by Fouch, 1977, and 1979, report localities that grade upward into tuffaceous sediments which are included in the Sheep Pass Formation.)

Hague, Arnold, 1883, Abstract of report on the geology of the Eureka district, Nevada: U.S. Geological Survey 3rd Annual Report, p. 237-290.

Hague, Arnold, and Emmons, S. F., 1877, Report of geological exploration of the fortieth parallel--Descriptive geology: U.S. Army Professional Paper 18, v. 2, 890 p.
Agreed with assignment of oil shales near Elko to the Eocene Green River Formation by King (1876, 1878).

Harper, Doug, 1974, Fifty years too soon--the Catlin Shale Products Company: Northeastern Nevada Historical Society Quarterly, v. 5, p. 1-19.

Hastings, D. D., 1980, Results of Exploratory Drilling, Northern Fallon Basin, Western Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 64, p. 443.
Reports on a joint investigation by Chevron and Amoco of the Tertiary northern Fallon basin in western Nevada in the early 1970's. The Tertiary section is 8300 ft thick and consists of a lower volcanic member, a middle fluviolacustrine and volcanic-derived sedimentary member, and an upper basalt member. The northern Fallon basin contains highly-organic oil-prone source rocks; oil and gas shows included free-oil in vugs at the top of a basalt core. Reservoir rocks were absent; subsurface temperatures are not sufficient to generate significant amounts of oil. During the last 4 to 6 m.y. extensional faulting and formation of basin-and-range structure occurred in western Nevada.

Hope, R. A., and Coats, R. R., 1976, Preliminary geologic map of Elko County, Nevada: U.S. Geological Survey Open-File Map 76-779, scale 1:100,000.
Compilation of geologic mapping shows limited exposures of Paleogene rocks are widespread throughout Elko County.

Hose, R.K., and Blake, M.C., Jr., 1976, Geology, Part I of Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines Bulletin 85, p. 1-35.

Kellogg, H. E., 1964, Cenozoic stratigraphy and structure of the southern Egan Range, Nevada: Geological Society of America Bulletin, v. 75, p. 949-968.
Describes the Eocene Sheep Pass Formation first named by Winfrey (1958). This formation consists of lacustrine sedimentary deposits that unconformably overlie Paleozoic rocks in the Egan Range, east-central Nevada. (The Sheep Pass Formation may be a petroleum source rock. See Winfrey, 1958, 1960; Fouch, 1977, 1979; and Fouch and others, 1979.)

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.
Oil shale is reported in the northern Adobe Range at Coal Mine Canyon overlying a lower Tertiary coarse conglomerate. Mentions the possibility of the oil shale being deeply buried in major valleys around the Adobe Range. In most places the oil shale is probably deeply buried, approaching the surface only near the hills and mountain ranges. (Oil shale in Coal Mine Canyon is now considered part of the Elko Fm. See Madrid, this report.)

Ketner, K. B., 1980, Preliminary geologic map of the Coal Mine Basin quadrangle, Elko County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map, MF-367, scale 1:24,000.
Lower Tertiary sedimentary and volcanic deposits including oil shale mapped in the southeast corner of the quadrangle. (This oil-shale-bearing unit is in the Coal Mine Canyon study area and is included in the Elko Formation. See Madrid, this report.)

_____, 1980, Ordovician Vinini Formation of northern Nevada [abs.]: in U.S. Geological Survey Professional Paper 1150, p. 80-81.

Ketner, K. B., and Smith, J. F., Jr., 1963(a), Composition and origin of siliceous mudstones of the Carlin and Pine Valley quadrangles, Nevada, in Short papers in Geology and Hydrology: U.S. Geological Survey Professional Paper 475-B, p. B45-B47.
Refers to siliceous mudstones of Ordovician, Silurian, and Devonian age in the upper plate of the Roberts Mountains thrust. (Some of these rocks are organic rich and now considered as possible petroleum source rocks. See Desborough and others, 1979; 1978; Foster and Dolly, 1980; Poole and Desborough, 1980; Smith and Ketner, 1972, 1975, 1978; and Veal, 1978.)

King, Clarence, 1876, Geological and topographical atlas accompanying the report of the geological exploration of the fortieth parallel: U.S. Army Professional Paper 18, scale 1:250,000.
The first published account describing post-Paleozoic rocks near Elko. Oil shales near Elko were assigned to the Eocene Green River Formation, on the basis of lithologic similarities to that unit in Utah.

_____, 1878, Report of the geological exploration of the fortieth parallel--systematic geology: U.S. Army Professional Paper 18, v. 1, 803 p.
See King (1876).

Knowlton, F. H., 1919, A catalogue of the Mesozoic and Cenozoic plants of North America: U.S. Geological Survey Bulletin 696, 815 p.
On the basis of fossil plant remains, Knowlton considered oil shales near Elko to be of Miocene age.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada: Reno, Nevada, Newsletter Publication Co., 295 p.
p. 38-39: Reports on occurrence of coal and oil shale in the Carlin area, southwestern Elko County (probably refers to the Pinon Range study area). An occurrence of oil-shale float was reported near the Charleston Mining District by Copper Mountain in northern Elko County.
p. 43: Describes the oil shale occurrence at Elko, including geology and mining activity by Southern Pacific Railroad and Catlin Shale Products Company between 1914 and 1923. Oil shale reported to yield 50 to 75 gallons of shale oil per ton and contains unusually high amounts of paraffin.

Mason, H. L., 1927, Fossil records of some west American conifers: Carnegie Institute of Washington Publication 346, p. 139-158.
Assigned an age of Oligocene or Miocene to the Tertiary beds near Elko, on the basis of conifer fossil remains.

Maughan, E. K., 1978, Permian source rocks, northeastern Great Basin [abs.]: U.S. Geological Survey Professional Paper 1100, p. 20.
Refers to a preliminary evaluation of the Permian Phosphoria Fm. in northeastern Nevada and eastern Utah. The Meade Peak Phosphatic Shale Member of the Phosphoria Fm., has relatively high organic-carbon contents up to 5.4 percent. This high organic content, the regional extent, and volume of these rocks suggests that they are possible petroleum source rocks.

______, E. K., 1979, Petroleum source rock evaluation of the Permian Park City Group in the northeastern Great Basin, Utah, Nevada, and Idaho, in Newman, G. W., and Goode, H. D., eds., Basin and Range symposium and Great Basin field conference: Rocky Mountain Association of Geologists and Utah Association, p. 523-530.
Refers to the petroleum source rock potential of the Meade Peak Phosphatic Shale Member and Tongue of the Permian Phosphoria Foundation. The Meade Peak Phosphatic Shale Tongue thins and wedges out into Elko County of northeastern Nevada. In Nevada the Meade Peak averages as much as 1.0 weight-percent organic carbon.

Merriam, C. W., and Anderson, C. A., 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geological Society of America Bulletin, v. 53, p. 1675-1726.
p. 1693-1698: Names and describes the Ordovician Vinini Formation at the type locality on the east-side of the Roberts Mountains. (The Vinini Formation locally contains organic-rich marine shales. See Poole and Desborough, 1980.)

Mikinis, F. P., and Smith, J. W., 1982, An NMR survey of United States oil shales, in Gary, J. H., (ed.), fifteenth Oil Shale Symposium Proceedings: Colorado School of Mines Press, p. 50-62.
Reports solid state ^{13}C nuclear magnetic resonance (NMR) techniques used to measure the fraction of aliphatic carbon in U.S. oil shales. Includes data from the Ordovician Vinini Formation, Devonian Woodruff Formation, and the Tertiary Elko Formation. Results indicate the aliphatic carbon fraction correlates directly with the fraction of organic matter that can be converted to oil during Fischer assay. Results of the NMR tests for oil shale samples from Nevada:

Formation	Fraction of Aliphatic Carbon	Fraction of Carbon Converted to oil
Vinini	0.58	0.39
Vinini	0.54	0.30
Woodruff	0.54	0.35
Elko	0.77	0.52

These results suggest that both the Vinini and Elko Formations contain enough aliphatic carbon to yield significant quantities of oil from pyrolysis. Results also indicate that organic matter from the Elko Formation contains more straight-chain aliphatic carbon types than Colorado oil shale.

Minnick, E., 1977, Stratigraphy and structure of the Vinini Formation in the Tyrone Gap area, Eureka County, Nevada [M.S. thesis]: Athens, University of Ohio.

Moore, S. W., and Solomon, B. J., 1982, Preliminary results of core-drilling and other geologic studies of Paleogene oil-shale-bearing deposits near Elko, Nevada, in Gary, J. H., ed., Proceedings of the 15th Annual Oil Shale Symposium: Colorado School of Mines Press, p. 69-78.
Summarizes geology and reports on preliminary results of a USGS core-drilling project near Elko. Richest oil shale zones are identified in members 2 and 3 of the Elko Formation of Eocene and Oligocene(?) age. Richest oil-shale zone in member 2 has an average oil yield of 25.2 gallons/short ton over an 18-ft-thick interval. Individual beds have oil yields as high as 60 to 85 gallons/short ton.

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, 77 p.
Names the Cretaceous Newark Canyon Formation consisting of heterogeneous nonmarine rocks in the Diamond Range, near Eureka, Nevada.

Nolan, T. B., Merriam, C. W., and Brew, D. A., 1971, Geologic map of the Eureka quadrangle, Eureka and White Pine Counties, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-612, scale 1:31,680.
Shows locations of the Newark Canyon Formation. (See Nolan and others, 1956.)

Osmond, J. C., and Elias, D. W., 1971, Possible future petroleum resources of Great Basin--Nevada and Western Utah: American Association of Petroleum Geologists Memoir 15, v. 1, p. 424-425.
Mentions Elko oil shale and other hydrocarbon occurrences in Elko County. The Elko oil shale in the Dixie Flat area (Pinon Range) may correlate with oil shale in Bull Run basin. (See Smith and Ketner, 1972, 1976, and 1978.)

Poole, F. G., and Desborough, G. A., 1980, Oil and metals in Ordovician and Devonian kerogenous marine strata of central Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 64, p. 767.
Discusses organic-rich shales of the Ordovician Vinini Formation and the Devonian Woodruff Formation in central Nevada. These formations contain potential resources of syncrude oil and heavy metals including V, Zn, Se, Ag, and Cr. Upon pyrolysis, shales have oil yields ranging from less than 10 gal/ton to over 30 gal/ton on selected beds. Refers to the locality of Brooks and Potter (1974).

Poole, F. G., Desborough, G. A., Holdsworth, B., Hose, R. K., 1978, Devonian Woodruff Formation in central Nevada [abs.]: U.S. Geological Survey Professional Paper 1100, p. 71.

Poole, F. G., Fouch, T. D., Claypool, G. E., 1979, Evidence for two major cycles of petroleum generation in Mississippian Chainman Shale of east-central Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 63, p. 838.
Discusses a proposed two-cycle model to explain variations in thermochemical maturity between Paleozoic and Paleogene rocks in uplifted terranes and those deeply buried beneath Neogene rocks. The first cycle of petroleum generation was in the early Mesozoic time; the second cycle is presently occurring in Neogene basins where adequate fill and temperature increase have occurred. The Chainman Shale is probably a major source of petroleum in fractured ash-flow tuff reservoirs in Railroad Valley.

Regnier, J., 1960, Cenozoic geology in the vicinity of Carlin, Nevada: Geological Society of America Bulletin, v. 71, p. 1189-1210.
Subdivides and names Tertiary sedimentary and volcanic stratigraphic units formerly considered part of the Humboldt group near Carlin, Nevada. Rocks are dominantly tuffaceous; no oil-shale-bearing units are reported.

Russell, P. L., 1980, History of western oil shale: East Brunswick, New Jersey, the Center for Professional Advancement, p. 75-83.
Summarizes early mining activities on oil-shale deposits near Elko. Reports on efforts by the Catlin Shale Products Company during 1917-1930 to mine, process, and market shale oil from the Elko area. Catlin's operation produced about 12,000 barrels of shale oil and represented the first pioneer effort to try to produce marketable products from western oil shale to compete with conventional petroleum products. Also reported on retorts constructed and operated during 1919-1921 by Southern Pacific Railroad Co., Inc.

Schrader, F. C., Stone, R. W., and Sanford, S., 1917, Useful minerals of the United States (Revision of U.S. Geological Survey Bulletin, 585): U.S. Geological Survey Bulletin 624, p. 198.
Compilation of mineral locations in glossary format. Reports oil shale at Elko to be "rich in oil" and assigned to the Eocene Green River Formation. (The oil shale at Elko is assigned to the Elko Fm. of Eocene and Oligocene? age. See Smith and Ketner, 1972, 1976; and Solomon, 1981.)

Server, G. T., Jr., and Solomon, B. J., 1983, Geology and oil shale deposits of the Elko Formation in the Pinon Range, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1546, scale 1:24,000.
Detailed geologic mapping and description of oil-shale deposits and associated rocks at the type section area of the Elko Formation, named by Smith and Ketner (1976), in the Pinon Range. General lithologic column of portions of the Elko Formation are shown along with Fischer assays of selected beds yielding up to about 21 gallons of oil per ton.

Sharp, R. P., 1939, The Miocene Humboldt Formation in northeastern Nevada: Journal of Geology, v. 47, p. 133-160.

Sibley, F. H., 1925, Comparative properties of lubricating oil made from Elko, Nevada, oil shale: University of Nevada Bulletin, v. xix, no. 6.

Silitonga, P. H., 1974, Geology of part of the Kittridge Springs quadrangle, Elko County, Nevada [M.S. thesis]: Golden, Colorado School of Mines, 88 p.
Geologic mapping, stratigraphic and structural study of an area about 5 miles north of Elko. Report refers to oil shale in the "Lower member of the Humboldt Formation". (These oil shale and associated deposits are probably correlative with the Elko Formation and other Paleogene deposits in the Elko study area. See Solomon, 1981.)

Smith, A. L., 1957, Resources Report, Elko County, Nevada: Report for the office of George W. Malone, U.S. Senate, University of Nevada, Reno, MacKay School of Mines Library, p. 30-31.

Smith, J. F., Jr., and Howard, K. A., 1977, Geologic map of the Lee 15-minute quadrangle, Elko County, Nevada: U.S. Geological Survey Quadrangle Map GQ-1393, scale 1:62,500.
This quadrangle is south of Elko. Small outcrops of Elko Formation are mapped along the west margin of the quadrangle and are composed of limestone, ostracode coquinites, oolitic limestone, shale, siltstone, claystone, and tuff.

Smith, J. F., Jr., and Ketner, K. B., 1972, Generalized geologic map of the Carlin, Dixie Flats, Pine Valley, and Robinson Mountain quadrangles, Elko and Eureka Counties, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-481, scale 1:125,000.
Geologic mapping in northeastern Nevada shows exposures of Elko Formation and other rocks of possible petroleum-resource potential. (See Smith and Ketner, 1975, 1976, 1977, and 1978.)

_____, 1975, Stratigraphy of Paleozoic rocks in the Carlin-Pinon Range area, Nevada: U.S. Geological Survey Professional Paper 867-A, 87 p.
Describes stratigraphy of Paleozoic rocks over an area that includes four 15-minute quadrangles in northeastern Nevada. (Rock units in this area considered to have some potential as petroleum source rocks include: the Vinini Formation, the Chainman Shale, and the Woodruff Formation. See Smith, R. M., 1976; Poole and Desborough, 1980; Desborough and others, 1979, 1981; Foster and Dolly, 1980.)

_____, 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, 48 p.
p. B19 to B23: Names and describes the type section for the Elko Formation located in secs. 10 and 15, T. 31 N., R. 53 E., M.D.M., on the Dixie Flats quadrangle (Pinon Range study area). Assigns an age of Eocene or Oligocene, on the basis of a K-Ar age of 38.6 m.y. Reports a Fischer assay oil yield of 51.2 gal/ton from a sample in the type section. Also describes other related Tertiary stratigraphy.

_____, 1977, Tectonic events since early Paleozoic in the Carlin-Pinon Range area, Nevada: U.S. Geological Survey Professional Paper 867-C, 18 p.
p. C12-C13: Discusses the early Oligocene deformation of the Elko Formation due to compressional forces. The 4 m.y. period of deformation is supported by potassium-argon age dates of about 34 to 38 m.y.

_____, 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.
An update of Smith and Ketner (1972).

Smith, J. W., 1980, Oil shale resources of the United States: Mineral and Energy Resources, Colorado School of Mines, v. 23, 20 p.
A good overview of U.S. oil shale resources.
p. 17: Mentions the oil shale in the Elko Formation of Nevada. These shales yield oil up to 85 gal/ton. Suggests the total resource of oil "may be substantial". (See Solomon and others, 1978, 1979a, b; Solomon and Moore, 1982a,b.)

Smith, R. M., 1976, Mineral Resources, Part II of Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines and Geology Bulletin 85, p. 36-105.
p. 90: Considers the Pilot Shale, Joana Limestone, and Chainman Shale of Devonian and Mississippian age to be petroleum source rocks in east-central Nevada.

Smith, W. L., 1960, History of oil exploration in Railroad Valley, Nye County, Nevada, in Intermountain Association of Petroleum Geologists 11th Annual Field Conference, Geology of east-central Nevada, p. 233-236.
Summary of oil and gas exploration in Railroad Valley, Nye County, Nevada, up to 1960. Refers mostly to the Eagle Springs area.

Solomon, B. J., 1981, Geology and oil shale resources near Elko, Nevada: U.S. Geological Survey Open-File Report 81-709, 146 p.
A detailed study, presenting geologic mapping and stratigraphy of oil-shale bearing Elko Formation near Elko. Reports Fischer assay oil yields from trench and surface samples. A preliminary estimate of oil shale resources of about 191 million barrels of shale oil is calculated from members 2 and 3 of the Elko Formation near Elko.

Solomon, B. J., and Brook, C. A., 1978, Geology and oil shale resources of the south Elko Basin in Nevada [abs.]: in U.S. Geological Survey Professional Paper 1100, p. 26.
(See Solomon and others, 1978.)

Solomon, B. J., McKee, E. H., and Andersen, D. W., 1979a, Eocene and Oligocene lacustrine and volcanic rocks near Elko, Nevada, in Newman, G. W., and Goode, H. D., eds., Basin and Range symposium and Great Basin field conference: Rocky Mountain Association of Geologists and Utah Geological Association, p. 325-337.
Describes 5 informally designated members of the Elko Formation and related Eocene and Oligocene lacustrine and volcanic rocks near Elko, Nevada. Rocks of the Elko Formation represent lacustrine and marginal-lacustrine depositional environments. Siliceous oil shale was probably deposited in an open-lacustrine environment under alkaline, low-salinity conditions. Age of the Elko Formation is substantiated by K/Ar ages bracketing a range from about 43 to 37 m.y.

_____, 1979b, Stratigraphy and depositional environments of Paleogene rocks near Elko, Nevada, in Armentrout, J. M., Cole, M. R., and TerBest, Harry, eds., Cenozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 75-88.
(See Solomon and others, 1979a.)

Solomon, B. J., McKee, E. H., Brook, C. A., and Smith, J. W., 1978, Tertiary geology and oil shale resources of the south Elko Basin, Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 62, p. 2362-2363.
Summarizes Tertiary geology, including the Elko Formation near Elko, Nevada. Analyses of oil shale indicate yields up to 360 L/t (86 gal/ton) of 24° to 34° API oil. Preliminary estimates of approximately 150 bbl of shale oil in the Elko area.

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.
Geologic mapping of mostly Tertiary stratigraphic units near Elko, Nevada. Shows distribution of oil-shale-bearing Elko Formation. Oil-yield histogram of trench COS-3, in sec. 26, T. 34 N., R. 55 E., M.D.M., indicates oil yields of up to 35 gal/ton. Area is transected by north- and northeast-trending normal faults.

_____, 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.
Geologic mapping of mostly Tertiary stratigraphic units near Elko, Nevada, shows distribution of oil-shale-bearing Elko Formation. Oil yield histogram of trench COS-4, in sec. 26, T. 34 N., R. 55 E., indicates oil yields of up to 62 gal/ton. Area transected by dominantly north- and northeast-trending normal faults.

Stewart, J. H., 1980, Geology of Nevada; A discussion to accompany the Geologic Map of Nevada: Nevada Bureau of Mines and Geology, Special Publication 4, 136 p.
A comprehensive summary of Nevada geology based on the compilation of numerous references.

Vanderburg, W. O., 1938, Reconnaissance of mining districts in Eureka County, Nevada: U.S. Bureau of Mines Information Circular 7022, p. 56-57.
Reports occurrence of asphaltite in the Pinon Range 15 miles south of Palisade, about 4 miles east of Yates ranch and 12 miles south of Palisade and 7 miles south of the Yates ranch. The asphaltite is the impsonite variety that resembles a very light coal and occurs within steeply dipping alternating beds of shale and sandstone. Analyses show vanadium pentoxide concentrations up to 0.918 percent. (This vanadium occurrence has been subsequently reported in the Ordovician Vinini Formation and the Devonian Woodruff Formation in east-central Nevada. See Brooks and Potter, 1974; and Desborough and others, 1981.)

Van Houten, F. B., 1956, Reconnaissance of Cenozoic sedimentary rocks of Nevada: American Association of Petroleum Geologists Bulletin, v. 40, p. 2801-2825.
General treatment of Cenozoic nonmarine sedimentary stratigraphy throughout Nevada. Suggests correlations of oil-shale-bearing deposits at Elko to other localities and refers to these rocks as the "eastern sedimentary sequences". The oil-shale deposit at Elko and correlative sequences are considered as constituting an Oligocene? tuffaceous bituminous-rich formation of limited extent in northeastern Nevada.

Veal, H. K., 1978, Roberts Mountains Thrust; Its significance in oil exploration in central Nevada [abs.]: American Association of Petroleum Geologists Bulletin, v. 62, p. 893.
Refers to possible petroleum source, seal, and reservoir rocks of the Ordovician Vinini Formation in the Roberts Mountains area of central Nevada. Pyrolytic oil yield of some thin-bedded shales of 25 gallons/ton. Exploratory well drilling has been limited in this area; however, valleys underlain by Vinini and overlying Cretaceous-Eocene sedimentary units are considered to have good potential for oil. The Vinini Fm. is included in the "western silicic facies" composed of eugeosynclinal, Ordovician and Devonian age organic marine shales, siltstones, cherts, and limestones in the upper plate of the Roberts Mountains Thrust.

Winchester, D. E., 1917, Oil shale in northwestern Colorado and adjacent areas: U.S. Geological Survey Bulletin 641-F, p. F139-F198.

_____, 1923, Oil shale of the Rocky Mountain region: U.S. Geological Survey Bulletin 729, p. 91-102.
Mentions early attempts to use darker shales at Elko as coal by the Southern Pacific Railroad. The oil shale of the Elko area was considered to belong to the Green River Formation. Describes the general geology and notes the presence of abundant tuffaceous material in Tertiary sediments. Notes oil yields from distillation tests on several Elko oil-shale samples range from a few gallons per ton up to about 87 gallons/ton. Discusses mining and retorting efforts of the Catlin Shale Products Company.

Winfrey, W. M., Jr., 1960, Stratigraphy, correlation, and oil potential of the Sheep Pass Formation, east-central Nevada, <u>in</u> Boettcher, J. S., and Sloan, W. W., eds., Guidebook to the geology of east-central Nevada: Intermountain Association of Petroleum Geologists and Eastern Nevada Geological Society 11th Annual Field Conference, Salt Lake City, Utah, p. 126-133.
Defines and describes the Sheep Pass Formation of Late Cretaceous and early Tertiary age. This fluvial and lacustrine unit occurs over scattered localities in east-central Nevada and is a suspected source rock for oil and gas reservoirs. The Sheep Pass Formation is a producing horizon in the Eagle Springs oil field. Dead-oil shows and petroliferous odors have been observed in the Sheep Pass Fm.

Young, J. C., 1960, Structure and stratigraphy in north-central Schell Creek Range, <u>in</u> Boettcher, J. W., and Sloan, W. W., eds., Guidebook to the geology of east-central Nevada: Intermountain Association of Petroleum Geologists and Eastern Nevada Geological Society 11th Annual field conference, Salt Lake City, Utah, p. 158-172.
(Mentions sedimentary rocks that are correlative with the Elko Formation. See Fouch and others, 1979.)

APPENDIX B

FISCHER ASSAY TABLES OF CORE SAMPLES AND OTHER SAMPLES

Samples processed under the supervision of

Laurence G. Trudell,

U.S. Department of Energy,

Laramie Energy Technology Center, Laramie, Wyoming

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-1 corehole drilled in the NE1/4NW1/4SE1/4 (approximately 2,050 ft. N and 1,500 ft. W of SE corner) of sec. 22, T 34 N, R 55 E, Elko County, Nevada

Surface elevation: 5,160 feet (estimated)

Sample number		Run	Yield of product: Weight percent				Yield of product: Gal per ton		Specific gravity	Properties of spent shale	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	of oil at 60°/60° F	Tendency to coke	Remarks
SBR82-847	28.0-29.7	74071	0.0	5.6	93.8	0.6	Trace	13.3		None	Weathered
SBR82-848	29.7-32.0	74072	0.0	6.8	92.7	0.5	Trace	16.2		None	Some rubble
SBR82-849	33.1-36.5	74073	0.0	5.7	93.1	1.2	Trace	13.8		None	Some rubble
SBR82-850	36.5-38.1	74075	1.9	3.3	93.5	1.3	5.0a	7.8		None	Partly weather
SBR82-851	38.1-40.0	74076	0.1	1.6	97.7	0.6	0.2a	3.8		None	Partly weather
SBR82-852	40.4-43.4	74077	0.2	2.1	97.0	0.7	0.4a	5.0		None	Partly weather
SBR82-853	43.4-45.0	74079	0.2	6.0	92.3	1.5	0.4a	14.4		None	
SBR82-854	45.0-46.0	74080	1.5	5.2	92.2	1.1	3.9a	12.5		None	
SBR82-855	46.0-47.0	74081	1.4	5.0	92.4	1.2	3.7a	12.0		None	
SBR82-856	47.0-48.0	74082	1.6	4.4	91.1	2.9	4.3a	10.5		None	
SBR82-857	48.0-49.0	74083	2.6	4.5	90.8	2.1	7.1	10.8	0.877	None	
SBR82-858	49.0-50.0	74084	1.9	6.0	90.3	1.8	4.9a	14.4		None	
SBR82-859	50.0-51.0	74087	1.4	6.3	90.8	1.5	3.7a	15.1		None	
SBR82-860	51.0-52.0	74088	2.6	5.0	89.0	3.4	7.0	12.0	.890	None	
SBR82-861	52.0-53.0	74089	4.8	3.7	89.2	2.3	12.9	8.9	.889	None	
SBR82-862	53.0-54.0	74091	3.7	2.6	91.6	2.1	10.0	6.2	.886	None	
SBE82-863	54.0-55.0	74092	1.6	3.4	92.5	2.5	4.2a	8.1		None	
SBR82-864	55.0-56.2	74093	0.7	7.0	90.6	1.7	1.8a	16.8		None	
SBR82-865	56.2-57.4	74094	0.1	8.1	88.8	3.0	0.3a	19.4		None	
SBR82-866	57.4-58.6	74095	0.1	1.5	97.6	0.8	0.3a	3.6		None	
SBR82-867	58.6-59.9	74096	0.2	1.6	97.8	0.4	0.5a	3.8		None	
SBR82-868	59.9-61.8	74097	1.6	7.3	89.2	1.9	4.1a	17.5		None	Some rubble
SBR82-869	61.8-62.8	74099	4.7	2.5	90.6	2.2	12.9	6.0	.878	None	
SBR82-870	62.8-64.0	74100	4.3	4.5	88.6	2.6	11.8	10.8	.880	None	
SBR82-871	64.0-65.0	74101	3.5	5.0	89.0	2.5	9.7	12.0	.876	None	
SBR82-872	65.0-66.0	74103	4.6	6.0	86.5	2.9	12.4	14.4	.881	None	
SBR82-873	66.0-67.0	74104	0.0	8.2	89.7	2.1	Trace	19.7		None	
SBR82-874	67.0-68.2	74105	1.0	2.6	95.3	1.1	2.7a	6.2		None	
SBR82-875	68.2-69.5	74106	3.3	4.8	89.0	2.9	9.1	11.4	.878	None	
SBR82-876	69.5-70.8	74107	2.2	7.0	88.7	2.1	5.9	16.8	.872	None	
SBR82-877	70.8-72.0	74108	3.5	7.0	86.7	2.8	9.4	16.8	0.896	None	
SBR82-878	72.0-72.7	74109	0.0	7.4	91.6	1.0	Trace	17.8		None	
SBR82-879	73.0-74.0	74111	0.0	7.9	90.2	1.9	Trace	19.0		None	
SBR82-880	74.0-75.0	74112	1.4	6.9	89.1	2.6	3.6a	16.5		None	
SBR82-881	75.0-76.0	74113	4.3	4.8	88.5	2.4	11.7	11.4	.876	None	
SBR82-882	76.0-77.0	74115	3.9	3.9	90.0	2.2	10.8	9.3	.872	None	
SBR82-883	77.0-78.0	74116	3.1	5.2	89.5	2.2	8.4	12.5	.870	None	
SBR82-884	78.0-79.0	74117	3.5	4.5	90.0	2.0	9.5	10.8	.882	None	
SBR82-885	79.0-80.0	74118	1.2	5.1	91.7	2.0	3.1a	12.2		None	
SBR82-886	80.0-81.2	74119	3.9	5.7	88.1	2.3	10.6	13.7	.879	None	
SBR82-887	81.2-82.3	74120	3.2	5.2	89.6	2.0	8.8	12.5	.865	None	
SBR82-888	82.3-83.7	74121	3.3	4.0	90.3	2.4	9.2	9.6	.874	None	
SBR82-889	83.7-84.8	74123	1.4	4.5	91.8	2.3	3.6a	10.8		None	
SBR82-890	84.8-86.0	74124	0.0	6.6	91.3	2.1	Trace	15.9		None	
SBR82-891	86.0-87.8	74125	0.0	6.0	93.0	1.0	Trace	14.5		None	
SBR82-892	87.8-89.5	74127	0.0	5.6	93.2	1.2	Trace	13.4		None	
SBR82-893	89.5-91.0	74128	1.4	4.6	91.2	2.8	3.5a	11.0		None	Some rubble
SBR82-894	91.3-92.4	74129	0.3	7.2	90.6	1.9	0.9a	17.3		None	
SBR82-895	92.4-93.2	74130	1.6	4.9	90.4	3.1	4.2a	11.7		None	
SBR82-896	93.2-94.9	74131	3.8	3.7	90.4	2.1	10.5	8.9	.867	None	
SBR82-897	94.9-97.3	74132	0.0	6.6	92.6	0.8	Trace	15.8		None	
SBR82-898	97.3-98.5	74133	3.6	2.5	92.4	1.5	9.9	6.0	.868	None	
SBR82-899	98.5-99.8	74135	2.2	2.1	94.0	1.7	6.1	5.0	.862	None	
SBR82-900	99.8-100.6	74136	0.0	5.2	93.2	1.6	Trace	12.4		None	Rubble
SBR82-901	102.6-105.7	74137	0.0	5.6	92.8	1.6	Trace	13.4		None	
SBR82-902	105.7-108.3	74139	0.0	6.6	92.0	1.4	Trace	15.7		None	
SBR82-903	108.3-109.0	74140	2.9	1.5	93.4	2.2	7.9	3.6	.870	None	
SBR82-904	109.0-110.5	74141	4.2	1.2	93.0	1.6	11.5	2.9	.880	None	
SBR82-905	110.5-111.8	74142	2.4	1.0	94.6	2.0	6.6	2.4	.889	None	
SBR82-906	111.8-112.7	74143	2.7	1.4	94.8	1.1	7.2	3.4	.888	None	
SBR82-907	112.7-113.7	74144	2.7	1.5	94.8	1.0	7.2	3.5	0.897	None	
SBR82-908	113.7-114.4	74145	3.5	1.2	93.9	1.4	9.6	2.9	.889	None	
SBR82-909	114.4-115.1	74147	2.9	2.0	93.0	2.1	8.0	4.8	.879	None	
SBR82-910	115.1-117.0	74148	0.3	7.0	90.7	2.0	0.8a	16.8		None	Rubble

1/ "a"--indicates specific gravity estimated at .920.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration

March 26, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from the United States Geological Survey's EOS-2 corehole drilled in the NW1/4NW1/4SE1/4 (approximately 2,500 ft. N and 2,450 ft. W of SE corner) of sec. 26, T 34 N, R 55 E of Elko County, Nevada

Surface elevation: 5,600 feet (estimated)

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil[1/]	Water	60°/60° F	coke	Remarks
SBR82-751	27.2-29.0	73945	0.6	1.5	97.2	0.7	1.5a	3.6		None	Weathered
SBR82-752	29.0-32.0	73947	0.0	4.8	94.0	1.2	Trace	11.5		None	Weathered
SBR82-753	32.0-35.6	73948	0.0	1.9	95.9	2.2	Trace	4.5		None	Weathered
SBR82-754	35.6-37.3	73949	0.4	3.5	94.9	1.2	1.1a	8.4		None	Weathered
SBR82-755	37.8-41.0	73950	0.0	6.7	90.2	3.1	Trace	16.1		None	
SBR82-756	41.0-43.1	73951	0.0	9.0	90.6	6.4	Trace	21.7		None	
SBR82-757	44.2-46.3	73952	0.0	8.8	90.8	0.4	Trace	21.0		None	
SBR82-758	46.3-48.8	73953	0.0	8.4	91.0	0.6	Trace	20.0		None	
SBR82-759	49.1-51.2	73955	0.0	6.6	92.2	1.2	Trace	15.8		None	
SBR82-760	53.8-56.0	73956	0.0	8.1	91.0	0.9	Trace	19.5		None	
SBR82-761	56.0-57.5	73957	0.0	5.8	93.2	1.0	Trace	14.0		None	
SBR82-762	57.5-58.7	73959	8.0	3.0	86.1	2.9	21.4	7.2	0.901	None	
SBR82-763	58.7-59.7	73960	5.7	2.8	89.2	2.3	15.2	6.7	.893	None	Partly weathere
SBR82-764	59.7-60.7	73961	6.7	3.5	87.5	2.3	18.0	8.4	.886	None	
SBR82-765	60.7-61.6	73962	2.0	3.4	91.7	2.9	5.5	8.1	.891	None	Weathered rubbl
SBR82-766	64.0-65.0	73963	24.7	3.7	68.6	3.0	67.0	8.9	.882	None	
SBR82-767	65.0-66.0	74008	28.4	3.8	57.0	10.8	76.4	9.1	.891	None	Paraffin; bad wt. lo
SBR82-768	66.0-67.0	73965	22.1	5.0	66.7	6.2	59.2	12.0	.895	None	Partly weathere
SBR82-769	67.0-68.0	73967	4.0	4.5	88.1	3.4	11.0	10.8	.880	None	Weathered
SBR82-770	68.0-69.0	73973	29.6	3.1	59.5	7.8	81.0	7.4	.876	None	
SBR82-771	69.0-70.0	73974	4.7	3.7	89.4	2.2	12.8	8.9	.875	None	
SBR82-772	70.0-71.0	73975	6.2	2.8	88.9	2.1	17.1	6.7	.865	None	
SBR82-773	71.0-72.0	73976	2.3	2.2	93.5	2.0	6.4	5.3	.856	None	
SBR82-774	72.0-73.0	73977	0.5	2.6	96.1	0.8	1.4a	6.2		None	
SBR82-775	73.0-74.0	73979	0.0	3.4	96.3	0.3	Trace	8.1		None	
SBR82-776	74.0-75.0	73980	0.0	3.2	95.6	1.2	Trace	7.7		None	
SBR82-777	75.0-76.0	73981	0.0	4.3	95.4	0.3	Trace	10.4		None	
SBR82-778	76.0-77.4	73983	0.0	5.7	93.4	0.9	Trace	13.6		None	
SBR82-779	79.7-80.8	73984	0.0	4.6	93.5	1.9	Trace	11.1		None	Some rubble
SBR82-780	80.8-82.7	73985	15.2	2.7	77.3	4.8	40.2	6.5	.904	None	
SBR82-781	83.0-84.0	73986	23.3	2.8	65.5	8.4	63.6	6.7	0.877	None	
SBR82-782	84.0-85.0	73987	17.3	3.5	73.6	5.6	47.5	8.4	.874	None	
SBR82-783	85.0-85.9	73988	10.2	3.9	82.7	3.2	27.9	9.3	.877	None	
SBR82-784	88.3-89.3	73989	17.3	2.8	74.9	5.0	47.1	6.7	.879	None	
SBR82-785	89.3-90.4	73991	2.6	5.0	91.2	1.2	7.0	12.0	.874	None	
SBR82-786	90.4-92.0	73992	4.7	2.3	90.3	2.7	12.8	5.5	.885	None	
SBR82-787	92.0-95.0	73993	3.5	3.8	90.3	2.4	9.7	9.1	.874	None	
SBR82-788	95.0-98.0	73995	3.2	4.5	91.0	1.3	8.8	10.8	.875	None	
SBR82-789	98.0-101.8	73996	4.4	3.4	90.1	2.1	12.1	8.1	.879	None	
SBR82-790	102.2-104.0	73997	3.0	4.0	91.3	1.7	7.8	9.6	.910	None	
SBR82-791	104.0-105.0	73998	2.8	3.0	91.2	3.0	7.7	7.2	.879	None	
SBR82-792	105.0-106.3	73999	2.4	4.6	91.3	1.7	6.6	11.0	.878	None	
SBR82-793	106.3-107.0	74000	11.4	2.1	83.4	3.1	30.7	5.0	.890	None	
SBR82-794	107.0-108.2	74001	9.2	3.3	83.7	3.8	24.9	7.9	.884	None	
SBR82-795	108.2-109.6	74003	6.3	5.9	84.7	3.1	17.3	14.1	.876	None	
SBR82-796	109.6-110.6	74051	15.6	4.2	75.4	4.8	42.6	10.1	.876	None	
SBR82-797	110.6-111.6	74005	14.5	2.9	78.1	4.5	39.4	7.0	.880	None	
SBR82-798	111.6-112.6	74007	9.7	4.3	82.4	3.6	26.3	10.3	.885	None	
SBR82-799	112.6-113.9	74085	10.7	4.3	80.5	4.5	28.3	10.3	.910	None	
SBR82-800	113.9-115.2	74010	13.0	3.8	77.6	5.6	35.2	9.1	.886	None	
SBR82-801	115.2-116.2	74011	9.0	3.0	84.4	3.6	23.0	7.2	.934	None	
SBR82-802	116.2-117.2	74012	3.6	3.7	90.5	2.2	9.8	8.9	.888	None	
SBR82-803	117.2-117.9	74013	0.0	7.8	91.0	1.2	Trace	18.8		None	
SBR82-804	117.9-119.2	74015	4.0	4.7	88.7	2.6	10.9	11.3	.886	None	
SBR82-805	119.6-120.6	74053	0.5	9.0	88.9	1.6	1.2a	21.6		None	
SBR82-806	120.6-122.0	74055	0.0	9.9	89.0	1.1	Trace	23.8		None	
SBR82-807	123.5-124.4	74019	0.0	11.1	87.6	1.3	Trace	26.7		None	Rubble; bad wt. l
SBR82-808	124.4-125.5	74020	1.9	3.5	92.3	2.3	5.1	8.4	.877	None	
SBR82-809	125.5-126.7	74021	2.6	4.5	91.3	1.6	7.0	10.8	.884	None	
SBR82-810	126.7-127.8	74022	3.2	3.0	90.2	3.6	8.5	7.2	.891	None	

See footnote at end of table.

Core samples received December 12, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5120P March 16, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-2 corehole

Surface elevation: 5,600 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton				
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	of oil at 60°/60° F	Tendency to coke	Remarks
SBR82-811	127.8-129.3	74023	6.4	4.0	86.9	2.7	17.4	9.6	0.888	None	
SBR82-812	129.3-130.7	74024	0.4	1.8	96.5	1.3	1.0a	4.3		None	
SBR82-813	130.7-132.2	74025	0.4	2.5	95.9	1.2	1.0a	6.0		None	
SBR82-814	132.2-133.6	74027	0.7	2.3	94.9	2.1	1.9a	5.5		None	
SBR82-815	133.6-135.0	74028	0.9	2.0	95.1	2.0	2.3a	4.8		None	
SBR82-816	135.0-136.0	74029	0.0	1.6	96.9	1.5	Trace	3.7		None	
SBR82-817	136.0-137.0	74031	0.1	1.9	96.7	1.3	0.3a	4.6		None	
SBR82-818	137.0-138.0	74032	0.1	1.7	96.7	1.5	0.4a	4.0		None	
SBR82-819	138.0-139.0	74033	0.1	2.2	96.7	1.0	0.2a	5.2		None	
SBR82-820	139.0-140.0	74034	0.0	1.4	96.3	2.3	Trace	3.3		None	
SBR82-821	140.0-141.0	74035	0.3	2.1	96.0	1.6	0.8a	5.0		None	
SBR82-822	141.0-142.0	74036	0.2	2.5	96.6	0.7	0.4a	6.0		None	
SBR82-823	142.0-143.3	74037	0.0	3.9	95.1	1.0	Trace	9.3		None	
SBR82-824	143.3-144.3	74039	0.0	7.2	91.4	1.4	Trace	17.2		None	
SBR82-825	144.3-145.3	74040	0.0	8.1	89.3	2.6	Trace	19.4		None	
SBR82-826	150.0-151.0	74041	0.0	8.7	90.5	0.8	Trace	20.8		None	
SBR82-827	151.0-152.3	74043	0.0	8.4	89.2	2.4	Trace	20.2		None	
SBR82-828	152.3-154.7	74044	0.0	5.7	93.4	0.9	Trace	13.7		None	Some rubble
SBR82-829	159.4-162.4	74045	0.0	4.2	95.1	0.7	Trace	10.1		None	
SBR82-830	162.4-165.5	74046	0.0	9.7	88.6	1.7	Trace	23.3		None	
SBR82-831	165.5-166.5	74047	0.0	11.9	87.4	0.7	Trace	28.6		None	
SBR82-832	166.5-167.5	74048	0.1	2.8	96.5	0.6	0.2a	6.7		None	
SBR82-833	167.5-168.7	74049	0.0	3.2	95.9	0.9	Trace	7.6		None	
SBR82-834	168.7-170.0	74056	0.0	2.4	95.6	2.0	Trace	5.8		None	
SBR82-835	173.4-175.0	74057	0.0	3.1	96.0	0.9	0.1a	7.3		None	
SBR82-836	175.0-176.0	74058	0.1	2.8	94.6	2.5	0.3a	6.7		None	
SBR82-837	176.0-177.0	74059	0.3	4.1	94.4	1.2	0.8a	9.8		None	
SBR82-838	177.0-178.0	74060	0.4	4.0	94.4	1.2	1.2a	9.6		None	
SBR82-839	178.0-179.2	74061	0.1	3.5	95.6	0.8	0.2a	8.4		None	Some rubble
SBR82-840	179.6-180.1	74063	0.0	1.6	97.6	0.8	0.1a	3.8		None	Some rubble

1/ "a"--indicates specific gravity estimated at .920.

Core samples received December 12, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5120P March 16, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-3 corehole drilled in the SE1/4NE1/4NE1/4 (approximately 800 ft. S end 250 ft. W of NE corner) of sec. 36, T 34 N, R 55 E, Elko County, Nevada

Surface elevation: 5,820 feet (estimated)

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	60°/60° F	coke	Remarks
SBR82-49	59.0-59.8	72983	8.1	1.3	88.7	1.9	21.8	3.1	0.888	None	
SBR82-50	59.8-61.0	72984	0.0	9.9	88.0	2.1	Trace	23.7		None	
SBR82-51	61.0-62.0	73023	7.5	5.9	83.9	2.7	20.7	14.2	.871	None	
SBR82-52	62.0-63.0	72986	7.1	7.0	82.2	3.7	18.9	16.8	.895	None	
SBR82-53	63.0-65.3	72987	0.0	9.4	89.4	1.2	Trace	22.6		None	0.9' missing
SBR82-54	65.3-66.2	72989	0.0	6.2	92.5	1.3	Trace	14.9		None	
SBR82-55	66.2-67.3	72990	0.0	9.1	89.6	1.3	Trace	21.8		None	
SBR82-56	67.3-68.6	72991	6.5	3.0	87.5	3.0	17.4	7.2	.899	None	Waxy oil
SBR82-57	68.6-69.7	72993	7.6	2.4	87.7	2.3	20.3	5.8	.893	None	Waxy oil
SBR82-58	69.7-70.8	72994	6.0	1.6	90.4	2.0	16.2	3.8	.891	None	Waxy oil
SBR82-59	70.8-71.5	73005	5.2	2.3	90.1	2.4	13.9	5.5	.906	None	
SBR82-60	73.4-75.0	73006	0.0	9.5	89.0	1.5	Trace	22.8		None	
SBR82-61	75.0-80.0	73044	0.0	9.0	88.6	2.4	Trace	21.6		None	
SBR82-62	80.5-85.2	73045	0.0	10.4	89.1	0.5	Trace	25.0		None	Bad assay, 1.5' missing
SBR82-63	86.2-88.2	73046	0.0	10.8	88.8	0.4	Trace	25.8		None	Bad assay
SBR82-64	90.4-91.2	73010	No Data - Bad Weight Loss - Unable to Rerun								Rubble
SBR82-65	91.4-96.7	73047	0.0	11.6	87.7	0.7	Trace	27.9		None	Bad assay
SBR82-66	96.9-98.6	73013	2.5	6.0	89.3	2.2	6.9	14.4	.879	None	
SBR82-67	98.7-99.4	73014	15.6	2.7	76.1	5.6	42.2	6.5	.886	None	
SBR82-68	99.6-100.6	73015	8.8	2.5	84.6	4.1	23.9	6.0	.887	None	
SBR82-69	100.6-101.8	73017	6.3	7.0	84.3	2.4	17.3	16.8	.878	None	
SBR82-70	101.8-103.0	73018	8.5	3.5	84.4	3.6	23.1	8.4	.884	None	
SBR82-71	103.0-104.7	73021	5.5	2.8	89.3	2.4	14.8	6.7	.889	None	
SBR82-72	104.7-105.9	73022	5.9	5.5	86.4	2.2	15.8	13.2	.890	None	
SBR82-73	105.9-106.9	73025	21.2	5.0	67.7	6.1	58.1	12.0	.873	None	
SBR82-74	106.9-107.9	73048	7.9	6.0	55.8	10.3	75.4	14.4	.887	None	Bad assay
SBR82-75	107.9-108.9	73027	25.9	9.0	56.7	8.4	69.8	21.6	.891	None	Bad assay
SBR82-76	108.9-109.7	73029	14.2	5.1	76.6	4.1	38.7	12.2	.879	None	
SBR82-77	109.7-110.7	73030	10.5	7.5	78.1	3.9	28.3	18.0	.889	None	
SBR82-78	110.7-111.6	73031	31.3	5.0	55.5	8.2	85.3	12.0	.879	None	
SBR82-79	111.6-112.4	73032	6.9	1.6	89.0	2.5	18.9	3.8	0.880	None	
SBR82-80	112.6-113.8	73033	2.5	2.7	92.7	2.1	6.8	6.5	.872	None	
SBR82-81	113.8-114.8	73034	1.1	3.5	94.8	0.6	2.8a	8.4		None	
SBR82-82	116.3-117.4	73035	0.0	5.5	93.5	1.0	Trace	13.1		None	
SBR82-83	118.9-122.9	73086	0.0	6.7	91.0	2.3	Trace	16.0		None	
SBR82-84	123.5-125.4	73038	0.0	4.8	93.2	2.0	Trace	11.6		None	
SBR82-85	125.8-130.6	73087	0.0	5.3	93.4	1.3	Trace	12.6		None	0.3' missing
SBR82-86	132.6-137.8	73088	0.0	5.1	94.2	0.7	Trace	12.3		None	2.0' missing
SBR82-87	138.6-140.9	73042	0.0	8.5	90.1	1.4	Trace	20.5		None	
SBR82-88	141.2-143.0	73043	0.0	8.1	91.4	0.5	Trace	19.5		None	
SBR82-89	143.2-147.2	73089	0.0	5.6	93.6	0.8	Trace	13.5		None	
SBR82-90	147.8-153.0	73050	0.0	8.7	89.8	1.5	Trace	20.7		None	0.6' missing
SBR82-91	153.3-156.2	73091	0.0	7.4	91.9	0.7	Trace	17.8		None	0.3' missing
SBR82-92	157.0-160.7	73092	0.0	7.5	91.8	0.7	Trace	18.0		None	
SBR82-93	161.3-162.7	73093	0.0	6.9	92.6	0.5	Trace	16.6		None	
SBR82-94	163.0-164.2	73059	0.0	3.8	95.6	0.6	Trace	9.1		None	
SBR82-95	164.2-165.9	73095	0.0	2.0	97.7	0.3	Trace	4.9		None	
SBR82-96	166.0-167.0	73061	1.5	2.8	94.4	1.3	3.8a	6.7		None	
SBR82-97	167.0-168.0	73062	0.6	5.0	91.8	2.6	1.6a	12.0		None	
SBR82-98	168.0-169.1	73063	0.6	7.1	90.6	1.7	1.6a	17.0		None	
SBR82-99	169.3-170.3	73064	0.1	2.1	97.3	0.5	0.3a	5.0		None	
SBR82-100	170.3-171.3	73065	0.1	2.6	96.6	0.7	0.4a	6.2		None	
SBR82-101	171.3-172.3	73067	0.1	8.0	90.7	1.2	0.4a	19.2		None	
SBR82-102	172.3-172.9	73068	0.0	4.2	94.3	1.5	Trace	10.1		None	Rubble
SBR82-103	172.9-174.2	73069	0.3	10.0	88.3	1.4	0.8a	24.0		None	
SBR82-104	174.2-175.7	73071	0.0	9.6	88.8	1.6	Trace	23.0		None	Partly rubble
SBR82-105	175.7-178.1	73072	0.0	2.7	95.5	1.8	Trace	6.4		None	
SBR82-106	178.1-179.2	73073	1.1	9.6	87.4	1.9	2.8a	23.0		None	
SBR82-107	179.2-180.4	73074	0.1	8.6	87.7	3.5	0.3a	20.6		None	
SBR82-108	180.5-181.4	73075	0.8	11.0	86.4	1.8	2.0a	26.4		None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5121P

February 12, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-3 corehole

Surface elevation: 5,820 feet

Sample number		Run	Yield of product						Specific gravity of oil at	Properties of spent shale	
			Weight percent				Gal per ton				
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	60°/60° F	Tendency to coke	Remarks
SBR82-109	181.4-182.4	73076	0.9	12.0	85.5	1.6	2.2a	28.8		None	
SBR82-110	182.5-183.7	73077	0.0	6.2	93.2	0.6	Trace	14.8		None	Partly rubble
SBR82-111	190.0-190.8	73079	1.1	16.0	80.4	2.5	2.8a	38.4		None	Partly rubble
SBR82-112	192.4-194.3	73080	0.0	6.0	92.3	1.7	Trace	14.5		None	Rubble
SBR82-113	195.6-196.1	73081	0.4	7.0	90.7	1.9	1.0a	16.8		None	
SBR82-114	196.1-197.5	73083	0.0	9.4	90.2	0.4	Trace	22.6		None	
SBR82-115	198.2-199.0	73084	0.0	9.2	88.9	1.9	Trace	22.1		None	Rubble
SBR82-116	199.0-200.0	73085	0.0	5.8	93.2	1.0	Trace	14.0		None	
SBR82-117	200.0-201.0	73096	0.0	4.1	95.5	0.4	Trace	9.8		None	
SBR82-118	201.0-202.0	73097	0.0	4.5	94.6	0.9	Trace	10.9		None	
SBR82-119	202.0-203.0	73098	0.0	3.8	95.0	1.2	Trace	9.0		None	
SBR82-120	203.0-204.3	73099	0.0	4.6	94.7	0.7	Trace	11.1		None	
SBR82-121	204.3-206.1	73100	0.0	2.0	97.5	0.5	Trace	4.8		None	
SBR82-122	206.1-207.3	73101	1.6	7.6	88.6	2.2	4.3a	18.2		None	
SBR82-123	207.3-208.5	73103	2.8	8.0	86.5	2.7	7.4	19.2	0.916	None	
SBR82-124	209.3-210.4	73104	1.9	6.1	89.1	2.9	4.9a	14.6		None	
SBR82-125	210.4-211.4	73105	0.2	7.0	91.6	1.2	0.6a	16.8		None	
SBR82-126	211.4-212.4	73109	0.0	10.1	89.0	0.9	Trace.	24.3		None	
SBR82-127	212.6-213.5	73108	0.0	5.3	93.2	1.5	Trace	12.8		None	
SBR82-128	213.8-215.0	73110	0.0	7.2	90.3	2.5	Trace	17.4		None	
SBR82-129	215.0-216.6	73111	0.0	4.0	95.7	0.3	Trace	9.6		None	
SBR82-130	216.9-218.9	73112	0.0	3.8	96.1	0.1	Trace	9.0		None	
SBR82-131	218.9-220.2	73113	0.0	6.9	92.6	0.5	Trace	16.5		None	
SBR82-132	220.2-222.2	73156	0.3	5.8	92.3	1.6	0.9a	13.9		None	Some rubble
SBR82-133	222.6-223.0	73116	0.6	3.9	94.3	1.2	1.5a	9.3		None	
SBR82-134	223.1-224.3	73117	0.1	3.3	95.7	0.9	0.3a	7.9		None	
SBR82-135	224.4-226.2	73119	0.1	5.4	93.5	1.0	0.1a	13.1		None	
SBR82-136	226.2-227.3	73120	1.7	6.0	90.3	2.0	4.5a	14.4		None	
SBR82-137	227.5-229.0	73121	0.0	1.7	97.8	0.5	Trace	4.1		None	
SBR82-138	229.4-230.3	73122	0.0	11.5	86.7	1.8	Trace	27.4		None	Rubble
SBR82-139	230.4-231.5	73123	1.5	10.0	86.6	1.9	3.9a	24.0		None	
SBR82-140	232.0-233.0	73124	0.0	2.9	96.7	0.4	Trace	6.9		None	
SBR82-141	233.3-234.0	73125	0.0	5.9	93.0	1.1	Trace	14.2		None	
SBR82-142	234.0-235.0	73127	0.7	5.9	92.5	0.9	1.7a	14.1		None	
SBR82-143	235.0-236.0	73128	0.1	4.6	92.9	2.4	0.4a	11.0		None	
SBR82-144	236.0-237.3	73129	0.3	5.9	92.2	1.6	0.8a	14.1		None	
SBR82-145	237.3-239.1	73131	0.0	6.1	92.8	1.1	Trace	14.6		None	
SBR82-146	239.1-240.3	73132	0.0	1.4	97.4	1.2	Trace	3.3		None	
SBR82-147	240.9-241.4	73133	0.0	8.1	90.9	1.0	Trace	19.3		None	Rubble
SBR82-148	241.6-242.8	73134	0.0	8.9	87.9	3.2	Trace	21.3		None	
SBR82-149	243.0-244.3	73135	0.1	7.5	90.9	1.5	0.4a	18.0		None	
SBR82-150	244.3-245.3	73136	0.2	4.6	94.0	1.2	0.6a	11.0		None	
SBR82-151	245.3-246.3	73137	0.3	4.1	95.0	0.6	0.8a	9.8		None	
SBR82-152	246.3-247.3	73139	0.1	4.0	94.5	1.4	0.3a	9.7		None	
SBR82-153	247.3-248.4	73140	0.0	10.2	88.3	1.5	Trace	24.5		None	
SBR82-154	248.4-249.4	73141	0.0	9.7	89.2	1.1	Trace	23.3		None	
SBR82-155	249.4-250.7	73143	0.5	7.0	90.9	1.6	1.4a	16.8		None	
SBR82-156	250.7-252.0	73144	0.1	4.3	91.3	1.7	0.2a	10.3		None	
SBR82-157	252.0-253.0	73145	1.2	6.4	90.1	2.3	3.1a	15.3		None	
SBR82-158	253.0-254.0	73146	1.0	5.0	90.8	3.2	2.7a	12.0		None	
SBR82-159	254.0-254.9	73147	1.8	6.6	89.3	2.3	4.7a	15.8		None	
SBR82-160	255.0-256.0	73148	1.1	7.0	89.9	2.0	2.8a	16.8		None	
SBR82-161	256.0-257.0	73149	1.5	8.9	87.2	2.4	4.0a	21.3		None	
SBR82-162	257.0-258.2	73151	0.0	0.3	96.3	3.4	Trace	0.8		None	
SBR82-163	258.2-259.5	73152	0.5	14.0	82.5	3.0	1.4a	33.6		None	Rubble
SBR82-164	260.0-261.4	73153	0.1	5.4	93.4	1.1	0.4a	12.9		None	
SBR82-165	261.4-262.8	73155	0.0	8.3	90.9	0.8	Trace	19.9		None	Some rubble
SBR82-166	263.8-264.5	73163	0.1	1.5	97.8	0.6	0.3a	3.6		None	
SBR82-167	266.5-268.2	73164	0.0	14.7	82.6	2.7	Trace	35.3		None	Rubble
SBR82-168	268.2-269.5	73165	0.0	4.0	95.4	0.6	Trace	9.7		None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5121P

February 12, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-3 corehole

Surface elevation: 5,820 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil[1/]	Water	60°/60° F	coke	Remarks
SBR82-169	269.5-270.5	73166	0.0	4.8	93.6	1.6	Trace	11.5		None	
SBR82-170	270.5-271.5	73167	0.7	6.5	91.6	1.2	1.8a	15.6		None	
SBR82-171	271.5-272.5	73169	1.7	6.0	89.2	3.1	4.4a	14.4		None	
SBR82-172	272.5-273.5	73170	0.8	4.5	91.9	2.8	2.1a	10.8		None	
SBR82-173	274.0-275.0	73171	1.0	11.0	85.9	2.1	2.7a	26.4		None	
SBR82-174	275.0-276.0	73173	4.1	6.9	86.7	2.3	11.2	16.5	0.871	None	
SBR82-175	276.0-277.0	73174	5.7	5.5	86.3	2.5	15.8	13.2	.872	None	
SBR82-176	277.0-278.0	73175	4.8	7.0	85.8	2.4	13.2	16.8	.867	None	
SBR82-177	278.0-279.5	73176	0.3	8.9	88.5	2.3	0.7a	21.3		None	
SBR82-178	280.3-282.1	73177	1.8	13.5	82.9	1.8	4.6a	32.4		None	Some rubble
SBR82-179	283.0-284.0	73178	0.2	2.6	96.6	0.6	0.5a	6.2		None	
SBR82-180	284.0-285.7	73179	1.5	6.7	89.9	1.9	3.9a	16.1		None	0.3' missing
SBR82-181	285.7-287.0	73181	0.1	10.0	87.8	2.1	0.3a	24.0		None	
SBR82-182	287.0-288.2	73182	1.3	3.5	93.0	2.2	3.3a	8.4		None	
SBR82-183	288.2-289.2	73183	1.2	4.0	93.6	1.2	3.3a	9.6		None	
SBR82-184	289.5-291.1	73185	3.1	6.0	88.2	2.7	8.5	14.4	.874	None	
SBR82-185	291.1-292.9	73186	1.0	6.1	90.3	2.6	2.5a	14.6		None	Some rubble
SBR82-186	293.0-293.7	73187	0.0	25.7	73.2	1.1	Trace	61.6		None	Rubble
SBR82-187	294.4-296.0	73188	0.5	8.5	87.7	3.3	1.4a	20.4		None	
SBR82-188	296.0-297.0	73189	1.6	6.5	89.8	2.1	4.1a	15.6		None	
SBR82-189	297.0-298.0	73190	1.9	8.0	87.6	2.5	5.1a	19.2		None	
SBR82-190	298.0-299.0	73191	2.5	5.0	90.8	1.7	6.9	12.0	.858	None	
SBR82-191	299.0-300.0	73193	1.9	6.4	89.5	2.2	5.0a	15.3		None	
SBR82-192	300.0-301.0	73194	1.6	5.8	90.5	2.1	4.1a	13.9		None	
SBR82-193	301.0-302.0	73234	1.2	7.1	89.4	2.3	3.2a	17.0		None	
SBR82-194	302.0-303.0	73197	2.9	5.3	90.3	1.5	8.2	12.7	.866	None	
SBR82-195	303.0-304.0	73198	6.5	6.9	83.5	3.1	17.6	16.5	.878	None	
SBR82-196	304.0-305.0	73238	4.0	6.9	87.0	2.1	11.2	16.5	.861	None	
SBR82-197	305.0-306.0	73200	1.1	4.4	92.4	2.1	2.8a	10.5		None	
SBR82-198	306.0-307.0	73201	0.3	7.5	90.6	1.6	0.7a	18.0		None	
SBR82-199	307.0-308.2	73248	0.0	9.3	88.8	1.9	Trace	22.4		None	
SBR82-200	308.2-310.0	73203	0.3	8.0	90.2	1.5	0.8a	19.2		None	
SBR82-201	310.0-311.1	73246	0.3	7.9	90.3	1.5	0.9a	18.9		None	Some rubble
SBR82-202	311.1-312.0	73206	0.7	6.2	91.6	1.5	1.9a	14.9		None	
SBR82-203	312.0-313.0	73207	0.8	6.5	91.5	1.2	2.1a	15.6		None	
SBR82-204	313.0-314.0	73209	0.3	7.0	91.4	1.3	0.7a	16.8		None	
SBR82-205	314.0-315.0	73210	1.1	8.0	89.6	1.3	2.8a	19.2		None	
SBR82-206	315.0-316.0	73211	0.7	6.9	90.9	1.5	1.8a	16.5		None	
SBR82-207	316.0-317.6	73212	0.1	8.0	90.4	1.5	0.3a	19.2		None	
SBR82-208	317.6-318.8	73213	0.1	6.2	91.7	2.0	0.2a	14.9		None	
SBR82-209	318.8-320.0	73214	0.1	8.5	90.0	1.4	0.2a	20.4		None	
SBR82-210	320.0-321.4	73215	0.2	9.0	89.7	1.1	0.6a	21.6		None	Some rubble
SBR82-211	321.4-322.4	73217	1.0	9.8	87.4	1.8	2.5a	23.5		None	
SBR82-212	322.4-323.5	73218	1.5	7.5	88.0	3.0	3.9a	18.0		None	
SBR82-213	323.5-324.7	73219	1.6	9.5	87.0	1.9	4.2a	22.8		None	
SBR82-214	324.7-325.9	73221	1.9	8.0	88.2	1.9	4.8a	19.2		None	
SBR82-215	325.9-327.0	73222	0.9	5.4	91.1	2.6	2.2a	12.9		None	
SBR82-216	327.0-328.0	73223	0.7	6.1	91.9	1.3	1.8a	14.6		None	
SBR82-217	328.0-329.0	73224	0.0	6.3	91.3	2.4	Trace	15.1		None	
SBR82-218	329.0-330.0	73225	0.6	6.0	92.2	1.2	1.6a	14.4		None	
SBR82-219	330.0-331.0	73226	1.8	7.2	89.5	1.5	4.6a	17.3		None	
SBR82-220	331.0-332.0	73227	1.8	8.0	88.2	2.0	4.7a	19.2		None	
SBR82-221	332.0-333.0	73229	0.6	9.5	87.3	2.6	1.6a	22.8		None	
SBR82-222	333.0-334.0	73230	0.8	8.0	89.0	2.2	2.1a	19.2		None	
SBR82-223	334.0-335.0	73231	1.1	7.2	89.4	2.3	2.9a	17.3		None	
SBR82-224	335.0-336.0	73233	0.4	9.0	89.1	1.5	1.0a	21.6		None	
SBR82-225	336.0-337.0	73235	1.2	7.0	90.1	1.7	3.0a	16.8		None	
SBR82-226	337.0-338.0	73236	0.2	7.4	89.3	3.1	0.5a	17.7		None	
SBR82-227	338.0-339.0	73237	0.5	9.0	88.3	2.2	1.4a	21.6		None	
SBR82-228	339.0-340.0	73241	2.1	6.0	89.5	2.4	5.7	14.4	0.865	None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-3 corehole

Surface elevation: 5,820 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton				
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil[1/]	Water	of oil at 60°/60° F	Tendency to coke	Remarks
SBR82-229	340.0-341.0	73288	2.6	5.2	90.4	1.8	7.2	12.5	0.864	None	
SBR82-230	341.0-342.0	73243	1.9	8.0	87.7	2.4	4.9a	19.2		None	Some rubble
SBR82-231	342.0-343.0	73245	0.9	10.0	87.1	2.0	2.4a	24.0		None	
SBR82-232	343.0-344.0	73253	4.4	7.0	86.6	2.0	11.8	16.8	.882	None	
SBR82-233	344.0-345.0	73254	4.2	6.0	87.4	2.4	11.3	14.4	.886	None	
SBR82-234	345.0-346.0	73255	4.1	6.2	87.7	2.0	11.3	14.9	.875	None	
SBR82-235	346.0-347.0	73256	1.5	7.5	89.4	1.6	3.9a	18.0		None	0.1' missing
SBR82-236	347.0-348.4	73257	0.6	7.0	90.8	1.6	1.7a	16.8		None	
SBR82-237	348.4-350.3	73259	0.0	7.2	91.8	1.0	Trace	17.4		None	
SBR82-238	350.3-351.3	73260	0.1	5.5	92.1	2.3	0.4a	13.2		None	
SBR82-239	351.3-352.8	73261	0.5	6.5	91.8	1.2	1.3a	15.6		None	
SBR82-240	352.8-354.0	73263	0.3	8.5	89.3	1.9	0.7a	20.4		None	
SBR82-241	354.0-355.0	73264	1.5	7.0	88.6	2.9	3.8a	16.8		None	
SBR82-242	355.0-356.0	73265	5.7	8.5	83.8	2.0	15.3	20.4	.890	None	
SBR82-243	356.0-357.0	73266	2.9	7.2	85.7	4.2	7.9	17.3	.892	None	
SBR82-244	357.0-358.0	73267	1.9	10.0	86.2	1.9	5.0a	24.0		None	
SBR82-245	358.0-359.0	73268	1.9	9.0	87.4	1.7	5.0a	21.6		None	
SBR82-246	359.0-360.1	73269	1.4	11.0	85.8	1.8	3.6a	26.4		None	
SBR82-247	362.0-363.0	73271	1.7	12.5	83.2	2.6	4.4a	30.0		None	
SBR82-248	363.0-364.0	73272	1.5	8.5	87.7	2.3	4.0a	20.4		None	
SBR82-249	364.0-365.4	73273	1.9	8.5	87.3	2.3	5.0a	20.4		None	
SBR82-250	365.4-366.5	73275	1.8	5.8	91.1	1.3	4.6a	13.9		None	
SBR82-251	367.2-368.4	73276	2.1	5.0	90.9	2.0	5.7	12.0	.889	None	
SBR82-252	368.4-369.5	73277	1.9	7.4	89.0	1.7	4.9a	17.7		None	Some rubble
SBR82-253	369.6-371.0	73278	1.7	6.0	89.6	2.7	4.4a	14.4		None	
SBR82-254	371.0-372.8	73279	4.3	5.5	88.2	2.0	11.7	13.2	.884	None	
SBR82-255	373.0-374.0	73280	2.4	7.2	88.3	2.1	6.5	17.3	.881	None	
SBR82-256	374.0-375.0	73281	2.0	7.0	89.3	1.7	5.2a	16.8		None	
SBR82-257	375.0-376.4	73283	4.2	3.5	89.6	2.7	11.5	8.4	.875	None	
SBR82-258	376.4-377.9	73284	3.5	4.5	89.8	2.2	9.5	10.8	.881	None	
SBR82-259	377.9-379.6	73285	0.1	7.9	90.4	1.6	0.4a	18.9		None	
SBR82-260	379.6-380.6	73324	0.2	4.0	95.1	0.7	0.4a	9.6		None	Some rubble
SBR82-261	380.6-381.6	73289	5.1	4.4	88.6	1.9	13.8	10.5	0.885	None	
SBR82-262	381.6-382.6	73290	1.0	6.8	89.5	2.7	2.5a	16.3		None	
SBR82-263	382.6-383.6	73291	1.9	6.6	89.8	1.7	4.8a	15.8		None	
SBR82-264	383.6-384.6	73292	3.3	7.0	88.0	1.7	9.0	16.8	.882	None	
SBR82-265	384.6-385.6	73293	0.1	8.8	89.1	2.0	0.2a	21.1		None	
SBR82-266	385.6-386.6	73295	1.2	8.3	89.3	1.2	3.1a	19.9		None	
SBR82-267	386.6-387.7	73296	0.0	7.3	90.2	2.5	Trace	17.5		None	
SBR82-268	387.7-389.0	73297	2.0	8.0	88.0	2.0	5.3	19.2	.900	None	0.1' missing
SBR82-269	389.0-390.2	73299	3.2	6.0	88.9	1.9	8.7	14.4	.885	None	Rubble
SBR82-270	390.3-391.3	73300	4.0	5.1	87.7	3.2	10.7	12.1	.899	None	
SBR82-271	391.3-392.4	73301	2.4	6.0	89.7	1.9	6.3	14.4	.914	None	
SBR82-272	392.5-393.0	73302	0.0	4.8	94.2	1.0	Trace	11.6		None	
SBR82-273	393.1-395.0	73303	0.3	4.0	94.6	1.1	0.7a	9.6		None	
SBR82-274	395.0-396.0	73304	0.0	8.5	90.9	0.6	Trace	20.3		None	
SBR82-275	396.0-397.5	73305	0.2	6.4	91.9	1.5	0.6a	15.3		None	
SBR82-276	397.5-398.5	73307	3.1	7.1	87.2	2.6	8.2	17.0	.898	None	
SBR82-277	398.5-399.5	73308	3.0	6.0	89.4	1.6	8.0	14.4	.909	None	
SBR82-278	399.5-400.5	73309	1.5	5.8	91.5	1.2	3.9a	13.9		None	
SBR82-279	400.5-401.5	73311	2.4	4.8	91.2	1.6	6.5	11.4	.896	None	
SBR82-280	401.5-402.5	73312	2.4	2.6	93.8	1.2	6.6	6.2	.891	None	
SBR82-281	402.5-404.0	73313	0.2	5.0	93.5	1.3	0.5a	12.0		None	
SBR82-282	404.0-405.0	73314	1.4	2.4	94.5	1.7	3.8a	5.8		None	
SBR82-283	405.0-406.0	73315	2.9	5.0	90.2	1.9	8.0	12.0	.882	None	
SBR82-284	406.0-407.0	73316	3.2	5.0	90.2	1.6	8.7	12.0	.883	None	
SBR82-285	407.0-408.0	73317	0.7	6.3	90.9	2.1	1.9a	15.1		None	
SBR82-286	408.0-409.0	73319	3.1	5.2	89.4	2.3	8.5	12.5	.871	None	
SBR82-287	409.0-410.0	73320	3.2	2.4	91.2	3.2	8.7	5.8	.877	None	
SBR82-288	410.0-411.0	73321	1.2	5.0	92.0	1.8	3.2a	12.0		None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5121P February 12, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-3 corehole

Surface elevation: 5,820 feet

Sample number		Run	Yield of product						Specific gravity of oil at	Properties of spent shale	
			Weight percent				Gal per ton				
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	60°/60° F	Tendency to coke	Remarks
SBR82-289	411.0-412.0	73323	1.4	4.0	93.4	1.2	3.8a	9.6		None	
SBR82-290	412.0-413.0	73325	2.1	3.3	93.3	1.3	5.7	7.9	0.874	None	
SBR82-291	413.0-414.0	73326	3.0	3.8	91.5	1.7	8.2	9.1	.872	None	
SBR82-292	414.0-415.0	73327	0.8	4.0	93.8	1.4	2.2a	9.6		None	
SBR82-293	415.0-416.0	73328	1.4	3.0	94.9	0.7	3.7a	7.2		None	
SBR82-294	416.0-417.0	73329	2.0	5.0	91.3	1.7	5.5	12.0	.892	None	
SBR82-295	417.0-418.0	73331	3.2	5.2	90.1	1.5	8.5	12.5	.908	None	
SBR82-296	418.0-419.0	73365	3.5	4.5	89.8	2.2	9.3	10.8	.910	None	
SBR82-297	419.0-420.0	73333	3.6	5.7	89.1	1.6	9.7	13.7	.894	None	
SBR82-298	420.0-421.0	73335	4.6	5.5	88.0	1.9	12.5	13.2	.878	None	
SBR82-299	421.0-422.0	73336	2.5	4.0	91.0	2.5	6.7	9.6	.882	None	
SBR82-300	422.0-423.0	73337	1.0	6.0	91.8	1.2	2.5a	14.4		None	
SBR82-301	423.0-424.0	73338	0.5	3.9	93.8	1.8	1.2a	9.3		None	
SBR82-302	424.0-425.8	73339	1.0	3.5	94.7	0.8	2.5a	8.4		None	
SBR82-303	425.8-426.9	73340	1.5	6.0	91.2	1.3	3.9a	14.4		None	
SBR82-304	426.9-428.0	73341	1.5	3.8	89.0	5.7	3.9a	9.1		None	Bad weight loss
SBR82-305	428.0-429.0	73343	3.1	3.5	91.5	1.9	8.3	8.4	.883	None	
SBR82-306	429.0-430.4	73344	3.0	5.0	89.8	2.2	8.2	12.0	.875	None	
SBR82-307	430.4-431.4	73345	1.4	5.0	91.9	1.7	3.6a	12.0		None	
SBR82-308	431.4-432.4	73347	3.2	5.0	90.4	1.4	8.9	12.0	.864	None	
SBR82-309	432.4-433.8	73348	2.8	5.7	89.5	2.0	7.7	13.7	.871	None	
SBR82-310	433.8-435.0	73349	2.7	6.8	88.5	2.0	7.4	16.3	.864	None	
SBR82-311	435.0-436.0	73350	1.7	6.0	88.8	3.5	4.5a	14.4		None	
SBR82-312	436.0-437.0	73351	2.7	6.1	89.3	1.9	7.4	14.6	.872	None	
SBR82-313	437.0-438.2	73352	2.6	6.0	89.7	1.7	7.1	14.4	.878	None	
SBR82-314	438.3-439.8	73353	1.8	7.1	89.5	1.6	4.6a	17.0		None	Rubble
SBR82-315	439.8-441.2	73355	3.8	4.7	88.9	2.6	10.4	11.3	.884	None	Some rubble
SBR82-316	441.3-442.6	73356	2.9	5.0	90.6	1.5	7.8	12.0	.880	None	
SBR82-317	442.6-443.9	73357	1.9	5.1	91.3	1.7	4.9a	12.2		None	
SBR82-318	443.9-445.0	73359	3.2	5.3	90.0	1.5	8.8	12.7	.883	None	
SBR82-319	445.0-446.3	73360	3.9	5.0	89.5	1.6	10.7	12.0	0.881	None	
SBR82-320	446.3-447.5	73361	2.8	4.8	90.0	2.4	7.7	11.5	.877	None	
SBR82-321	447.5-448.7	73362	4.3	4.7	88.0	3.0	11.7	11.3	.870	None	
SBR82-322	448.7-449.8	73363	6.7	3.8	87.3	2.2	18.2	9.1	.885	None	
SBR82-323	449.8-450.9	73364	3.1	3.7	91.4	1.8	8.3	8.9	.897	None	
SBR82-324	450.9-452.3	73367	0.7	5.8	91.7	1.8	2.0	13.9	.896	None	
SBR82-325	452.3-453.6	73407	3.6	3.4	91.7	1.3	9.7	8.1	.876	None	
SBR82-326	453.6-455.0	73369	1.9	4.3	92.2	1.6	5.2	10.3	.872	None	
SBR82-327	455.0-456.0	73371	4.1	3.6	89.6	2.7	11.3	8.6	.869	None	
SBR82-328	456.0-457.0	73373	3.0	3.9	91.2	1.9	8.3	9.3	.875	None	
SBR82-329	457.0-458.0	73374	2.2	4.5	90.8	2.5	6.0	10.8	.885	None	Some rubble
SBR82-330	458.0-459.0	73375	3.4	4.8	90.4	1.4	9.2	11.5	.883	None	
SBR82-331	459.0-460.0	73376	1.8	6.0	91.0	1.2	4.7a	14.4		None	Some rubble
SBR82-332	460.0-461.0	73377	2.7	4.9	91.0	1.4	7.2	11.7	.882	None	Some rubble
SBR82-333	461.0-462.0	73379	2.0	6.0	90.4	1.6	5.6	14.4	.866	None	
SBR82-334	462.0-463.0	73380	1.0	5.6	92.2	1.2	2.7a	13.4		None	
SBR82-335	463.0-464.0	73381	4.2	5.0	88.6	2.2	11.4	12.0	.873	None	
SBR82-336	464.0-465.1	73383	4.1	5.3	88.7	1.9	11.4	12.7	.870	None	
SBR82-337	465.1-466.3	73384	1.5	5.0	91.5	2.0	4.0a	12.0		None	
SBR82-338	466.3-467.5	73385	3.1	5.3	89.1	2.5	8.4	12.7	.886	None	
SBR82-339	467.5-469.1	73386	5.5	2.8	88.2	3.5	14.9	6.7	.882	None	
SBR82-340	469.2-470.0	73387	1.6	5.5	90.9	2.0	4.2a	13.2		None	
SBR82-341	470.0-471.0	73388	6.0	4.0	87.7	2.3	16.5	9.6	.874	None	
SBR82-342	471.0-472.0	73389	3.7	4.7	89.5	2.1	10.2	11.3	.875	None	
SBR82-343	472.0-473.0	73391	4.5	5.7	87.3	2.6	12.4	13.7	.867	None	
SBR82-344	473.0-474.0	73392	3.0	5.7	89.2	2.1	8.4	13.7	.865	None	
SBR82-345	474.0-475.0	73393	3.1	6.0	89.1	1.8	8.7	14.4	.863	None	
SBR82-346	475.0-476.0	73395	2.7	5.5	90.3	1.5	7.5	13.2	.866	None	
SBR82-347	476.0-477.0	73396	1.6	5.3	91.5	1.6	4.5	12.7	.870	None	
SBR82-348	477.0-478.3	73397	3.0	5.1	90.0	1.9	8.3	12.2	.882	None	
SBR82-349	478.5-479.0	73398	1.4	5.0	91.6	2.0	3.7a	12.0		None	
SBR82-350	479.6-480.8	73399	0.6	7.8	90.0	1.6	1.6a	18.7		None	0.1' missing
SBR82-351	480.8-482.0	73400	2.6	6.0	89.2	2.2	7.0	14.4	0.875	None	
SBR82-352	482.0-483.2	73401	2.9	5.8	89.0	2.3	7.9	13.9	.877	None	
SBR82-353	483.2-484.4	73403	3.8	6.0	88.8	1.4	10.4	11.4	.875	None	
SBR82-354	484.4-485.8	73404	1.8	5.0	90.7	2.5	4.9	12.0	.869	None	
SBR82-355	485.8-487.5	73405	5.2	5.4	87.2	2.2	14.3	12.9	.872	None	

1/ "a"--indicates specific gravity estimated at .920.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5121P February 12, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Drill cutting samples from United States Geological Survey's EOS-3A well drilled in the SE1/4NE1/4NE1/4 (approximately 800 ft. S and 250 ft. W of NE corner) of sec. 36, T 34 N, R 55 E, Elko County, Nevada

Surface elevation: 5,820 feet (estimated)

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton				
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	of oil at 60°/60° F	Tendency to coke	Remarks
SBR82-1	400-405	72923	1.6	3.7	93.3	1.4	4.1a	8.9		None	
SBR82-2	405-410	72924	2.8	3.5	91.7	2.0	7.6	8.4	0.882	None	
SBR82-3	410-415	72925	1.7	4.6	92.5	1.2	4.3a	11.0		None	
SBR82-4	415-420	72963	2.2	4.0	91.6	2.2	6.1	9.6	.882	None	
SBR82-5	420-425	72927	2.1	6.0	90.2	1.7	5.7	14.4	.873	None	
SBR82-6	425-430	72929	2.9	4.8	90.8	1.5	7.8	11.5	.878	None	
SBR82-7	430-435	72930	2.4	3.5	91.3	2.8	6.6	8.4	.875	None	
SBR82-8	435-440	72931	3.1	4.3	91.5	1.2	8.4	10.3	.877	None	
SBR82-9	440-445	72933	2.4	4.2	91.9	1.5	6.7	10.1	.872	None	
SBR82-10	445-450	72934	2.4	3.7	91.7	2.2	6.5	8.9	.875	None	
SBR82-11	450-455	72935	4.2	3.6	90.5	1.7	11.5	8.5	.880	None	
SBR82-12	455-460	72936	3.5	3.3	90.1	3.1	9.5	7.9	.874	None	
SBR82-13	460-465	72937	2.9	5.5	90.0	1.6	8.0	13.2	.872	None	
SBR82-14	465-470	72938	2.6	6.5	89.2	1.7	7.3	15.6	.868	None	
SBR82-15	470-475	72939	3.2	6.4	88.3	2.1	8.9	15.3	.865	None	
SBR82-16	475-480	72941	1.3	6.0	90.7	2.0	3.4a	14.4		None	
SBR82-17	480-485	72942	0.9	5.6	91.7	1.8	2.2a	13.4		None	
SBR82-18	485-490	72943	1.3	5.0	92.4	1.3	3.3a	12.0		None	
SBR82-19	490-495	72945	0.9	5.1	92.5	1.5	2.4a	12.2		None	
SBR82-20	495-500	72946	1.7	4.5	92.2	1.6	4.3a	10.8		None	
SBR82-21	500-505	72947	1.7	4.5	92.9	0.9	4.5a	10.8		None	
SBR82-22	505-510	72948	0.7	3.5	93.4	2.4	1.9a	8.4		None	
SBR82-23	510-515	72949	0.8	5.5	92.2	1.4	2.1a	13.2		None	
SBR82-24	515-520	72950	1.5	6.0	91.3	1.2	3.9a	14.4		None	
SBR82-25	520-525	72951	1.1	6.3	91.4	1.2	2.9a	15.1		None	
SBR82-26	525-530	72953	1.6	4.8	91.2	2.4	4.3a	11.4		None	
SBR82-27	530-535	72954	1.8	3.7	92.0	2.5	4.8a	8.9		None	
SBR82-28	535-540	72955	1.2	3.2	93.1	2.5	3.1a	7.7		None	
SBR82-29	550-555	72957	0.7	3.9	94.2	1.2	1.9a	9.3		None	
SBR82-30	555-560	72958	0.3	5.6	92.8	1.3	0.9a	13.4		None	
SBR82-31	560-565	72959	0.7	4.7	92.6	2.0	1.7a	11.3		None	
SBR82-32	565-570	72960	0.3	4.5	93.3	1.9	0.9a	10.8		None	
SBR82-33	570-575	72961	0.3	3.6	94.5	1.6	0.7a	8.6		None	
SBR82-34	575-580	72962	0.3	2.0	96.6	1.1	0.8a	4.8		None	
SBR82-35	580-585	72965	0.3	2.9	95.5	1.3	0.8a	7.0		None	
SBR82-36	585-590	72966	0.0	1.0	97.4	1.6	Trace	2.3		None	
SBR82-37	590-595	72967	0.1	1.4	97.4	1.1	0.3a	3.4		None	
SBR82-38	595-600	72969	0.0	1.4	97.6	1.0	Trace	3.2		None	
SBR82-39	600-605	72970	0.1	1.7	96.7	1.5	0.1a	4.0		None	
SBR82-40	605-610	72971	0.0	3.0	96.5	0.5	Trace	7.2		None	
SBR82-41	610-615	72972	0.1	2.2	96.3	1.4	0.2a	5.3		None	
SBR82-42	615-620	72973	0.1	3.4	95.9	0.6	0.2a	8.1		None	
SBR82-43	620-625	72974	0.4	4.1	94.5	1.0	1.0a	9.8		None	
SBR82-44	625-630	72975	0.8	6.8	90.2	2.2	2.0a	16.3		None	
SBR82-45	630-635	72977	0.6	6.0	91.0	2.4	1.5a	14.4		None	
SBR82-46	635-640	72978	0.3	6.0	91.8	1.9	0.8a	14.4		None	
SBR82-47	640-645	72979	0.4	6.0	92.1	1.5	0.9a	14.4		None	
SBR82-48	645-650	72981	0.8	5.2	93.3	0.7	2.0a	12.5		None	

1/ "a"--indicates specific gravity estimated at .920.

Drill cutting samples received December 17, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5122P

January 19, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Samples of cuttings from United States Geological Survey's EOS-4 corehole drilled in the SE¼SE¼SE¼ (approximately 450 ft. N and 800 ft. W of SE corner) of sec. 8, T. 34 N., R. 56 E., Elko County, Nevada. Interval: 3.9 to 19.0 ft.

Surface elevation: 5,660 feet (estimated)

Sample number		Run	Yield of product						Specific gravity	Properties of Spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas+ loss	Oil1/	Water	60°/60° F	coke	Remarks
SBR-82-417	3.0-5.0	73527	4.1	3.2	90.6	2.1	10.9	7.6	0.905	None	
SBR-82-418	5.0-10.0	73528	2.1	3.5	93.0	1.4	5.7	8.4	.896	None	
SBR-82-419	10.2-12.0	73529	0.9	2.4	95.6	1.1	2.2a	5.8	----	None	
SBR-82-420	12.0-13.0	73530	2.5	1.5	94.1	1.9	6.5	3.6	.905	None	
SBR-82-421	13.0-15.0	73531	0.2	2.5	96.2	1.1	0.5a	6.0	----	None	
SBR-82-422	15.0-17.0	73532	1.6	3.1	93.9	1.4	4.1a	7.4	----	None	
SBR-82-423	17.0-18.0	73533	2.5	2.5	92.9	2.1	6.8	6.0	.890	None	
SBR-82-424	18.0-19.0	73535	4.1	1.7	92.9	1.3	11.1	4.1	.887	None	

1/ "a" indicates specific gravity estimated at 0.920

Samples received February 16, 1982; assays made on air-dried samples by Laramie Energy Technology Center, Laramie, Wyoming.

Core samples from United States Geological Survey's EOS-4 corehole drilled in the SE1/4SE1/4SE1/4 (approximately 450 ft. N and 800 ft. W of SE corner) of sec. 8, T 34 N, R 56 E, Elko County, Nevada

Surface elevation: 5,660 feet (estimated)

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil1/	Water	60°/60° F	coke	Remarks
SBR81-17351	20.0-21.1	72633	4.9	1.6	92.3	1.2	13.3	3.8	0.886	None	
SBR82-17352	21.1-22.4	72635	5.3	1.7	91.2	1.8	14.3	4.0	.892	None	
SBR82-17353	22.4-23.5	72636	3.5	3.5	91.7	1.3	9.3	8.4	.892	None	
SBR82-17354	23.5-24.7	72637	4.1	1.8	93.2	0.9	10.8	4.3	.897	None	
SBR82-17355	24.7-26.0	72639	3.9	1.8	93.4	0.9	10.3	4.3	.896	None	
SBR82-17356	26.0-27.0	72640	3.7	1.6	93.3	1.4	9.8	3.8	.901	None	
SBR82-17357	27.0-28.0	72641	3.8	1.5	93.3	1.4	10.2	3.6	.895	None	
SBR82-17358	28.0-29.0	72642	4.0	1.1	93.2	1.7	11.0	2.6	.884	None	
SBR82-17359	29.0-30.0	72643	6.2	1.4	90.9	1.5	16.9	3.4	.882	None	
SBR82-17360	30.0-31.0	72644	5.5	1.3	92.3	0.9	14.8	3.1	.888	None	
SBR82-17361	31.0-32.0	72645	3.3	1.7	93.3	1.7	9.0	4.1	.879	None	
SBR82-17362	32.0-33.0	72647	4.6	2.0	91.8	1.6	12.2	4.8	.904	None	
SBR82-17363	33.0-34.0	72648	4.6	1.2	91.3	2.9	12.5	2.9	.880	None	
SBR82-17364	34.0-35.0	72649	4.2	2.0	91.9	1.9	11.6	4.8	.881	None	
SBR82-17365	35.0-36.0	72651	4.1	1.7	92.3	1.9	11.2	4.1	.878	None	
SBR82-17366	36.0-37.0	72652	4.5	1.8	91.1	2.6	12.4	4.3	.874	None	
SBR82-17367	37.0-38.0	72653	7.8	2.4	87.2	2.6	21.3	5.8	.874	None	
SBR82-17368	38.0-39.0	72654	5.0	2.0	89.7	3.3	13.4	4.8	.885	None	
SBR82-17369	39.0-40.8	72675	2.3	2.8	93.4	1.0	6.2	6.6	.890	None	
SBR82-17370	40.8-42.3	72656	1.2	0.8	97.4	0.6	3.0a	1.9		None	
SBR82-17371	42.7-44.0	72657	1.3	1.6	96.6	0.5	3.4a	3.8		None	
SBR82-17372	44.0-45.0	72669	1.1	1.8	96.5	0.7	2.8a	4.2		None	
SBR82-17373	45.0-46.0	72670	3.4	3.7	91.2	1.7	9.3	8.7	.880	None	
SBR82-17374	46.0-47.0	72671	5.9	3.0	89.3	1.8	15.6	7.2	.902	None	
SBR82-17375	47.0-48.0	72672	3.1	2.3	92.3	2.3	8.4	5.5	.882	None	
SBR82-17376	48.0-49.0	72673	1.8	3.0	93.5	1.7	4.6a	7.2		None	
SBR82-17377	49.0-50.0	72674	4.5	2.3	91.3	1.9	12.3	5.5	.879	None	
SBR82-17378	50.0-51.0	72677	3.7	2.7	91.9	1.7	10.2	6.5	.877	None	
SBR82-17379	51.0-52.0	72678	1.9	2.8	93.9	1.4	4.9a	6.7		None	
SBR82-17380	52.0-53.0	72679	4.0	2.2	92.4	1.4	10.9	5.2	.882	None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5123P

January 15, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-4 corehole

Surface elevation: 5,660 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil[1/]	Water	60°/60° F	coke	Remarks
SBR81-17381	53.0-54.6	72681	2.6	2.3	93.9	1.2	7.2	5.4	0.875	None	
SBR81-17382	55.0-56.0	72682	2.0	3.2	93.1	1.7	5.5	7.7	.873	None	
SBR81-17383	56.0-57.3	72683	4.8	2.8	91.0	1.4	13.0	6.7	.880	None	
SBR81-17384	57.7-58.7	72684	3.1	4.5	90.6	1.8	8.6	10.8	.873	None	
SBR81-17385	59.1-60.5	72685	0.0	8.5	90.6	0.9	Trace	20.5		None	
SBR81-17386	60.5-61.7	72686	1.7	6.0	91.5	0.8	4.5a	14.4		None	
SBR81-17387	61.7-62.8	72687	3.6	3.6	91.4	1.4	9.8	8.6	.868	None	
SBR81-17388	62.8-64.1	72689	5.2	3.7	89.1	2.0	14.4	8.9	.871	None	
SBR81-17389	64.1-65.5	72690	3.5	3.8	90.3	2.4	9.6	9.0	.873	None	
SBR81-17390	65.5-66.6	72691	1.3	4.3	93.4	1.0	3.4a	10.3		None	
SBR81-17391	66.6-67.6	72693	2.2	4.1	92.6	1.1	6.0	9.9	.865	None	
SBR81-17392	67.6-68.6	72694	1.7	4.5	91.6	2.2	4.4a	10.8		None	
SBR81-17393	68.6-69.6	72695	6.6	4.0	87.1	2.3	18.2	9.6	.872	None	
SBR81-17394	69.6-70.8	72696	4.9	2.4	90.0	2.7	13.4	5.8	.871	None	
SBR81-17395	70.8-71.8	72697	4.0	3.9	90.1	2.0	11.1	9.3	.873	None	
SBR81-17396	71.8-72.8	72698	3.2	4.7	90.8	1.3	8.9	11.3	.875	None	
SBR81-17397	73.0-74.1	72701	4.2	5.6	88.3	1.9	11.4	13.4	.880	None	
SBR81-17398	74.1-75.3	72702	2.0	5.0	90.7	2.3	5.5	12.0	.883	None	
SBR81-17399	75.3-76.3	72703	1.7	6.0	91.1	1.2	4.3a	14.4		None	
SBR81-17400	76.3-77.3	72704	1.4	6.4	91.1	1.1	3.7a	15.3		None	
SBR81-17401	77.3-78.3	72705	2.2	6.8	89.8	1.2	5.9	16.3	.878	None	
SBR81-17402	78.3-79.5	72707	4.2	3.9	90.4	1.5	11.5	9.3	.881	None	
SBR81-17403	79.5-80.8	72708	5.1	3.5	89.8	1.6	13.8	8.4	.888	None	
SBR81-17404	80.8-81.8	72709	3.4	3.5	92.2	0.9	9.3	8.4	.883	None	
SBR81-17405	81.8-82.8	72711	3.6	2.4	92.7	1.3	9.9	5.8	.879	None	
SBR81-17406	83.0-84.4	72717	5.6	1.9	90.6	1.9	15.5	4.6	.867	None	
SBR81-17407	84.4-85.6	72713	10.2	1.9	85.3	2.6	27.9	4.6	.876	None	
SBR81-17408	85.6-86.7	72714	7.0	1.4	89.4	2.2	19.2	3.2	.876	None	
SBR81-17409	86.7-88.5	72715	2.6	2.4	93.6	1.4	7.2	5.8	.883	None	
SBR81-17410	88.5-90.0	72716	1.0	2.4	95.7	0.9	2.6a	5.8		None	
SBR81-17411	90.0-91.0	72719	2.1	2.0	94.7	1.2	5.8	4.8	0.895	None	
SBR81-17412	91.0-92.7	72741	2.7	1.9	94.3	1.1	7.2	4.6	.899	None	
SBR81-17413	92.7-93.7	72721	2.9	1.6	94.2	1.3	7.9	3.8	.894	None	
SBR81-17414	93.7-95.1	72723	1.9	1.3	95.6	1.2	5.0a	3.1		None	
SBR81-17415	95.1-96.2	72724	1.4	1.4	95.3	1.9	3.7a	3.4		None	
SBR81-17416	96.9-98.0	72725	2.8	1.6	94.6	1.0	7.4	3.8	.890	None	
SBR81-17417	98.0-99.0	72726	1.3	1.5	95.3	1.9	3.3a	3.6		None	
SBR81-17418	99.0-100.2	72727	2.5	2.1	94.3	1.1	6.7	5.0	.894	None	
SBR81-17419	100.2-101.3	72728	3.3	1.7	93.7	1.3	9.0	4.1	.889	None	
SBR81-17420	101.7-103.0	72729	2.3	2.2	94.9	0.6	6.3	5.3	.894	None	
SBR81-17421	103.0-104.4	72731	1.5	1.7	95.3	1.5	3.8a	4.1		None	
SBR81-17422	104.4-105.6	72732	2.7	1.5	94.0	1.8	7.2	3.6	.881	None	
SBR81-17423	105.6-106.7	72733	2.1	1.9	94.8	1.2	5.8	4.6	.883	None	
SBR81-17424	106.7-107.9	72735	1.3	2.8	94.9	1.0	3.4a	6.7		None	
SBR81-17425	107.9-109.0	72736	1.0	1.7	95.8	1.5	2.6a	4.1		None	
SBR81-17426	109.0-110.0	72737	1.3	0.8	95.9	2.0	3.4a	1.9		None	
SBR81-17427	110.0-111.0	72738	1.6	1.8	94.6	2.0	4.1a	4.3		None	
SBR81-17428	111.0-112.0	72739	2.6	1.8	94.2	1.4	7.0	4.3	.899	None	
SBR81-17429	112.0-113.0	72743	0.9	2.9	94.8	1.4	2.4a	7.0		None	
SBR81-17430	113.0-114.1	72744	2.5	1.8	93.6	2.1	6.8	4.3	.890	None	
SBR81-17431	114.1-115.9	72745	0.9	3.3	95.2	0.6	2.3a	7.9		None	
SBR81-17432	115.9-116.9	72747	3.0	1.9	94.0	1.1	8.1	4.6	.896	None	
SBR81-17433	116.9-117.9	72748	3.3	1.6	93.8	1.3	8.9	3.8	.879	None	
SBR81-17434	117.9-119.4	72793	5.7	1.3	91.3	1.7	15.4	3.1	.881	None	Waxy
SBR81-17435	121.1-122.4	72795	1.3	2.5	95.0	1.2	3.3a	6.0		None	Rubble; waxy
SBR81-17436	122.4-123.4	72751	3.9	1.7	92.8	1.6	10.7	4.1	.883	None	
SBR81-17437	123.4-124.4	72753	4.2	1.4	93.1	1.3	11.5	3.4	.879	None	
SBR81-17438	124.4-125.5	72796	2.0	1.4	94.4	2.2	5.5	3.4	.887	None	Waxy
SBR81-17439	125.5-126.8	72755	0.3	1.7	97.1	0.9	0.8a	4.1		None	
SBR81-17440	130.4-131.5	72756	0.5	2.3	96.4	0.8	1.4a	5.5		None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5123P January 15, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-4 corehole

Surface elevation: 5,660 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at	Tendency to	
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil 1/	Water	60°/60° F	coke	Remarks
SBR81-17441	131.5-132.6	72757	0.2	2.3	96.8	0.7	0.5a	5.5		None	
SBR81-17442	132.6-133.4	72759	1.3	2.4	95.4	0.9	3.4a	5.8		None	
SBR81-17443	133.4-134.4	72760	4.3	1.6	92.7	1.4	11.8	3.8	.870	None	
SBR81-17444	134.4-135.4	72761	3.0	1.6	93.8	1.6	8.2	3.8	.881	None	
SBR81-17445	135.4-136.6	72813	1.6	1.6	94.8	2.0	4.2a	3.7		None	
SBR81-17446	136.6-137.6	72763	1.9	2.1	94.5	1.5	5.0a	5.0		None	
SBR81-17447	137.6-138.9	72764	1.7	2.8	94.7	0.8	4.5a	6.7		None	
SBR81-17448	138.9-140.3	72765	0.4	2.2	96.8	0.6	1.0a	5.3		None	
SBR81-17449	141.0-142.0	72767	0.1	3.0	95.3	1.6	0.4a	7.2		None	Footage correction
SBR81-17450	142.0-143.0	72803	0.7	3.2	94.4	1.7	1.8a	7.7		None	
SBR81-17451	143.0-144.3	72769	2.8	2.2	93.5	1.5	7.5	5.3	.884	None	
SBR81-17452	144.3-145.4	72771	3.3	2.3	92.9	1.5	8.8	5.5	.894	None	
SBR81-17453	145.4-147.1	72772	0.3	2.9	95.2	1.6	0.8a	7.0		None	
SBR81-17454	147.1-148.9	72773	0.8	3.3	95.3	0.6	2.0a	7.9		None	
SBR81-17455	148.9-150.0	72774	0.0	3.1	95.1	1.8	Trace	7.4		None	
SBR81-17456	150.0-151.0	72775	0.6	2.5	96.0	0.9	1.4a	6.0		None	
SBR81-17457	151.0-152.0	72776	2.3	1.5	95.1	1.1	6.4	3.6	.869	None	
SBR81-17458	152.0-153.0	72777	5.0	1.7	91.6	1.7	13.7	4.1	.871	None	
SBR81-17459	153.0-154.0	72779	6.2	1.5	90.8	1.5	17.0	3.6	.874	None	
SBR81-17460	154.0-155.0	72780	2.0	2.2	94.6	1.2	5.5	5.3	.881	None	
SBR81-17461	155.0-156.0	72781	2.8	1.9	94.5	0.8	7.6	4.6	.879	None	
SBR81-17462	156.0-157.0	72783	0.8	3.3	95.3	0.6	2.2a	7.9		None	
SBR81-17463	157.0-158.3	72784	1.8	2.0	95.4	0.8	4.6a	4.8		None	
SBR81-17464	158.3-159.6	72785	2.9	2.1	93.7	1.3	7.7	5.0	.896	None	
SBR81-17465	159.6-160.7	72786	3.5	1.9	92.6	2.0	9.5	4.6	.896	None	
SBR81-17466	160.7-161.7	72787	3.2	2.3	93.2	1.3	8.4	5.5	.904	None	
SBR81-17467	161.7-162.8	72788	2.5	2.4	94.3	0.8	6.8	5.8	.891	None	
SBR81-17468	162.8-163.9	72789	0.6	3.6	94.8	1.0	1.5a	8.6		None	
SBR81-17469	163.9-165.0	72791	0.8	4.7	93.0	1.5	2.2a	11.3		None	
SBR81-17470	165.0-166.5	72792	0.2	3.9	94.1	1.8	0.5a	9.3		None	
SBR81-17471	166.5-168.2	72797	1.0	4.5	93.4	1.1	2.6a	10.8		None	
SBR81-17472	168.2-169.4	72798	5.0	2.3	89.7	3.0	13.4	5.5	.891	None	
SBR81-17473	169.4-170.5	72799	3.5	3.2	91.8	1.5	9.3	7.7	.889	None	
SBR81-17474	170.5-171.3	72800	0.9	5.1	92.9	1.1	2.3a	12.2		None	
SBR81-17475	171.3-172.2	72801	2.5	3.0	93.2	1.3	6.8	7.2	.882	None	
SBR81-17476	172.2-174.2	72804	0.3	0.6	97.8	1.3	0.8a	1.4		None	
SBR81-17477	174.2-176.2	72805	0.2	1.0	98.2	0.6	0.5a	2.4		None	
SBR81-17478	176.2-177.5	72807	5.5	1.4	91.3	1.8	15.0	3.4	.873	None	
SBR81-17479	177.5-178.5	72808	4.1	2.0	91.6	2.3	10.5	4.8	.927	None	
SBR81-17480	178.5-179.5	72809	2.6	1.3	94.9	1.2	6.9	3.1	.885	None	
SBR81-17481	179.5-180.5	72810	0.2	3.0	94.8	2.0	0.4a	7.1		None	
SBR81-17482	180.5-181.5	72811	6.8	3.0	87.7	2.5	18.5	7.2	.885	None	
SBR81-17483	181.5-182.5	72837	4.4	1.9	92.1	1.6	11.9	4.6	.884	None	
SBR81-17484	182.5-184.5	72815	0.4	0.7	97.9	1.0	1.0a	1.7		None	
SBR81-17485	184.5-185.7	72816	0.9	0.8	96.9	1.4	2.3a	1.9		None	
SBR81-17486	185.7-187.0	72817	2.1	1.2	95.2	1.5	5.5	2.9	.895	None	
SBR81-17487	187.0-188.0	72819	0.7	2.9	95.0	1.4	1.9a	7.0		None	
SBR81-17488	188.0-189.0	72820	1.5	1.5	95.8	1.2	3.8a	3.6		None	
SBR81-17489	189.0-190.0	72821	0.5	2.0	96.5	1.0	1.2a	4.8		None	
SBR81-17490	190.0-191.0	72822	3.3	2.1	92.7	1.9	8.8	5.0	.885	None	
SBR81-17491	191.0-192.0	72823	2.6	1.9	94.2	1.3	7.0	4.6	.887	None	
SBR81-17492	192.0-193.0	72824	0.8	2.1	96.3	0.8	2.0a	5.0		None	
SBR81-17493	193.0-194.0	72825	0.1	3.1	96.3	0.5	0.4	7.4		None	
SBR81-17494	194.0-195.0	72827	0.6	2.7	95.6	1.1	1.7a	6.5		None	
SBR81-17495	195.0-196.0	72828	3.1	2.6	91.5	2.8	8.4	6.1	.878	None	
SBR81-17496	196.0-197.0	72829	3.6	2.2	92.7	1.5	9.7	5.3	.876	None	
SBR81-17497	197.0-198.0	72831	1.6	2.5	94.6	1.3	4.2a	6.0		None	
SBR81-17498	198.0-199.5	72832	0.3	0.8	97.7	1.2	0.9a	1.9		None	
SBR81-17499	199.5-201.1	72833	3.5	2.5	92.2	1.8	9.5	6.0	.876	None	
SBR81-17500	201.1-203.3	72834	0.1	0.9	97.2	1.8	0.2a	2.2		None	

See footnote at end of table.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5123P

January 15, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-4 corehole

Surface elevation: 5,660 feet

Sample number		Run	Yield of product						Specific gravity	Properties of spent shale	
			Weight percent				Gal per ton		of oil at		
Laramie	Depth (feet)	No.	Oil	Water	Spent shale	Gas + loss	Oil[1/]	Water	60°/60° F	Tendency to coke	Remarks
SBR81-17501	203.3-204.3	72835	1.0	1.2	96.3	1.5	2.5a	2.9		None	
SBR81-17502	204.3-205.0	72836	3.5	1.0	93.8	1.7	9.3	2.4	0.886	None	
SBR81-17503	205.0-206.9	72839	0.3	0.9	97.8	1.0	0.9a	2.2		None	
SBR81-17504	206.9-208.6	72840	1.4	1.5	95.4	1.7	3.7a	3.6		None	
SBR81-17505	208.6-209.3	72841	2.1	1.0	95.1	1.8	5.6	2.4	.889	None	
SBR81-17506	209.3-209.9	72843	0.9	1.9	96.1	1.1	2.4a	4.6		None	
SBR81-17507	209.9-210.6	72844	3.6	0.7	93.7	2.0	9.8	1.7	.894	None	
SBR81-17508	210.6-211.7	72845	2.5	1.3	94.6	1.6	6.8	3.1	.886	None	
SBR81-17509	211.7-212.8	72846	2.1	1.2	94.5	2.2	5.7	2.9	.885	None	
SBR81-17510	212.8-213.8	72847	1.9	1.4	95.4	1.3	4.8a	3.4		None	
SBR81-17511	213.8-214.6	72848	1.1	1.2	96.7	1.0	2.9a	2.9		None	
SBR81-17512	214.6-215.3	72849	3.8	1.0	93.7	1.5	10.4	2.4	.884	None	
SBR81-17513	215.3-216.4	72851	1.0	2.1	95.5	1.4	2.7a	5.0		None	
SBR81-17514	216.4-217.4	72852	0.6	3.6	94.2	1.6	1.6a	8.6		None	
SBR81-17515	217.4-218.4	72853	1.7	3.0	94.0	1.3	4.5a	7.2		None	
SBR81-17516	218.4-219.5	72855	0.2	2.5	96.7	0.6	0.4a	6.0		None	
SBR81-17517	219.5-221.2	72856	2.5	3.6	92.7	1.2	6.9	8.6	.875	None	
SBR81-17518	221.2-222.9	72857	0.4	3.5	95.4	0.7	1.1a	8.4		None	
SBR81-17519	222.9-223.4	72858	4.1	1.8	92.1	2.0	11.2	4.3	.883	None	
SBR81-17520	223.4-225.2	72859	0.8	3.3	95.0	0.9	2.1a	7.9		None	
SBR81-17521	225.2-226.9	72860	0.6	3.3	95.6	0.5	1.5a	7.9		None	
SBR81-17522	226.9-227.8	72861	2.5	2.3	94.3	0.9	6.8	5.5	.880	None	
SBR81-17523	227.8-228.7	72863	1.4	2.6	94.8	1.2	3.7a	6.1		None	
SBR81-17524	228.7-230.4	72864	0.1	0.8	97.8	1.3	0.2a	1.8		None	
SBR81-17525	230.4-232.8	72865	0.5	2.0	97.2	0.3	1.2a	4.8		None	
SBR81-17526	232.8-234.4	72867	0.6	0.6	98.3	0.5	1.5a	1.4		None	
SBR81-17527	234.4-236.4	72868	0.0	2.4	96.4	1.2	Trace	5.7		None	
SBR81-17528	236.4-237.9	72869	0.4	3.5	95.2	0.9	1.0a	8.4		None	
SBR81-17529	237.9-239.4	72870	0.1	1.2	97.0	1.7	0.3a	2.9		None	
SBR81-17530	239.4-240.8	72871	0.0	2.7	96.8	0.5	Trace	6.5		None	
SBR81-17531	240.8-241.5	72872	0.8	1.7	97.0	0.5	2.0a	4.1		None	
SBR81-17532	241.5-242.1	72909	0.0	5.3	93.8	0.9	Trace	12.8		None	
SBR81-17533	242.1-243.1	72875	0.9	1.1	96.4	1.6	2.3a	2.6		None	
SBR81-17534	243.1-244.2	72876	0.3	1.0	97.5	1.2	0.8a	2.4		None	
SBR81-17535	244.2-245.7	72877	0.0	1.2	98.0	0.8	Trace	2.9		None	
SBR81-17536	245.7-246.9	72879	1.1	1.0	96.6	1.3	2.9a	2.4		None	
SBR81-17537	246.9-248.0	72880	0.0	1.5	97.7	0.8	Trace	3.6		None	
SBR81-17538	248.0-249.1	72881	0.6	2.5	95.9	1.0	1.5a	6.0		None	
SBR81-17539	249.1-250.1	72882	0.4	1.4	96.4	1.8	1.2a	3.4		None	
SBR81-17540	250.1-251.3	72883	0.3	1.8	97.1	0.8	0.9a	4.3		None	
SBR81-17541	251.3-252.4	72834	0.8	1.5	96.8	0.9	2.1a	3.6		None	
SBR81-17542	252.4-253.7	72885	0.2	0.8	98.5	0.5	0.6a	1.9		None	
SBR81-17543	253.7-254.9	72887	0.2	0.8	98.2	0.8	0.6a	1.9		None	
SBR81-17544	254.9-255.5	72888	0.6	1.0	96.8	1.6	1.7a	2.4		None	
SBR81-17545	255.5-256.5	72889	1.3	1.2	96.3	1.2	3.3a	2.9		None	
SBR81-17546	256.5-257.8	72891	1.1	1.4	96.4	1.1	2.8a	3.4		None	
SBR81-17547	257.8-258.3	72892	0.4	0.6	98.4	0.6	1.1a	1.4		None	
SBR81-17548	258.3-259.3	72893	1.7	1.1	95.9	1.3	4.5a	2.6		None	
SBR81-17549	259.3-260.4	72894	0.9	1.2	96.5	1.4	2.2a	2.9		None	
SBR81-17550	260.4-261.5	72895	0.1	0.6	98.8	0.5	0.4a	1.4		None	
SBR81-17551	261.5-262.0	72896	2.4	2.3	94.1	1.2	6.6	5.5	.875	None	
SBR81-17552	262.0-263.5	72897	0.2	1.2	98.1	0.5	0.5a	2.9		None	
SBR81-17553	263.5-264.9	72899	0.0	2.1	97.0	0.9	Trace	5.0		None	
SBR81-17554	264.9-266.2	72900	0.0	1.0	97.3	1.7	Trace	2.5		None	
SBR81-17555	266.2-266.7	72901	2.4	1.4	94.9	1.3	6.5	3.4	.891	None	
SBR81-17556	266.7-268.0	72903	0.3	1.1	97.6	1.0	0.9a	2.6		None	
SBR81-17557	268.0-269.5	72904	0.2	1.1	97.3	1.4	0.5a	2.6		None	
SBR81-17558	270.0-273.7	72905	1.0	1.1	97.3	0.6	2.7a	2.6		None	0.8' missing
SBR81-17559	273.7-275.7	72906	0.2	0.5	98.0	1.3	0.5a	1.2		None	
SBR81-17560	275.7-276.1	72907	4.0	1.2	93.1	1.7	10.3	2.9	.926	None	
SBR81-17561	276.1-278.0	72908	0.9	0.5	97.7	0.9	2.2a	1.2		None	
SBR81-17562	278.0-281.5	72911	0.8	0.8	97.0	1.4	2.0a	1.8		None	0.5' missing
SBR81-17563	281.5-282.3	72921	3.2	2.3	92.6	1.9	8.3	5.5	0.927	None	
SBR81-17564	282.3-283.6	72913	1.4	0.7	96.7	1.2	3.6a	1.7		None	
SBR81-17565	283.6-286.3	72915	0.1	0.5	98.9	0.5	0.1a	1.2		None	
SBR81-17566	286.3-287.3	72916	1.7	0.6	96.3	1.4	4.5a	1.4		None	
SBR81-17567	287.3-288.4	72917	2.7	0.8	95.6	0.9	6.9	1.9	.931	None	
SBR81-17568	288.4-289.7	72918	0.0	0.3	98.6	1.1	0.1a	0.7		None	
SBR81-17569	289.7-291.2	72919	1.8	0.7	96.6	0.9	4.6a	1.7		None	
SBR81-17570	291.2-292.8	72920	0.6	0.5	98.3	0.6	1.6a	1.2		None	

1/ "a"--indicates specific gravity estimated at .920.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Enregy Technology Center, Laramie, Wyoming Illustration No. SBR-5123P

January 15, 1982

OIL-SHALE ASSAYS BY MODIFIED FISCHER RETORT METHOD

Core samples from United States Geological Survey's EOS-5 corehole drilled in the SE1/4SW1/4SE1/4 (approximately 550 ft. N and 1,650 ft. W of SE corner) of sec. 22, T 34 N, R 55 E, Elko County, Nevada

Surface elevation: 5,240 feet (estimated)

Sample number: Laramie	Sample number: Depth (feet)	Run No.	Yield of product: Weight percent: Oil	Weight percent: Water	Weight percent: Spent shale	Weight percent: Gas + loss	Gal per ton: Oil 1/	Gal per ton: Water	Specific gravity of oil at 60°/60° F	Properties of spent shale: Tendency to coke	Remarks
SBR82-841	21.0-24.0	74064	0.2	2.0	96.6	1.2	0.6a	4.8		None	Weathered rubbl
SBR82-842	32.0-33.0	74065	0.0	4.2	95.1	0.7	Trace	10.1		None	Weathered rubb
SBR82-843	40.3-43.0	74067	0.0	5.2	94.4	0.4	Trace	12.5		None	Weathered, some rub
SBR82-844	45.0-45.7	74068	0.0	2.8	96.3	0.9	Trace	6.6		None	Rubble
SBR82-845	47.7-49.3	74069	0.0	4.7	94.8	0.5	Trace	11.2		None	
SBR82-846	51.7-53.0	74070	0.0	2.6	95.8	1.6	Trace	6.3		None	Rubble

Core samples from United States Geological Survey's EOS-6 corehole drilled in the CSW1/4SE1/4 (approximately 800 ft. N and 1,850 ft. W of SE corner) of sec. 22, T 34 N, R 55 E, Elko County, Nevada

Surface elevation: 5,260 feet (estimated)

Sample number: Laramie	Sample number: Depth (feet)	Run No.	Yield of product: Weight percent: Oil	Weight percent: Water	Weight percent: Spent shale	Weight percent: Gas + loss	Gal per ton: Oil 1/	Gal per ton: Water	Specific gravity of oil at 60°/60° F	Properties of spent shale: Tendency to coke	Remarks
SBR82-426	113.0-113.4	73537	6.0	2.0	89.7	2.3	15.8	4.8	0.910	None	
SBR82-427	115.6-116.6	73539	6.2	1.9	90.1	1.8	16.8	4.4	.894	None	
SBR82-428	116.6-117.6	73540	8.7	0.8	87.9	2.6	23.6	1.9	.880	None	
SBR82-429	117.6-118.6	73541	9.5	2.2	85.3	3.0	25.3	5.3	.901	None	
SBR82-430	120.6-121.4	73542	3.4	1.3	92.8	2.5	9.2	3.0	.891	None	
SBR82-431	122.2-123.4	73543	8.9	1.2	87.5	2.4	24.0	2.8	.887	None	
SBR82-432	124.4-125.4	73544	9.2	1.0	87.3	2.5	24.7	2.4	.888	None	
SBR82-433	125.4-126.5	73545	6.0	2.9	88.9	2.2	16.3	7.0	.882	None	
SBR82-434	126.5-127.5	73547	11.1	1.2	84.1	3.6	30.2	2.9	.883	None	
SBR82-435	127.5-129.0	73548	6.0	2.4	89.0	2.6	16.2	5.8	.895	None	
SBR82-436	129.5-131.0	73549	6.6	1.4	89.1	2.9	17.6	3.4	.900	None	
SBR82-437	131.4-132.8	73551	0.0	9.6	89.6	0.8	Trace	22.9		None	
SBR82-438	133.8-134.7	73552	0.0	15.7	82.7	1.6	Trace	37.6		None	Rubble
SBR82-439	134.7-135.6	73553	0.0	12.0	87.2	0.8	Trace	28.9		None	Rubble
SBR82-440	136.3-139.3	73554	0.0	10.2	87.9	1.9	Trace	24.5		None	Rubble
SBR82-441	139.3-140.4	73555	0.0	10.3	89.4	0.3	Trace	24.7		None	
SBR82-442	140.7-141.2	73556	0.0	12.7	87.2	0.1	Trace	30.3		None	Rubble
SBR82-443	141.8-143.0	73557	0.0	11.2	88.1	0.7	Trace	26.8		None	
SBR82-444	143.6-145.2	73559	0.0	10.7	88.2	1.1	Trace	25.7		None	
SBR82-445	147.5-148.8	73560	7.7	1.9	87.4	3.0	20.7	4.6	.890	None	
SBR82-446	148.8-150.1	73561	5.2	4.0	88.2	2.6	14.0	9.6	.892	None	
SBR82-447	150.1-151.1	73563	4.7	5.3	87.8	2.2	12.8	12.7	.878	None	
SBR82-448	151.1-152.1	73564	21.9	5.5	66.7	5.9	59.6	13.2	.880	None	
SBR82-449	152.1-153.2	73565	23.8	5.5	62.6	8.1	64.2	13.2	.886	None	
SBR82-450	153.3-154.5	73566	5.7	5.1	85.4	3.8	15.3	12.2	.897	None	
SBR82-451	154.5-155.6	73567	19.0	5.0	69.4	6.6	51.9	12.0	.878	None	
SBR82-452	155.6-156.6	73568	3.2	4.5	90.6	1.7	8.7	10.8	.872	None	
SBR82-453	156.6-157.8	73569	4.3	3.2	89.9	2.6	11.8	7.7	.868	None	
SBR82-454	157.8-159.0	73571	1.7	3.8	92.2	2.3	4.5a	9.1		None	
SBR82-455	159.0-160.3	73572	0.2	3.4	94.5	1.9	0.5a	8.1		None	
SBR82-456	160.5-161.8	73573	0.0	4.7	94.7	0.6	Trace	11.3		None	
SBR82-457	162.0-163.2	73575	0.0	4.7	94.6	0.7	Trace	11.4		None	
SBR82-458	163.4-164.7	73576	0.0	3.4	93.2	3.4	Trace	8.3		None	
SBR82-459	164.7-166.0	73577	0.0	4.8	93.1	2.1	Trace	11.6		None	
SBR82-460	166.0-167.0	73578	0.0	3.8	92.0	4.2	Trace	9.0		None	
SBR82-461	167.0-168.0	73579	0.0	5.9	91.4	2.7	Trace	14.2		None	
SBR82-462	168.0-169.0	73580	0.0	6.1	92.0	1.9	Trace	14.5		None	
SBR82-463	169.0-170.0	73581	0.0	6.5	91.7	1.8	Trace	15.6		None	
SBR82-464	170.0-171.3	73583	0.0	6.4	91.0	2.6	Trace	15.2		None	
SBR82-465	171.4-173.0	73584	0.0	6.9	90.6	2.5	Trace	16.4		None	0.2' missing
SBR82-466	173.0-174.2	73585	0.0	12.8	85.7	1.5	Trace	30.7		None	
SBR82-467	174.2-175.2	73587	0.0	9.1	89.9	1.0	Trace	21.8		None	
SBR82-468	175.2-176.2	73588	0.0	10.8	87.7	1.5	Trace	26.0		None	
SBR82-469	176.2-177.3	73589	0.0	11.5	87.7	0.8	Trace	27.5		None	
SBR82-470	177.3-179.2	73590	0.0	10.0	87.3	2.7	Trace	23.9		None	
SBR82-471	179.2-180.6	73591	0.0	9.5	90.0	0.5	Trace	22.8		None	
SBR82-472	180.6-181.9	73595	0.0	6.6	92.2	1.2	Trace	15.9		None	Some rubble
SBR82-473	184.0-185.2	73600	13.2	2.0	80.8	4.0	36.0	4.8	0.877	None	
SBR82-474	185.2-186.3	73597	0.0	7.7	91.7	0.6	Trace	18.4		None	
SBR82-475	188.3-189.7	73599	0.0	8.1	91.3	0.6	Trace	19.3		None	

1/ "a"--indicates specific gravity estimated at .920.

Core samples received December 7, 1981; assays made on air-dried samples

Laramie Energy Technology Center, Laramie, Wyoming Illustration No. SBR-5125P February 23, 1982

APPENDIX C

DATA FROM THE COAL MINE CANYON AREA

By

Helen B. Madrid

APPENDIX C-1

Measured section of the Elko Formation in trench COS-1, Coal Mine Canyon area.

By Helen B. Madrid

Measured stratigraphic section of Elko Formation exposed in bladed-trench cut extending from NE1/4NW1/4NW/14 section 2, T. 37 N., R. 56 E., to the SE/14SW1/4SW1/4 section 35, T. 38 N., R. 56 E., M.D.M., Coal Mine Basin Quadrangle, Elko County, Nevada (plate 2). Section was measured by use of Brunton compass and steel tape. Standard of reference for color terms used in rock descriptions are according to the "Rock-Color Chart" prepared by the Rock-Color Chart Committee, distributed by the Geological Society of America, Boulder, Colorado.

Elko Formation (Oligocene? and Eocene)

Tuffaceous claystone member	Thickness meters	Thickness feet
29. Claystone, dusky yellowish-brown (10 YR 2/2); to very pale-orange (10 YR 8/2); very well sorted; minute parallel laminae; slightly calcareous.	0.17	0.56
28. Claystone, yellowish-gray (5 Y 7/2), weathers white (N 9) with limonite stain; tuffaceous; minute parallel laminae; siliceous.	0.13	0.43
27. Claystone, moderate-yellowish-brown (10 YR 5/4), weathers pale-grayish-orange (10 YR 8/4); tuffaceous; poorly consolidated; very well sorted, siliceous.	1.50	4.92
26. Claystone, very pale-orange (10 YR 8/2); tuffaceous; very well sorted; well indurated; indistinct convoluted laminae; calcareous; faint petroliferous odor emitted upon application of dilute HCl.	0.25	0.82
25. Claystone, mottled olive-gray (5 Y 4/1) and very pale-orange (10 YR 8/2); clay partings; tuffaceous; knobby texture; indistinct wavy laminae; weathers platy up to 2.5 cm thick; calcareous; strong fetid petroliferous odor emitted when fresh surface broken.	0.50	1.64
24. Oil shale and minor claystone; oil shale, dusky yellowish-brown (10 YR 2/2); weathers into platy		

	Thickness meters	feet
to flaggy layers up to 3 cm thick, minute parallel laminae, minor clay partings; claystone, moderate-yellowish-brown (10 YR 5/4), weathers very pale-orange (10 YR 8/2); well sorted; poorly consolidated; soapy texture (bentonitic); siliceous.	0.96	3.15
23. Claystone, very pale-orange (10 YR 8/2); minute parallel laminae; tuffaceous; calcareous; weathers into platy to flaggy layers up to 3 cm thick; poorly exposed.	3.20	10.50
22. Oil shale, moderate-brown (5 YR 3/4); weathers paper-thin; tuffaceous; well sorted; minute plant fragments; clay partings, dark-yellowish-orange (10 YR 6/6); siliceous.	0.18	0.59
21. Claystone; same as unit 23.	1.10	3.61
20. Tuff, very light-gray (N 7) to white (N 9); very well sorted, very fine grained; compact, weathers blocky with limonite stain, dark-yellowish-orange (10 YR 6/6); siliceous.	1.50	4.92
19. Siltstone and claystone; intercalated, very pale-orange (10 YR 8/2) to white (N 7); tuffaceous; fossiliferous, contains molds of fingernail? clams to 5 mm in diameter; clay partings; calcareous.	1.20	3.94
18. Tuff; same as unit 20.	0.80	2.63
17. Claystone, siltstone, and minor calcite; claystone, weathers very pale-orange (10 YR 8/2) to white (N 9); minute wavy indistinct clay-rich laminae, grayish-orange (10 YR 7/4); very fine grained, well-sorted; well indurated; tuffaceous; calcareous; weathers shaly to 5 cm thick; faint petroliferous odor emitted upon contact with dilute HCl; intercalated siltstone same as unit 19, nonfossiliferous; calcite vein 13 cm thick at base of unit.	3.67	12.04
16. Claystone and siltstone; same as unit 17.	4.26	13.98
15. Tuff, very light-gray (N 8) to white (N 9); very well sorted, very fine-grained; dense; siliceous; weathers blocky; limonite stain dark-yellowish-orange (10 YR 6/6) along surface; minute hornblende $\frac{1}{8}$ 1 mm long.	0.51	1.67
14. Claystone and siltstone; similar to unit 17,		

	Thickness meters	feet
upper 40 cm siliceous.	1.40	4.59
13. Claystone, weathers from lower to upper portion, light-gray (N 7) to light-olive-gray (5 Y 6/1) to yellowish-gray (5 Y 7/2); semi-consolidated; tuffaceous; siliceous; weathers in angular fragments 8 to 10 cm across, spheroidal fracture; lower portion of unit has soapy texture, bentonitic, abundant fine-to medium-grained biotite oriented subparallel to bedding.	1.10	3.60
12. Siltstone and minor oil shale; siltstone weathers very pale-orange (10 YR 8/2); tuffaceous; calcareous; fossiliferous, plant fragments to 4 mm long, ostracodes poorly preserved; weathers into flaggy layers to 2 cm thick; clay partings, minute wavy parallel laminae; well sorted; intercalated with minor oil shale; oil shale weathers same as unit 22; ranges from <5 mm to 3 cm thick, comprises about 15 percent of unit.	1.70	5.58
11. Claystone, weathers pale-yellowish-brown (10 YR 6/2) to very pale-orange (10 YR 8/2) with minor limonite stain moderate-yellowish-brown (10 YR 5/4); tuffaceous; very well sorted; shale partings; fine parallel laminae; minute plant fragments in clay partings; calcareous.	0.80	2.63
10. Claystone, very pale-orange (10 YR 8/2), weathers very pale-yellowish-brown (10 YR 7/2); tuffaceous; very well sorted; well indurated; minute indistinct wavy parallel laminae; calcareous; a 2 cm bed at base of unit is weathered moderate-yellowish-brown (10 YR 5/4); poorly consolidated; no apparent laminae; siliceous.	0.37	1.21
9. Claystone, weathers very pale-yellowish-brown (10 YR 7/2) to white (N 9); tuffaceous; very well sorted; minute parallel laminae; slightly fossiliferous, plant fragments to 1.5 cm long, well indurated; shale partings to 3 cm thick; calcareous; faint petroliferous odor emitted with application of dilute HCl.	0.54	1.77
8. Sandstone, weathers very pale-orange (10 YR 8/2); composed of dark-grey, white, and brown chert and white feldspar; fine to medium grained, poorly sorted; tuffaceous; minor intercalated lenses of siltstone and claystone, similar to unit 17, with no apparent laminae; bentonitic with minute biotite; iron stain around biotite and disseminated in matrix; faint petroliferous		

	Thickness meters	feet
odor emitted with application of dilute HCl.	0.48	1.58
7. Claystone, very pale-orange (10 YR 8/2), weathers white (N 9); tuffaceous; very well sorted; minute parallel laminae; well indurated; weathers into blocky to flaggy layers 5 cm thick; calcareous; occasional anastomosing depressions along bedding surface filled with organic clay (burrows ?) and minute weathered biotite; weathers dark-yellowish-brown (10 YR 4/2).	3.93	12.89
6. Claystone, dark-yellowish-brown (10 YR 4/2) and minor pale-yellowish-brown (10 YR 6/2), weathers very pale-orange (10 YR 8/2) and white (N 9); tuffaceous; very well sorted; minute parallel laminae; weathers platy to blocky; clay and shale partings, calcareous; fossiliferous, ostracodes poorly preserved at bottom 10 cm and top 1.1 m of unit; above the ostracodes near the base of the unit 20 cm thick poorly consolidated claystone, moderate-yellowish-brown (10 YR 5/4); well sorted; non-fossiliferous; siliceous.	2.60	8.53
5. Claystone, weathers moderate-brown (5 YR 4/4); poorly consolidated; very well sorted; no apparent laminae; non-fossiliferous, siliceous.	0.60	1.97
4. Siltstone and claystone; similar to unit 19, laminae not apparent to indistinct, wavy; calcareous; slight petroliferous odor emitted with application of dilute HCl; locally weathers platy; minor disseminated limonite staining dark-yellowish-orange (10 YR 6/6).	4.14	13.58
3. Siltstone, weathers very pale-orange (10 YR 8/2) to white (N 9); tuffaceous; very well-sorted; no apparent laminae; weathers massive, blocky; calcareous.	0.52	1.71
2. Claystone and siltstone; very pale-yellowish-brown (10 YR 7/2), weathers very pale-orange (10 YR 8/2) to white (N 9); tuffaceous; weathers into blocky to platy layers 5 mm thick; minute parallel laminae; well sorted; fossiliferous, containing ostracodes in the lower half of unit, plant fragments to 3 mm across, local clay partings; calcareous; middle of unit has moderate-brown (5 YR 3/4) paper-thin clay deposits localized in depressions of subparallel ropey-textured calcareous claystone.	3.85	12.63

	Thickness meters	Thickness feet
1. Claystone, dusky yellow (5 Y 6/4), weathers grayish-yellow (5 Y 8/4) to white (N 9); well sorted; fine-grained biotite oriented parallel to bedding; poorly consolidated; soapy texture (bentonitic); siliceous.	0.13	0.43
Total thickness of tuffaceous claystone member (Tetc)	42.09	138.09

Elko Formation (Oligocene? and Eocene)
Oil-shale member, conformable contact with the overlying tuffaceous claystone member

Oil-shale member

	Thickness meters	Thickness feet
20. Oil shale, moderate-brown (5 YR 3/4 and 5 YR 4/4); minute, indistinct, wavy laminae; distinct petroliferous odor when fresh surface broken; subparallel laminae paper-thin; minute plant fragments; tuffaceous; shale partings; calcareous.	0.35	1.15
19. Limestone, grayish-orange-pink (5 YR 7/2); tuffaceous; very well sorted; silty; faint, wavy, parallel laminae; weathers platy up to 7 mm thick; fossiliferous, unidentifiable shell (ostracodes?) 1 mm across, minute plant fragments; calcareous.	1.32	4.33
18. Oil shale and claystone; oil shale, moderate-brown (5 YR 3/4) to dusky brown (5 YR 2/2); limonite stain on surface dark-yellowish-orange (10 YR 6/6); weathers paper-thin; indistinct, wavy, subparallel laminae; fossiliferous, minute plant fragments and whole leaves to 1.7 cm; claystone, light-olive-gray (5 Y 5/2); limonite stain; semiconsolidated; no apparent laminae; tuffaceous; well sorted; two beds 5 cm and 14 cm thick.	0.59	1.94
17. Claystone, and minor oil shale; claystone, light-olive-brown (5 Y 5/6), weathers off-white with limonite stain, dark-yellowish-orange (10 YR 6/6); semiconsolidated; weathers blocky to 7 mm thick; spheroidal surfaces; well sorted; abundant calcite veinlets to 2 mm thick; possibly gouge of bedding plane fault?; calcareous; minor oil shale same as unit 18.	0.11	0.36
16. Limestone and minor claystone; limestone, pale-yellowish-brown (10 YR 6/2), weathers very pale-orange (10 YR 8/2); lower 60 cm and upper 75 cm		

	Thickness meters	feet
weathers platy to 2 cm; very thin wavy laminae, tuffaceous; calcareous; minor claystone, weathers yellowish-gray (5 Y 7/2); very well sorted, calcareous.	1.74	5.71
15. Claystone, oil shale and minor limestone; claystone, weathers very pale-orange (10 YR 8/2); weathers platy to blocky up to 8 cm thick; tuffaceous; minute parallel laminae; shale partings; calcareous; oil shale, moderate-brown (5 YR 3/4); weathers paper-thin, intercalated clay; at base of unit two beds 47 cm and 40 cm thick, top half of unit comprised of oil shale up to 5 cm thick intercalated with clay; minor limestone; similar to unit 16.	8.25	27.07
14. Oil shale, moderate-brown (5 YR 3/4); weathers paper-thin; thin, wavy, indistinct parallel laminae; siliceous; fossiliferous containing ostracodes, fish bones, and plant fragments, poorly sorted, minute to 3 cm long; calcite veinlets up to 5 mm thick parallel to bedding.	1.05	3.45
13. Siltstone, pale-yellowish-brown (10 YR 6/2); minute, indistinct, wavy parallel laminae; nonfossiliferous; tuffaceous; calcite veinlets to 3 mm thick; calcareous; dense; faint petroliferous odor emitted with application of dilute HCl.	0.30	0.98
12. Oil shale, grayish-brown (5 YR 3/2); weathers pale-brown (5 YR 5/2); weathers paper-thin; wavy, indistinct parallel laminae; nonfossiliferous; very well sorted; clay partings; calcite veins up to 10 cm thick, parallel to bedding.	1.53	5.02
11. Siltstone, pale-yellowish-brown (10 YR 6/2), weathers light-gray (N 7); tuffaceous; well sorted; thin indistinct laminae; calcareous; weathers blocky; faint petroliferous odor emitted with application of dilute HCl.	0.50	1.64
10. Oil shale, minor claystone and calcite; oil shale moderate-brown (5 YR 3/4); weathers paper-thin; thin, indistinct parallel laminae; fossiliferous, containing ostracodes and minor leaf fragments; minor claystone,same as unit 15, with calcite veins up to 8 cm thick parallel to bedding.	2.45	8.04
9. Claystone, grayish-orange-pink (5 YR 7/2), weathers very pale-orange (10 YR 8/2);		

	Thickness meters	feet
tuffaceous; porous; chalk-like; minute laminae; very well sorted; minor leaf fossils are poorly preserved; weathers to 2 cm thick; calcareous; petroliferous odor emitted with application of dilute HCl.	0.36	1.18
8. Claystone, pale-yellowish-brown (10 YR 6/2) to very pale-orange (10 YR 8/2); weathers blocky; very well indurated; minute, wavy, indistinct laminae to no apparent laminae; tuffaceous; slightly calcareous; conchoidal fracture; petroliferous, emits a fetid odor with application of dilute HCl; minor irregular cherty zones, dark-yellowish-brown (10 YR 4/2) to dusky yellowish-brown (10 YR 2/2).	1.00	3.28
7. Claystone, lower portion weathers grayish-brown (5 YR 3/2), upper portion to moderate-brown (5 YR 3/4); very well sorted; poorly consolidated; no apparent laminae; nonfossiliferous; siliceous.	1.63	5.35
6. Claystone, weathers grayish-orange (10 YR 7/4), with limonite stain dark-yellowish-orange (10 YR 6/6); very well sorted; soapy texture (bentonitic?); semi-consolidated; weathers blocky with some spheroidal surfaces; siliceous.	0.30	0.98
5. Claystone and oil shale; claystone, upper 70 cm ranges from pale-yellowish-brown (10 YR 6/2) to very pale-orange (10 YR 8/2); minute, parallel laminae with minor looped bedding; tuffaceous; calcareous; weathers blocky to 5 cm; conchoidal fracture; minor microfractures with minute displacement; some cracks filled with siltstone and clay; petroliferous odor emitted upon application of dilute HCl; oil shale similar to unit 10, with clay partings; grades upward into claystone, dark-yellowish brown (10 YR 4/2); poorly consolidated; no apparent laminae; siliceous.	1.15	3.77
4. Oil shale and claystone; oil shale similar to unit 10; claystone similar to unit 5.	0.90	2.95
3. Oil shale and calcite; oil shale similar to unit 12; calcite abundant up to 10 cm thick, exhibit "cone-in-cone" structures to 5 cm thick; minor clay partings.	1.90	6.23
2. Claystone and oil shale; claystone, similar to unit 9; oil shale dark-yellowish-brown		

	Thickness meters	feet
(10 YR 4/2); paper-thin; clay partings; friable; tuffaceous; siliceous; contains minute plant fragments.	0.95	3.12
1. Claystone, olive-gray (5 Y 4/1), weathers light-gray (N 7); poorly consolidated; no apparent laminae; limonite stain, dark-yellowish-orange (10 YR 6/6); minor gypsum flakes to 5 mm long.	0.28	0.92
Total thickness of the oil-shale member (Teo)	26.66	87.47

Elko Formation (Oligocene? and Eocene)
Claystone member in fault contact with oil-shale member, displacement a few meters.

Claystone member

	Thickness meters	feet
61. Claystone, pale yellowish-brown (10 YR 6/2), weathers very pale-orange (10 YR 8/2); tuffaceous; calcareous; emits a faint petroliferous odor with application of dilute HCl; wavy and indistinct laminae with thin clay partings; very fine grained, well sorted; mottled texture; thickness approximate due to fault contact with middle member.	0.22	0.72
60. Limestone, pale-brown (5 YR 5/2); cherty; blocky; conchoidal fracture; matrix very fine grained; tuffaceous; wavy and indistinct laminae with minor irregular cross beds.	0.90	2.95
59. Claystone, light-olive-gray (5 Y 5/2); siliceous; very well sorted; waxy texture (fault gouge?); semiconsolidated, forms blocky subangular chunks; minor veinlets of gypsum.	0.20	0.66
58. Limestone, yellowish-gray (5 Y 8/1); tuffaceous; calcareous; very well sorted; porous; weathers blocky; fossiliferous with shell impressions, shells not preserved (fingernail clams?) to 8 mm in diameter.	0.55	1.81
57. Claystone, moderate-brown (5 Y 4/4); very well sorted; semiconsolidated; very soapy texture (fault gouge?); siliceous; minor gypsum veinlets.	1.20	3.94
56. Limestone, ranges from pale-yellowish-brown (10 YR 6/2) to very pale-orange (10 YR 8/2); porous; generally poorly sorted with angular to subrounded rip-up clasts to 2 cm across;		

	Thickness meters	feet
matrix very fine grained; tuffaceous; some horizontal laminae 1 mm to 2 mm in basal and upper portion of unit, upper portion weathers platy, center portion of unit blocky; poorly sorted with rip-up clasts and black chert stringers (replaced plant material?) parallel to subparallel with bedding; cherty zones, dusky brown (5 YR 2/2) to black (N 1); limestone emits fetid petroliferous odor with application of dilute HCl.	1.97	6.46
55. Oil shale and claystone; oil shale dark-brown (10 YR 4/2), weathers pale-yellowish-brown (10 YR 6/2) into paper-thin layers intercalated with clay; beds 5 to 10 mm thick; friable; claystone, well sorted; siliceous; up to 10 cm thick; minor calcite veinlets parallel to bedding.	2.64	8.66
54. Siltstone, very pale-orange (10 YR 8/2); tuffaceous; very fine grained, poorly sorted; blocky; petroliferous odor emitted when dilute HCl applied; fossiliferous, broken shell and plant fragments, subangular to subrounded; no apparent laminae.	1.08	3.54
53. Oil shale and minor claystone; oil shale grayish-brown (5 YR 3/2) to pale-brown (5 YR 5/2); tuffaceous; weathers in plates up to 2 cm thick to paper-thin; siliceous in upward portion; weathers flaggy up to 4 cm thick; thin wavy indistinct laminae; fossiliferous, whole leaves (<u>Metasequoia</u>?), and plant fragments <1 mm; claystone, pale-yellowish-brown (10 YR 6/2); weathers white (N 9); tuffaceous, 70 cm thick; very weathered; friable; siliceous; with minor gypsum veinlets.	5.01	16.44
52. Claystone, very pale-orange (10 YR 8/2); silty; very well sorted; weathers blocky; siliceous; semiconsilidated, soapy texture on fresh surface (fault gouge?).	0.33	1.08
51. Oil shale and lignite; oil shale in upper 3.20 m dusky brown (5 YR 2/2) and grayish-brown (5 YR 3/2); silty; thin, wavy, indistinct laminae; weathers paper-thin to friable subangular pieces <5 mm; tuffaceous; very light weight and porous; intercalated with thin charcoal beds up to 1.5 cm thick; oil shale in lower portion of unit similar to above description with little or no charcoal, weathers in plates up to 2.5 cm thick to paper-thin beds; fossiliferous, whole leaves and plant fragments parallel to horizontal bedding, ostracodes abundant at base; weathered oil		

	Thickness meters	feet
shale will burn without flame and emit petroliferous odor when lighted; lignite, pale-brown (5 YR 5/2); silty; porous; tuffaceous; unidentifiable plant fragment remains with thin charcoal lenses.	5.44	17.85
50. Claystone, moderate-brown (5 YR 3/4); siliceous; fossiliferous, abundant broken plant remains to 8 mm long; shiny texture on fresh surface; semiconsolidated; lower 1 m similar to above description without plant fragments.	3.20	10.50
49. Claystone, dark-yellowish-brown (10 YR 4/2), weathers pale-yellowish-brown (10 YR 6/2); siliceous; semiconsolidated; matrix well sorted, minute plant fragments to 2 mm long.	0.15	0.49
48. Lignite and charcoal; same as lignite and charcoal of unit 51.	1.10	3.61
47. Claystone, pale-brown (5 YR 5/2), weathers grayish-orange-pink (5 YR 7/2); faint parallel laminae; fossiliferous with leaves and broken plant remains; semiconsolidated.	0.30	0.98
46. Lignite, moderate-brown (5 YR 3/4); with thin black charcoal lenses to 0.5 mm thick; parallel laminae; dry woody texture; porous; breaks easily.	0.73	2.40
45. Claystone and siltstone; claystone, moderate-brown (5 YR 3/4); matrix very well sorted at top of unit; lenses of carbonized plant fragments up to 2 cm long; siltstone at base of unit similar to claystone description with paper-thin interbeds of claystone.	1.36	4.46
44. Siltstone and minor sandstone; siltstone, pale-brown (5 YR 5/2); very light porous texture; tuffaceous; siliceous; fairly well sorted matrix; minute plant fragments; charcoal lenses to 2 mm thick; sandstone, fine grained; subrounded light-gray, white, and black chert, quartz, and feldspar to 2 mm in diameter; poorly consolidated; friable; tuffaceous clay matrix; and minute lenses of siltstone.	0.61	2.00
43. Claystone and minor lignite; claystone, dark-yellowish-brown (10 YR 4/2) in upper portion of unit; semiconsolidated; no apparent bedding; lower portion of unit grayish-brown (5 YR 3/2); similar to upper portion; lignite same as unit		

	Thickness meters	feet
46; thickness approximate due to small bedding plane fault, displacement probably on the order of a few meters.	1.00	3.28
42. Sandstone and minor claystone; sandstone, medium-gray (N 5), weathers light-gray (N 7), ranges from fine to coarse grain, similar to unit 44, but coarser and poorly sorted; intercalated with 2-to 5-mm-thick claystone lenses same as in unit 43.	2.30	7.55
41. Claystone, lower 2 cm, grayish-brown (5 YR 3/2), weathers pale-brown (5 YR 5/2); poorly consolidated, no apparent laminae; upper portion dark-yellowish-brown (10 YR 6/2), contains disseminated plant fragments to 1 mm long, waxy texture.	0.75	2.46
40. Lignite and claystone; lignite, grayish-brown (5 YR 3/2), weathers pale-brown (5 YR 5/2); indistinct wavy laminae with intercalated charcoal lenses up to 2 mm thick; tuffaceous; claystone same as lower portion of unit 41.	1.60	5.25
39. Claystone; lower 20 cm same as lower portion unit 41, upper 1 m similar to upper portion unit 41.	1.20	3.94
38. lignite, moderate-brown (5 YR 3/4); very fine indistinct laminae; carbonized plant fragments; very dry; porous; friable; siliceous; tuffaceous; three black charcoal lenses less than 3 cm thick.	1.60	5.25
37. Siltstone, dark-yellowish-brown (10 YR 4/2), weathers pale-yellowish-brown (10 YR 6/2); conchoidal fracture; tuffaceous; siliceous; very well sorted; porous; with thin surficial coat of powdery yellow jarosite; faint parallel laminae; minor platy shale partings; leaf fragments up to 5 cm long.	2.34	7.68
36. Oil shale and minor siltstone; oil shale dark-yellowish-brown (10 YR 4/2); thin indistinct wavy subhorizontal laminae <1 mm thick; intercalated white tuffaceous material; fossiliferous, abundant whole leaves (Metasequoia) and fragments parallel to bedding; siliceous; weathers platy to 2.5 cm thick; siltstone, moderate-yellowish-brown (10 YR 5/4); intercalated paper-thin oil shale; very fine grain; well sorted; fossiliferous, disarticulated fish, fingernail clam (Sphaerium?), Samara (winged-nut seed).	0.70	2.30

	Thickness meters	feet
35. Siltstone, pale-yellowish-brown (10 YR 6/2), weathers light-yellowish-brown (10 YR 7/2); tuffaceous; blocky; very well indurated; fossiliferous, plant fragments to 2 mm long; faint parallel laminae; very fine grained; siliceous.	0.30	0.98
34. Oil shale, grayish-orange (10 YR 7/4); weathers paper-thin; fossiliferous, ostracodes to 1 mm in diameter, poorly preserved; faint petroliferous odor on freshly broken surface; calcareous; small joint fillings of calcite along bedding planes to 2 mm thick.	0.44	1.44
33. Limestone, dusky yellow (5 Y 7/4), weathers grayish-yellow (5 Y 8/4); silty; very well sorted; weathers blocky up to 5 cm thick; very well consolidated; emits slight petroliferous odor when fresh surface broken; calcareous; fossiliferous, sparse fragments of plant (root) material to 2 mm long; porous; tuffaceous.	0.13	0.43
32. Claystone, olive-gray (5 Y 4/1), weathers light-olive-gray (5 Y 6/1); very well sorted; nonfossiliferous; semiconsolidated; siliceous; no apparent laminae.	1.70	5.58
31. Claystone and minor lignite; claystone, moderate-brown (5 YR 3/4), weathers moderate-brown (5 YR 4/4); tuffaceous; very well sorted; lignite same as unit 40, small lenses paper-thin black charcoal.	0.40	1.31
30. Clay, dusky yellow (5 Y 6/4), weathers light-dusky yellow (5 Y 7/4), very well sorted; weathers spheroidal; soapy texture (fault gouge?); very friable when dry, poorly consolidated.	0.95	3.12
29. Lignite, light-grayish-brown (5 YR 4/2), weathers pale-brown (5 YR 5/2); poorly sorted; matrix silty; fossiliferous, plant fragments; faint parallel laminae.	0.15	0.49
28. Claystone, lower 50 cm grayish-brown (5 YR 3/2), weathers pale-brown (5 YR 5/2); upper 1.30 m dusky yellowish-brown (10 YR 6/2); semiconsolidated; no apparent laminae; siliceous.	1.80	5.91
27. Lignite, pale-brown (5 YR 5/2); dry; friable; poorly consolidated; tuffaceous; contains fossiliferous plant fragments, leaves; abundant		

	Thickness meters	Thickness feet
limonite stain dark-yellowish-orange (10 YR 6/6); minor charcoal lenses in lower portion of unit up to 3 mm thick; friable.	0.30	0.98
26. Siltstone, grayish-brown (5 YR 3/2), weathers pale-brown (5 YR 5/2); minor plant fragments to 3 mm long; intercalated with thin charcoal lenses to 4 mm thick.	0.40	1.31
25. Lignite, pale-brown (5 YR 5/2), weathers grayish-orange-pink (5 YR 7/2); silty; clay-rich; top portion weathers paper-thin; fissile; indistinct laminae; fossiliferous, plant fragments, whole leaves (Metasequoia?); siliceous; tuffaceous; lignite will burn without flame when thin fresh surface subjected to flame of lighter; minor thin coating of yellow powdery jarosite along surfaces.	0.48	1.58
24. Claystone, grayish-olive (10 Y 4/2), weathers pale-olive (10 Y 6/2); very well sorted; siliceous; poorly consolidated; no apparent laminae.	0.83	2.72
23. Sandstone, medium-gray (N 5) weathers to very light-gray (N 8); very poorly sorted; coarse grained, clasts subrounded to 5 mm in diameter, clasts composed of black, light-gray, and dark-gray chert; clasts weather out of clay-rich matrix, light-olive-gray (5 Y 6/1); very poorly indurated.	0.30	0.98
22. Claystone and minor sandstone; claystone partiallcovered by slump, color ranges in sequence from top to base: moderate-olive-brown (5 Y 4/4), moderate-brown (5 YR 3/4), light-olive-gray (5 Y 5/2), pale-brown (5 YR 5/2); massive; poorly consolidated; no apparent laminae; very well sorted; siliceous; minor sandstone at base, similar to unit 23, fine-to medium-grained.	3.11	10.20
21. Claystone, dusky brown (5 YR 2/2), weathers pale-brown (5 YR 5/2); very well sorted; minor amounts of minute plant fragments; siliceous.	0.30	0.98
20. Claystone, brownish-gray (5 YR 4/1); abundant minute plant fragments; semiconsolidated; siliceous; no apparent laminae.	0.25	0.82
19. Sandstone and minor claystone; similar to unit 23; claystone beds intercalated with sandstone beds abundant in top 28 cm up to beds 6 cm thick.	0.85	2.79
18. Claystone, dark-yellowish-brown (10 YR 4/2),		

	Thickness meters	feet
weathers pale-yellowish-brown (10 YR 6/2); well sorted; minute fragments of plant material; no apparent laminae.	0.45	1.48
17. Lignite, light-grayish-brown (5 YR 4/2), weathers very pale-brown (5 YR 6/2); matrix very fine grained; well sorted; broken plant fragments; minute black charcoal lenses; minor gypsum in thin zones to 5 mm thick; dry; friable; light; porous; surface covered with thin coating of powdery yellow jarosite.	0.58	1.90
16. Claystone, weathers pale-yellowish-brown (10 YR 6/2) at lower 1 m; upper portion weathers light-gray (N 7); well sorted; no apparent laminae; nonfossiliferous; siliceous	1.95	6.40
15. Lignite; same as unit 27.	0.87	2.85
14. Claystone and minor lignite; claystone, light-grayish-brown (5 YR 4/2) weathers pale-brown (5 YR 5/2); very well sorted matrix; semi-consolidated; siliceous; faint subparallel laminae; minute plant fragments; minor lenses of lignite, dusky brown (5 YR 2/2); 3 beds 10 to 30 cm thick; thin charcoal lenses to 4 mm thick; friable.	0.43	1.41
13. Claystone and lignite; claystone, light-grayish-brown (5 YR 4/2), weathers very pale-brown (5 YR 6/2); matrix very well sorted; tuffaceous; faint subparallel laminae; abundant plant fragments minute to 1 cm long, leaves (Metasequoia?); light; porous; minor lignite; same as unit 17.	0.43	1.41
12. Oil shale, dusky brown (5 YR 2/2) to pale-brown (5 YR 5/2), weathers light gray (N 7); thin wavy indistinct laminae; poorly sorted; fossiliferous, minute broken plant fragments, disarticulated fish scales, bones; siliceous; tuffaceous; weathers platy to 7 mm thick.	0.45	1.48
11. Limestone with minor oil shale; limestone, grayish-orange (10 YR 7/4), weathers to very light-gray (N 8); well sorted, very fine grained; tuffaceous; clay-rich; minute parallel laminae; petroliferous odor when fresh surface broken; fossiliferous, ostracodes; calcareous; minor oil shale; same as unit 12.	0.37	1.21
10. Lignite, grayish-brown (5 YR 3/2), weathers		

	Thickness meters	feet
pale-brown (5 YR 5/2); upper portion platy; friable; wavy subparallel laminae; abundant minute plant fragments; blocky lower portion; well-indurated; tuffaceous; minor charcoal beds up to 2 mm thick; siliceous.	4.85	15.91
9. Claystone, very dark-yellowish-brown (10 YR 4/2), weathers pale-yellowish-brown (10 YR 6/2); semi-consolidated; fossiliferous, plant fragments minute to 4 mm long; tuffaceous; minute parallel laminae; siliceous.	0.27	0.89
8. Lignite; same as unit 10; upper 20 cm platy; lower portion blocky.	0.38	1.25
7. Claystone; same as unit 18 in lower 27 cm; upper portion grayish-brown (5 YR 3/2), weathers pale-brown (5 YR 5/2); charcoal lenses to 4 mm thick; siliceous.	1.27	4.17
6. Limestone, weathers grayish-orange (10 YR 7/4); platy to 5 mm thick; silty; fossiliferous, containing fingernail clams, disarticulated fish scales, bones; petroliferous odor emitted when when fresh surface broken; minor gypsum crystals to 5 mm long.	0.85	2.79
5. Claystone; upper 92 cm weathers yellowish-gray (5 Y 7/2); middle 1.08 m weathers dusky yellow (5 Y 6/4); lower 1.50 m weathers light-gray (N 7); well sorted; poorly consolidated; nonfossiliferous; no apparent laminae; siliceous.	3.50	11.48
4. Conglomerate and claystone; conglomerate, weathers medium-light-gray (N 6); very poorly sorted; chert-pebbles to 10 cm in diameter; chert pebbles dark-gray, light-gray, minor black, white; well rounded; poorly indurated; intercalated claystone, weathers yellowish-gray (5 Y 8/1); one bed 10 cm thick.	1.15	3.77
3. Sandstone and claystone; sandstone; similar to unit 23, fine to medium grained; claystone; same as unit 4; fairly well indurated; siliceous.	1.05	3.45
2. Claystone and minor lignite; claystone, dusky brown (5 YR 2/2), weathers pale-brown (5 YR 5/2); indistinct wavy laminae; intercalated with clay, dark-yellowish-orange (10 YR 6/6) and lignite; lignite to 4 mm thick; same as unit 27.	0.20	0.66
1. Conglomerate and claystone; same as unit 4.	0.30	0.98
Total thickness of claystone member (Tec)	70.52	231.37

Appendix C-2

Fischer assay report of analysis of Elko Formation, Trench COS-1, Coal Mine Canyon, Elko County, Nevada. Oil yields are minimum values based on analysis of weathered surface samples. Fischer assay by L. G. Trudell, Laramie Energy Technology Center, Laramie, Wyoming.

Sample		Yield of Product						Specific gravity of oil at 60/60°F
		Weight Percent				Gallons per ton		
Unit	Number	Oil	Water	Spent Shale	Gas & loss	Oil[1]	Water	
Tuffaceous claystone member (Tetc)	25	0.2	2.0	96.8	1.0	0.4a	4.8	-
	4	2.1	5.0	91.2	1.7	5.7	12.0	0.875
	22	2.2	7.0	88.6	2.2	6.0	16.8	0.894
	14(2)	0.0	0.5	97.9	1.6	trace	1.2	-
	14(1)	0.5	7.0	90.8	1.7	1.2a	16.8	-
	11	1.8	2.7	94.0	1.5	4.8a	6.5	-
	10	0.0	0.5	98.6	0.9	trace	1.1	-
	6(3)	1.6	2.3	94.6	1.5	4.2a	5.5	-
	6(2)	0.9	1.7	96.0	1.4	2.4a	4.1	-
	6(1)	3.1	4.0	90.3	2.6	7.9	9.6	0.926
	4	0.8	1.9	96.4	0.9	2.0a	4.6	-
	2	0.2	2.0	97.3	0.5	0.4a	4.8	-
Oil-shale member (Teo)	20	1.7	5.0	90.2	3.1	4.4a	12.0	-
	19	0.6	0.9	97.6	0.9	1.5a	2.2	-
	18(2)	9.7	10.9	73.2	6.2	25.2	26.1	0.918
	18(1)	2.1	2.9	93.2	1.8	5.6	7.0	0.920
	17	10.3	11.9	72.7	5.1	26.9	28.5	0.915
	16(3)	0.0	1.6	97.0	1.4	trace	3.8	-
	16(2)	0.0	1.1	98.3	0.6	trace	2.6	-
	16(1)	0.0	0.3	98.7	1.0	trace	0.7	-
	15	0.0	0.9	98.1	1.0	trace	2.2	-
	14(2)	7.5	13.0	74.5	5.0	19.8	31.2	0.914
	14(1)	6.3	15.0	72.5	6.2	16.3	36.0	0.920
	13	0.1	0.3	99.2	0.4	0.3a	0.7	-
	12	6.3	13.0	75.6	5.1	16.5	31.2	0.919
	11	0.0	0.6	99.0	0.4	trace	1.3	-
	10	4.6	12.0	79.2	4.2	12.1	28.8	0.905
	7(2)	0.0	9.8	88.6	1.6	trace	23.6	-
	7(1)	0.0	9.3	89.3	1.4	trace	22.4	-
	6	0.0	13.1	86.0	0.9	trace	31.5	-
	4	0.3	0.6	98.4	0.7	0.8a	1.4	-
	3(2)	0.4	1.1	97.9	0.6	1.1a	2.6	-
	3(1)	4.7	5.4	85.6	4.3	12.2a	12.9	0.916
	2	0.5	1.3	97.5	0.7	1.3a	3.1	-
Claystone member (Tec)	61	0.0	0.2	99.2	0.6	trace	0.5	-
	57	0.0	2.6	96.7	0.7	trace	6.3	-
	56	0.0	1.9	96.6	1.5	trace	4.5	-
	55	2.4	6.0	88.5	3.1	6.3	14.4	0.907
	54	0.0	1.6	96.8	1.6	trace	3.8	-
	53	0.9	3.4	94.7	1.0	2.3a	8.1	-
	52	0.0	13.6	85.9	0.5	trace	32.7	-
	51(3)	0.0	10.7	82.0	7.3	trace	25.6	-
	51(2)	0.2	3.1	94.3	2.4	0.6a	7.4	-
	51(1)	5.5	18.5	70.7	5.3	14.5	44.4	-

[1] 'a' indicates specific gravity of oil estimated at 0.920

Appendix C-3

Potassium-Argon age data for a rhyodacite from an unnamed unit above the Elko Formation, Coal Mine Canyon area.

Experiment Number	Material	Weight (grams)	K_2O%	Radiogenic ^{40}Ar		Age (MY)	Estimated Error in Age	
				%	Mol/gm		±MY	%
82I562	Plagioclase	4.8574	.656	21.4063	3.65426×10^{-11}	38.2834	0.392957	1.02644
82I571	Hornblende	3.4777	.804	69.3911	4.76691×10^{-11}	40.7192	0.254459	0.624912
82I577	Biotite	0.3008	8.115	62.8654	4.71066×10^{-10}	39.8764	0.269474	0.675774

Potassium-Argon age data for sample 60479-1, hornblende-biotite rhyodacite, located T. 37 N., R. 56 E., MDM, section 11, NE1/4SE1/4SW1/4NE1/4. Constants used in calculations: $^{40}K = 0.01167$ atm %K

$$\lambda\beta = 4.962 \times 10^{-10} \text{ year}^{-1}$$

$$\lambda\epsilon + \lambda\epsilon' = 0.581 \times 10^{-10} \text{ year}^{-1}$$

Analyses by R.W. Kistler, U.S. Geological Survey, Branch of Isotope Geology, Menlo Park, California.