WASHINGTON'S COAL — HISTORY AND FUTURE DEVELOPMENT POTENTIAL

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INTRODUCTION

Coal is one of the most valuable mineral resources known to occur in Washington. Our coal has the potential to not only supply the needs of the Northwest industry, but also to be a valuable export product to Pacific Rim Countries, such as Japan, Taiwan, and Korea.

At one time, coal exceeded in value all other minerals produced annually in the state. Then it lost its leading position to industrial minerals as the country switched to less costly and available oil and gas. The state, anticipating a reversal in the downward trend which coal had taken, reevaluated its coal reserves in 1960 using new data that had become available.

The Arab Oil Embargo of 1973 put an end to cheap oil and gas, limiting their future as fuels for electrical generating purposes and increasing the potential for coal. As a result, a renewed interest in the state's coal resources was shown by both U.S. and Canadian exploration companies. The state, recognizing the need to again evaluate this valuable resource, initiated a coal program to first look at its own holdings on the 2.9 million acres of state land managed by the Department of Natural Resources. This program was expanded to evaluate the coal resources in other areas as well. This effort was to provide information which would be useful to exploration companies looking for coal deposits to mine, and to planners as a basis for making decisions on urban growth and development.

This paper will discuss the history of coal mining in the state, the current status of mining and exploration, the coal program of the Washington Division of Geology and Earth Resources, and the future development potential of Washington's coal resources.

Geographic and Geologic Setting

Most of the commercially significant coal deposits in the State of Washington occur in a discontinuous belt that extends southward from near the Canadian border in Whatcom County to the Columbia River in Cowlitz County (figure 1). The Kittitas County coal fields, situated on the east flank of the Cascades, in the center of the state, are a notable exception. In addition, coal occurs in a number of small, isolated areas in other parts of the state.

All of the coal in the state is of Tertiary age with the exception of several thin beds of semi-anthracite of pre-Tertiary age on Orcas Island in San Juan County. Most of the significant coal deposits are found in Eocene age rocks where they were formed in swamps occurring along the eastern margin of a north-south depositional basin. The coal-bearing rocks typically grade into, or interfinger with, marine-equivalent rocks to the west that are non-coal-bearing. Deposition and volcanism were contemporaneous in many parts of the basin, accounting for locally high ash levels in the coal. In some places volcanic rocks are the lateral equivalents of the coal-bearing sequence.

The degree of structural folding and faulting of the rocks in all coal-bearing areas varies greatly. In the Roslyn field, and in the Centralia-Chehalis district, and Kelso-Castle Rock area the rocks are gently folded into broad folds with dips commonly less than 30°. By contrast, the coal sequence of the Wilkeson-Carbonado district has been deformed into a series of plunging folds, dominated by a northwest-trending anticline, all of which have been further complicated by normal and high-angle reverse faulting. Dips of 60° or more are common in this field. Coal deposits of southeastern King County display similar characteristics, but to a somewhat lesser degree.

Coal Rank and Reserves

The rank of Washington's coal ranges from lignite in the southwestern part of the state to anthracite in the Glacier field in north-central Whatcom County (figure 2). In general, the rank increases with age: early to middle Eocene deposits are bituminous rank coals, most late Eocene deposits are subbituminous rank coals, and Oligocene deposits are lignites. The anthracite occurrences are found only in small areas of intense deformation.

The coal reserves of Washington remaining in the ground as of January 1, 1960 were estimated to be 6,185 million short tons (Beikman, and others, 1961). Of that total, about 5 million tons was anthracite, 1,869 million tons bituminous, 4,194 million tons subbituminous coal, and 117 million tons of lignite. Since that time, mining has removed 54 million tons[1/] of subbituminous and 2 million tons[2/] of bituminous coal. However, new reserves have been reported by Moen (1969) and Vonheeder (1976) that increase the remaining reserves of bituminous coal in Whatcom County by approximately 53 million tons. Additional coal resources have also been reported for the Green River District of King County (Morris and Ames, 1980) that increase the in-place reserve of bituminous coal by 179 million tons. These totals are summarized in table 1.

Table 1. — *Coal reserves of Washington, 1981, by rank (in millions on tons)*

Anthracite	5
Bituminous	2,099
Subbituminous	4,140
Lignite	117
TOTAL	6,361

[1/] Based on production of clean coal reported to the Division of Geology and Earth Resources (recovery factor of 80 percent, commonly used for strip mining, included.

[2/] A recovery factor of 50 percent was used based on reported tonnage of clean coal, most of which was mined by underground methods.

The resulting total in-place reserves, based on published information, is 6,361 million tons or a net increase of 176 million tons. No doubt the total in-place reserves have been increased by exploratory drilling which has occurred over the past 22 years. Such data remains unpublished as companies wish to keep it proprietary.

HISTORY OF MINING

The earliest recorded discovery of coal in Washington was in 1833 when an Englishman for the Hudson Bay Co. described coal outcrops along the banks of the Toutle River near its junction with the Cowlitz River. In 1848 more coal was found in this area, but there was no mining as coal had no value during that early period of territorial development. The next recorded coal discovery was in 1852 on the shore of Bellingham Bay. Captain William Pattle, while inspecting timber in the area, had his attention called to coal outcrops along the shore by local Indians. He and several men working with him, filed a claim and opened a small mine. They removed a small amount of coal thus initiating mining in the Territory. During the next year, 1853, a more ambitious undertaking was started on one of the partner's claims which resulted in a shipment of 150 tons of coal to San Francisco. In the meantime, 2 miles to the north, a coal seam was exposed as a result of a large tree having been blown down during a storm. This discovery in the fall of 1853 resulted in the formation of the Bellingham Bay Co., and eventual development of coal reserves. Those reserves supported large-scale operations until 1955, despite numerous turnovers in names and managements, fires, and other difficulties.

The early settlers of the territory needed and valued the coal, which was familiar to them. Also, California's population was experiencing a phenomenal growth, and its lack of coal provided an immediate export market and source of much-needed cash. San Francisco was the largest market on the Pacific coast during that time. The coal deposits of Skagit, King, Pierce, and Kittitas Counties were waiting to be discovered. One occurrence after another was found and prospected during the years after the Bellingham Bay discoveries. Coal was discovered in 1853 on Black River, near Renton, and a mine was opened the following year. The coal fields of the Issaquah and Newcastle areas of King County, and the coking coal of the Carbon River and the Wilkeson area of Pierce County, were discovered a few years later. The coals in the Roslyn area of Kittitas County were discovered around 1871 and production commenced in 1886. By this time the industry was well established throughout the coal-producing regions of the state. Annual coal production grew from 5,000 tons in 1860, to 100,000 tons by 1876; by 1888 it exceeded 1 million tons per year. By 1890 coal ranked second in importance to lumber as an export product of Washington.

In the three decades that followed 1890, coal production increased significantly owing to its use as a domestic heating fuel, as well as for fuel for the nation's railroads. Peak production was reached in 1918 when 4.1 million tons of coal were produced. The state record in 1918 was primarily the result of increased demand as oil users switched to coal because of federal allocations of oil for military purposes during World War I.

The period from 1918 to 1970 saw a general decline in coal production, with only a brief interruption around World War II. The annual and cumulative coal production since 1860 is shown in figures 3 and 4. One of the most important factors in the decline was the discovery and exploitation of oil in California. The effects of oil substitution for coal were immediate. Washington had been shipping a significant portion of its coal production to San Francisco from 1880-1900. A peak was reached in 1900 when 700,000 tons, representing more than 25 percent of that year's production, was shipped to San Francisco. By 1907 exports to that city had declined to 90,000 tons and to 50,000 tons by 1912. Shipments of coal to San Francisco ceased in 1919. Furthermore, oil was increasingly imported to the Puget Sound area during this time for industrial and domestic uses, thus competing in the local coal market. Further competition was felt by coals from Wyoming, Utah, Montana and British Columbia when railroad access to Washington was completed by 1910. The coals from these areas burned with less ash and smoke and were less costly to mine.

Railroads were among the first industrial users in western Washington to convert to oil. In 1917 railroads consumed nearly 50 percent of the state's coal output. By 1927 that consumption had declined to 43 percent. Absolute consumption for the same period declined from 2 million to 1.1 million tons as the railroads converted from coal to oil-fueled steam locomotives (Melder, 1931).

There were other factors that contributed to the decline of coal production in Washington. Technological advances resulted not only in the development of substitute fuels but also improved efficiency. Consequently, coal consumption grew more slowly than that for other fuels. The iron smelting industry began to use increasingly available scrap iron and, therefore, needed lesser amounts of coal. Washington's only byproduct coking plant in Seattle, a large purchaser of coking coal, was shut down in 1936. This resulted in a termination of production in 1937 by the Wilkeson Coal and Coke Co. in Pierce County.

The cost of mining coal in Washington was also a significant factor in the decline. Coal in Washington was mined chiefly by underground methods. Because so many of the coal seams have dips of 20° or more, there was a low level of mechanization. Mining had to be done with pick and shovel and blasting, which resulted in low productivity per man-hour and increased mining costs. The steep pitches also made it impossible to separate refuse from the coal at the mine face, therefore requiring washing at the surface. This was significant because the fraction of waste at mines in King and Pierce Counties amounted to 20 to 50 percent of the output. The washing operation often resulted in nut-size coal which was difficult to market because it burned too fast. Consumers preferred the slower burning lump coal from the Rocky Mountain States. Washington coal at the mine head was 30 percent or more expensive than Rocky Mountain competitors and more than 80 percent higher than the national average (Corson, 1974).

With the conclusion of World War I, coal producers were faced with renewed competition by alternate fuel forms, each less expensive and more convenient to use than local coal. Coal production was directly linked to consumer demand.

As that demand decreased, production was reduced accordingly. The construction of large hydro-electric facilities in the state further reduced the need for coal.

Despite large reserves, production continued its downward slide with only a brief interruption around World War II. In the 1960's annual production dropped below 100 thousand tons and hit an all-time low of 51 thousand tons in 1965. This trend was reversed sharply in 1970 with the opening of the Centralia coal-fired thermo-electric plant. Production increased until it reached a plateau of around 5 million tons annually. Current estimates indicate that 4.2 million tons will be mined during 1982.

RENEWED INTEREST IN WASHINGTON COAL

Renewed interest in Washington's coal deposits occurred in the 1970's as a result of two factors. First, the Arab Oil Embargo of 1973 put an end to cheap oil and gas, limiting their future as fuels for electric-generating purposes and increasing the potential for coal. Second, in 1977 the Carter Administration launched its energy program with coal as its cornerstone. An annual 65 percent increase in coal production by the year 1985 was recommended. Utilities and large industrial users of oil were encouraged to convert to coal. Also, the administration proposed a 10-year, $10 billion program to encourage domestic coal production and stimulate development of export markets. As a result, coal bounded into world prominence. There was a great increase in foreign demand for steam and metallurgical coal. At the same time U.S. demand increased sharply.

Such emphasis rekindled interest in the state's coal resources by both American and Canadian exploration companies. Many of the coal fields in the state have been studied in the past decade. A number of them have been drilled to evaluate their resource potential.

Whatcom and Skagit Counties

Although coal mining ceased in Whatcom County in 1955, there was still the possibility that coal would be mined in the future. In 1959 and 1961 the Puget Sound Power and Light Co. undertook exploratory drilling to determine whether sufficient coal was present to operate a steam-electric plant. Eight holes were drilled to depths of approximately 2,000 ft. 5 to 10 miles north of Bellingham. Several coal seams as much as 15 ft. thick were encountered in the drilling. The combination of reserves, coal quality, and projected mining costs, however, was not considered economic to support such a project.

Recent interest has been shown by several major mining and energy companies in the area north of Bellingham. Amax Coal Co. of Denver has been exploring throughout western Washington for the past several years. Last year Amax completed a drilling project between Bellingham and Lynden in the Whatcom basin. Approximately 15,000 ft. of drilling in 11 drill holes was completed. Amax was actively involved in a leasing program last year, and they hope to resume further exploration efforts in 1983.

North American Exploration Co. was reported to have drilled 1,300 ft. last summer in Whatcom County for a major Oklahoma petroleum company.

Utah International, Inc. of Salt Lake City has been engaged in active exploration of Washington coal for the past several years. They were engaged in exploratory drilling in Whatcom and Skagit Counties this past summer.

The only anthracite in Washington occurs in central Whatcom County on the northwestern slopes of Mount Baker. The occurrence of the high-rank coal has provided the incentive for considerable exploration, but to date sufficient work has not been done to unravel the complex geology and provide a meaningful estimate of reserves or mining conditions. A program of exploration and development was undertaken by Canadian-American Exploration Co. and Gates and Fox, Inc., an affiliate, from 1974-1976. Several old adits and tunnels were reopened, some exploratory drilling was accomplished, and coal was removed and sent in for testing.

The only mining in Skagit County was at Cokedale. From 1891 until 1922, when operations were suspended, it produced about 180,000 tons of coal, a large part of which was made into coke. Relatively little exploration has been carried out in Skagit County. Combined reserves of 830 million tons have been estimated for Whatcom and Skagit Counties, based on comparatively limited exploration and development.

King County

The King County coal deposits are located in the central and south-central part of the county. The Green River district, the largest and most extensively mined area, includes all the coal deposits in the south-central part of the county. This area has received much attention in recent years. In 1960 and 1961, United States Smelting and Refining Co. drilled 11 holes over the Kummer or Black Diamond anticline on property controlled by the Palmer Coking Coal Co. Four of the holes confirmed at least five previously uncorrelated coal beds. The five coal beds were estimated to contain 179 million tons of in-place coal (Morris and Ames, 1980).

Palmer Coking Coal Co. is the only producer presently mining in King County. Palmer is currently strip mining underground mine barrier pillars in the McKay and Franklin No. 12 seams. Palmer has also mined the Franklin No.'s 10 and 12 seams by underground methods as recently as 1974, and the Landsburg beds as recently as 1976. Palmer has been producing approximately 5,000 tons of coal annually for the past 3 years. Their coal is used for local institutional and residential heating.

In a press release on August 5th of this year, the Pacific Coast Coal Co. announced plans to develop a new coal mine near Black Diamond on lands leased from Palmer Coking Coal Co. The mine is to be an open-pit type operation with a design production capacity of 250,000 clean tons per year. The coal produced will compete directly with comparable coal from Utah and Wyoming presently being consumed by Washington industry and various federal and state institutions.

Construction was scheduled for late 1982. The mine is expected to begin production by June 1983. Estimated mine life at full production is 16 years. Pacific Coast Coal Co. anticipates that underground mining may once again be economical by the 1990's and could extend the mine life. The new mine will be named the John Henry No. 1. Pacific Coast Coal Co. will join Washington Irrigation and Development Company and Palmer Coking Coal Co. as one of only three coal producers in Washington when it goes into production.

Meridian Land and Minerals Co., a Burlington Northern subsidiary, drilled six holes in their mineral holdings in the Green River area to establish reserves during the summers of 1980 and 1981.

The Newcastle area, in the central part of King County, 8 miles east of Seattle is next in importance. Mining was continuous there from 1863 to 1960, with a lifetime total production of 13 million tons. Because of its close proximity to Seattle, the Newcastle area is rapidly becoming suburbanized. Little interest has been shown by coal exploration companies in this area in recent years.

Kittitas County

Although coal occurs in the Taneum and Manastash areas of Kittitas County, the only area of importance in the past or which offers much likelihood for future development is the Roslyn field. This field has seen a fair amount of exploratory drilling in the past decade or so. The more recent activities include 31 boreholes drilled by Burlington Northern, Inc. in 1978. Three holes were drilled by Amax Coal Co. in 1979. AMCA/Luscar, based in Kentucky, recently evaluated the coal reserves on an area under lease by Petrominerals of Santa Ana, California, in the Roslyn and Cle Elum area and believes there is a potential reserve base of 30 to 35 million tons. The Roslyn district is one of the few areas in Washington where underground mechanized mining has been successfully employed in the past.

Pierce County

In recent years the coals of Pierce County have received considerable attention because they comprise the only known U.S. reserves of coking coal on the Pacific coast. The Wilkeson-Carbonado field, located 25 miles from tidewater at Tacoma, is the most important deposit. However, the geologic structure is complex, consisting of plunging anticlinal and synclinal folds with dips on the fold limbs averaging 55-60° that are locally vertical or overturned. Two companies who held leases on Burlington Northern coal lands during the past two decades probed three facets needed to revitalize the field. They were penetration of the Japanese market, suitable coal preparation techniques, and mechanical and hydraulic mining methods suitable for mining the steep pitches. The real hurdle has been the development of a mining method for steeply pitching beds that will provide acceptable productivity, meet health and safety regulations, and comply with environmental requirements. Although a couple of systems were considered as having a chance at succeeding,

they were never implemented. However, a remote hydraulic extraction process was tested in the late 1970's, which met with only limited success.

Currently, Meridian Land and Minerals Co. (Burlington Northern) is involved in a core drilling program to evaluate their mineral holdings in the Wilkeson to Fairfax area. Also, Terraspace, Inc., of Rockville, Maryland, has taken over a project initially started by Gulf Resources and Chemicals Exploration Co. to do a technical and economic feasibility study of hydraulic coal mining in the Wilkeson-Carbonado coal field. The first phase of this project, the potential site evaluation, is due to be completed by July of 1983. The contract is with the U.S. Bureau of Mines. The objective of the program is to design an economically viable underground hydraulic coal mining system for moderate to steeply pitching bituminous coalbeds.

Southwestern Washington Coal Fields

The southwestern Washington coal fields include the Centralia-Chehalis area, the Kelso-Castle Rock area, and the Vader area.

WIDCO continued confirmation drilling and seam characterization on its reserve holdings in the Tono basin where it produces about 5 million tons a year from the Centralia strip mine located in the Centralia-Chehalis district. Reserves are estimated to be adequate for another 35 years.

Kennecott Minerals Co., of Salt Lake City, is currently involved in exploratory drilling of the Curtis-Vader-Ryderwood area of western Lewis and northwestern Cowlitz Counties. Kennecott has explored the area for the past 2 years. They are involved in a joint venture with GCO Minerals Co., a subsidiary of International Paper Co. According to Kennecott's public relations officer — Kennecott has a land base of 9,000 acres; GCO has a much larger base reported to be in the vicinity of 40,000 acres. Drilling is being done to block out reserves and to determine coal quality. The project is still in its early stages. The coal rank in this area is believed to be subbituminous.

During 1978 a major Northwest timber firm retained the John T. Boyd Co., of Denver, to drill 27 drill holes in the Toledo-Castle Rock area, which included an area of strippable lignite reserves of 8 million tons reported by the U.S. Bureau of Mines back in 1947. Total footage drilled was in excess of 7,000 lineal feet. AMCA Coal Leasing, Inc. of Price, Utah, was also evaluating the same resource on an adjacent property during the same time period. A few mines were developed in this area. However, very little information about past mining has been recorded. Past production in the area is negligible. Total original reserves of coal and lignite total about 150 million tons, but current exploration activity indicates that the potential is much greater.

Asotin County

Lignite occurs in southeastern Asotin County within sedimentary strata that is interbedded with flows of Yakima basalt of Miocene age. Minor amounts of lignite were produced for local use in the early part of the century. No further mining has occurred since that time. However, the area is again receiving consideration. Utah International, Inc. began drilling in 1977.

They drilled 10 to 12 holes, totaling approximately 2,000 lineal feet. The company is reported to be actively exploring on the Oregon side of the lignite field. Kemmerer Coal Co. (now part of Gulf Resources) drilled 10 to 11 holes totaling 2,500 to 3,000 ft. in 1980 and 1981.

Several other mining and energy companies, not mentioned here, continue to evaluate existing data in office studies prior to committing funds for exploration and drilling. Some of the companies are listed in table 2. Interest shown by companies active in coal exploration in Washington was somewhat diminished in 1982 due to the generally poor state of the economy.

Table 2. — *Companies active in coal exploration in Washington, 1982*

Cominco American, Inc.
Getty Oil Co.
Kennecott Minerals Co.
Meridian Land & Minerals Co.
North American Coal Corporation
Shell Oil Co.
United States Steel Corp.
Utah International, Inc.
Washington Irrigation & Development Co.

COAL ACTIVITIES OF THE DIVISION OF GEOLOGY AND EARTH RESOURCES

The Division of Geology and Earth Resources (DGER) of the state's Department of Natural Resources has been conducting studies of Washington's coal resources since 1974. With renewed interest in the nation's coal resources as a result of the energy shortage, the state became interested in learning more about coal on state-administered lands. A one-man program was initiated, concentrating on Whatcom County, where the greatest amount of state land underlain by coal-bearing rocks occurs. Initially, a compilation of all available data relating to the geology and coal resources of Whatcom County was generated. In addition, a series of folios which outline the areas of coal-bearing rocks, computed coal reserves, and locations of state-owned lands for all the major coal areas of the state (except King County) was produced. A coal-sampling program was also underway during this time period.

Results of the coal-sampling program were released as an open-file report in July of this year. The report presents analysis for 135 coal samples from 89 sampling localities in nine Washington counties. Stratigraphic sections, measured and recorded at 37 of the sampling localities, are also included in the report. In 1977 the coal program was expanded to include all of Washington's coal deposits.

In 1978 a project was initiated in the Roslyn-Cle Elum area resulting in a DGER open-file report containing information on coal quality, coal reserves, and 25 separate maps illustrating the geology, geologic structure of the major coal beds, mining conditions, stratigraphic relationships of the coal measures and surrounding rocks, and seam thickness, and overburden thickness.

A second project was begun in 1980 to study the Miocene lignite occurrences in Asotin County in the southeast corner of the state. A program that involved reconnaissance mapping, data collection, and sampling of basalts and lignite was carried out during 1980. The results of the first season's field work were presented in a DGER open-file report released in 1981. A second season of field work was conducted to answer questions raised during the first half of the project. A final report on the results of the project is currently being prepared and should be available sometime in 1983.

Projects to study the coal resources in the Newcastle-Tiger Mountain area and the Green River district of King County were also initiated in 1980. A similar project to study the coal resources of the Wilkeson-Carbonado coal field in Pierce County was begun in 1981. The King and Pierce County studies should be completed by late 1983.

The objective of the Division's coal resource program is to provide high-quality basic information on coal quality, tonnage, and geologic setting for the major coal fields in the state. This is accomplished by collecting data in the field from available outcrops. This includes measuring, describing, and sampling all important outcropping coal seams and associated coal-bearing rocks to provide surface geologic control which will enable the geologist to make a meaningful interpretation of the subsurface geology. Geologic mapping of coal-bearing areas in western Washington is hampered by a thick mantle of soil, glacial drift, and by a dense growth of vegetation.

A key part of the Division's coal resource program is the definition of structural and stratigraphic features that control the occurrence and depth of coal deposits in areas where surface and subsurface geologic control is lacking. A drilling program coupled with seismic surveys would probably be the best way to study such frontier areas. However, financial constraints limit the Division to inexpensive geophysical methods, namely gravity and ground-based magnetics. Work is currently being conducted in a till-covered area of King County where outcrops are practically nonexistent. Subsurface control is limited to shallow water wells which do not penetrate coal-bearing Eocene strata.

As part of the Division's efforts to assess coal occurrences in the state, we have evaluated trends in coal-rank variation for all of the major coal fields. This has enabled estimates of thermal maturation of potential oil and gas-bearing rocks in the Puget Lowland and central Washington. It also permits estimates to be made of the approximate rank of coal that may be present in areas adjacent to previously mined coal fields for which there is no coal quality data.

FUTURE DEVELOPMENT POTENTIAL OF WASHINGTON COAL

Washington's coal development has been hampered by the limited size of individual coal fields, their variable composition, and by hard-to-mine steeply dipping beds. These factors coupled with the considerable thickness of overburden over many areas make them unsuitable for low-cost, open-pit mining operations (the Centralia coal field is an exception). These factors have historically contributed to the high cost of mining Washington coal, making it very difficult for Washington coal producers to compete in markets within the state, and virtually impossible for them to compete in out-of-state markets. However, with the recent surge of interest shown by exploration companies over the past decade or so, the potential exists for the discovery of new reserves, particularly in frontier areas which could also be amenable to economically competitive mining methods.

The currently established coal reserves in Washington underlie an area of only about one-third of the known area of coal-bearing rock in the state (figure 5). Possibly other large areas of coal-bearing rocks are concealed beneath a mantle of glacial drift or alluvium as seen in figure 5. The principal areas where such conditions exist are north of Enterprise in northwestern Whatcom County, between the Skagit and King County areas, between the Newcastle-Tiger Mountain and Green River coal fields of King County, between the King and Pierce County areas, and between the Centralia-Chehalis coal district and the Kelso-Castle Rock area. There is good reason to believe that many of these areas contain potentially significant coal deposits within 3,000 ft. of the surface. There are large areas in Chelan and Kittitas Counties and smaller areas in Snohomish and eastern King Counties underlain by Cretaceous or lower Tertiary sedimentary rocks of the Swauk Formation. Although these rocks are intensely deformed in most of these areas and are of doubtful value as potential commercial sources of coal, some of these rocks may contain significant amounts of coal.

Progress has been made utilizing hydraulic techniques in underground mining by the Canadians, the Japanese, and the Russians. In Canada, Kaiser Resources, Ltd. has been successfully employing hydraulic mining at its Sparwood, British Columbia operations since the early 1970's.

Kaiser's underground hydraulic mining operation produces approximately 1 million tons of raw coal per year. The hydraulic technique uses a high pressure water jet to dislodge the coal. Coal combined with water is flumed out of the mine to a dewatering plant on the surface, where the water is separated from the coal by screening and then recycled in a closed circuit for reuse in the mine. In a 50-foot-thick seam that dips 25-50°, Kaiser has increased recovery from 10 to 12 percent, where conventional underground mining had been formerly employed, to 55 to 60 percent with hydraulic mining. Productivity also increased significantly to between 25 to 30 tons per worker shift. Similar successes have been experienced by the Japanese and Russians in seams with dips as steep as 60 to 80°.

As mentioned earlier, a company is currently operating under a grant from the U.S. Bureau of Mines to do a feasibility study of hydraulic mining of the steeply dipping coal seams in the Wilkeson-Carbonado area of Pierce County. They will be investigating methods similar to those employed by Kaiser Resources. Hopefully, these efforts will develop techniques that will eventually allow state coal producers to be more competitive in the regional and the international marketplace.

Concerns brought on by the energy crisis have brought in-situ or underground coal gasification (UCG) into consideration as an alternate energy source. Underground coal gasification is one of the most promising of the various processes to produce clean fuels from coal. With this method both low and medium BTU product gas have been obtained by air and steam/oxygen injection, respectively. If successful, underground coal gasification would quadruple the proven U.S. reserves of coal. Costs of fuels produced by UCG are projected to be 65 to 75 percent of those produced by conventional surface coal-conversion processes. Through this technique lignites and other low-grade coals, uneconomical to mine through conventional means, could be developed as a commercial energy source. Steeply dipping and tectonically disturbed seams, ignored in the past as being uneconomical to mine, could be gasified.

At least eighteen UCG field tests have been conducted in the U.S. since 1973. The U.S. Department of Energy and Gas Research Institute jointly sponsored a series of tests being conducted by Lawrence Livermore National Laboratory (LLNL) in cooperation with the Washington Irrigation and Development Co. (WIDCO) in the Tono basin about 5 miles northeast of Centralia. During the past year a series of five large block field experiments were performed within the Big Dirty coal seam. The blocks were later excavated so that burn cavity geometry could be studied, as well as the cavity growth process response to changes in varying amounts of steam/oxygen and air which were injected during the tests. The tests were successful and indicated that the Big Dirty seam is suitable for in-situ gasification. Further tests are scheduled for the summer of 1983. The tests will be conducted at commercial process well spacings (100 to 200 ft.) and at commercial depths (500 ft. or more).

The ultimate goal of these experiments is the successful gasification of multiple seams approximately 600 ft. below ground level in the Tono basin 2 miles east of the WIDCO mine and powerplant complex. A successful experiment would allow a transfer of UCG technology to many of Washington's coal seams that are presently uneconomical to mine. Ultimate use of the generated gas would probably be as boiler feedstock for electrical power generation. A consensus of opinion indicates that the UCG process can be commercial within the next 10 years.

Another factor that would increase the development potential of Washington's coal would be the establishment of a deep-water coal port in the Puget Sound region. Pacific Rim countries, such as Japan, Korea, and Taiwan, are switching to steam coal for electric generation and for heat in the cement and the pulp and paper industries. Forecasts of the East Asia steam coal market show a 21 percent per year growth rate for the 1985-1990 period (figure 6). This graph shows the lowest estimate of demand by 1985 to be 40 million tons, and

100 million tons by 1990. However, the current recession has dampened considerably such optimistic forecasts. Reports are stating that Japanese demand, in fact, may be only half or less what was previously expected.

One barrier to expanded exports to Japan has been the higher price of western U.S. coal due to transportation problems and limited port loading facilities on the Pacific coast. Japan will most likely be supplied by four countries: Australia, South Africa, Canada, and the United States. Currently the U.S. is the highest cost producer because of the long distances involved from mine to port. Figure 7 shows estimates of the CIF (cost, insurance, freight) price for seven steam coals delivered to Japan under production and market conditions that are likely to prevail in the mid-to-late 1980's. The prices are expressed in 1980 dollars per million BTU. The Wyoming coal prices were based on the assumption that coals would be shipped via Washington State through a port on the Columbia River which would limit ship size to 60,000 DWT and hence increase shipping costs. Wyoming's mining costs are low, but so is the quality of its coal in terms of BTU per pound. Wyoming's bid for the East Asian market is further hampered by high overland (approximately 1,000 miles) rail costs. While Utah has high quality coal, its development requires expensive underground mining, followed by about 800 miles of rail transport to a port such as Long Beach, California, which would accommodate ships of 110,000 DWT. Wyoming could improve its competitive position some if it could ship its coals through a deep-water port that could accommodate larger ships of deeper draft. In spite of the higher costs of its coals, the U.S. can reasonably expect to capture 10 to 20 percent of the East Asian export market, because a concern of Pacific Rim buyers is stability of supply.

The quality of coal required by Pacific Rim buyers at least until 1990-1995 should have the following minimum specifications: 10,800 BTU's per pound heating value; 10 percent ash, 10 percent moisture, and less than 1 percent sulfur. Coals of this quality are found in southwest Wyoming, northeast Utah, northwest Colorado, southwest Utah, and parts of the San Juan River and Raton Mesa regions of Colorado and New Mexico (figure 8). Washington also has coals that meet the specifications mentioned above, although current production is very small and comes from one mine in King County.

At least 11 possible coal port terminal sites have been proposed for Washington. The only port facility in the advanced stages of development in Washington is at Kalama on the Columbia River. The likelihood that a deep-water port will be built on Washington's coast or in the Puget Sound region, at least within the next decade, is slim. Besides the dampening effects of the current recession on projected energy demand of East Asian countries, there is also the fact that there is already a large Canadian coal port just a few miles north of Washington's border. The Roberts Bank facility is doubling its capacity and will be completed in a couple of years. This will increase Canada's competitive position in the East Asian coal market.

An increased demand for steam coal in East Asia, and some technological advances will allow lower BTU coal to be used. Then the geographic area which can supply coal will expand to include the Powder River basin area of Wyoming and Montana. This will increase the possibility for a deep-water coal port in the Puget Sound region of Washington to handle these coals. With

a coal port located within the state, Washington's coal would become attractive by virtue of its location.

In order to take full advantage of economic recovery in the future, exploration of Washington coal fields should be initiated as rapidly as possible. The Geology and Earth Resources Division of the Department of Natural Resources is doing everything possible to assemble and make data available so that new coal development becomes a reality in Washington.

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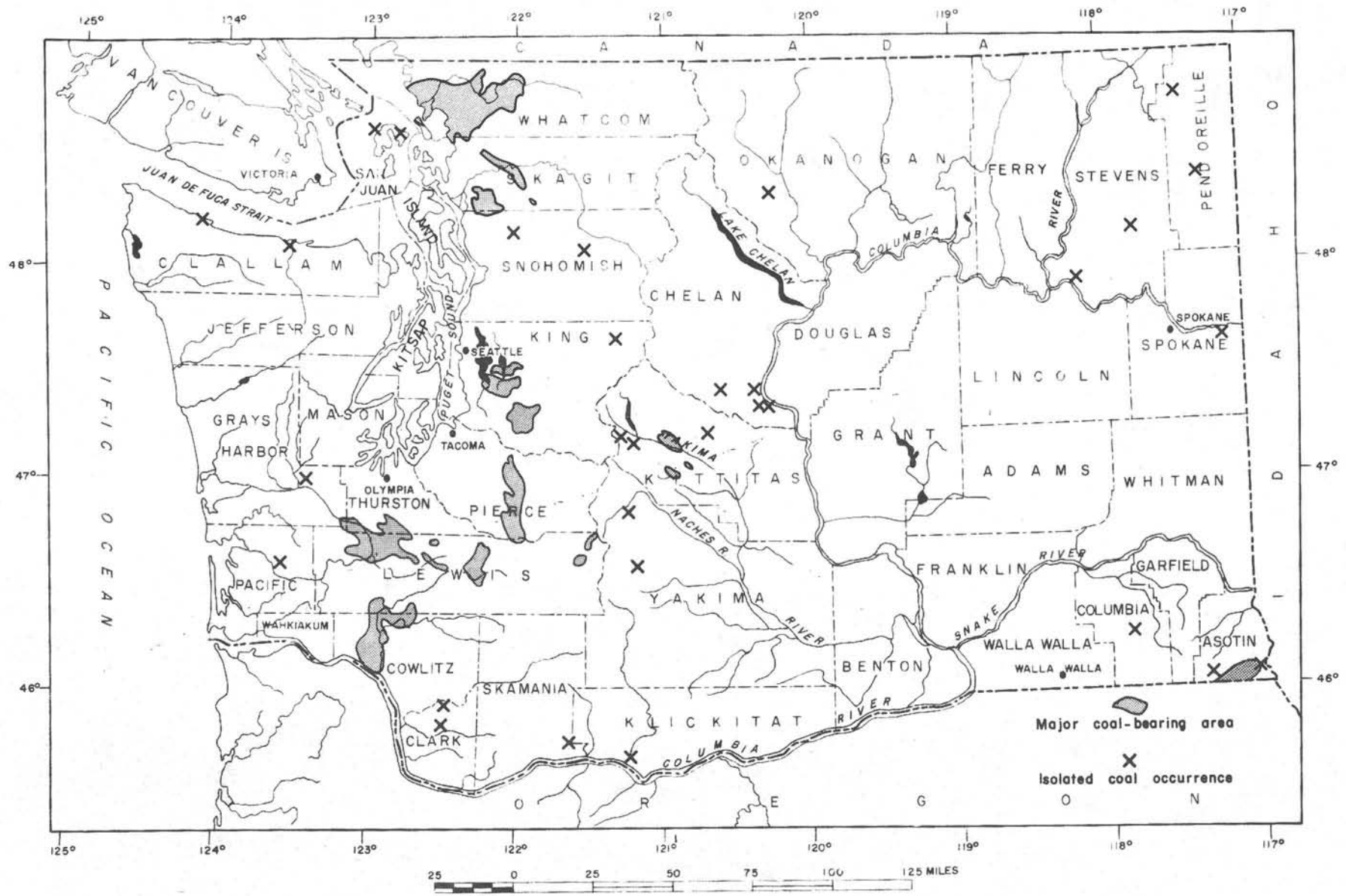


Figure 1. Index map of Washington showing major coal-bearing areas and isolated occurrences of coal.

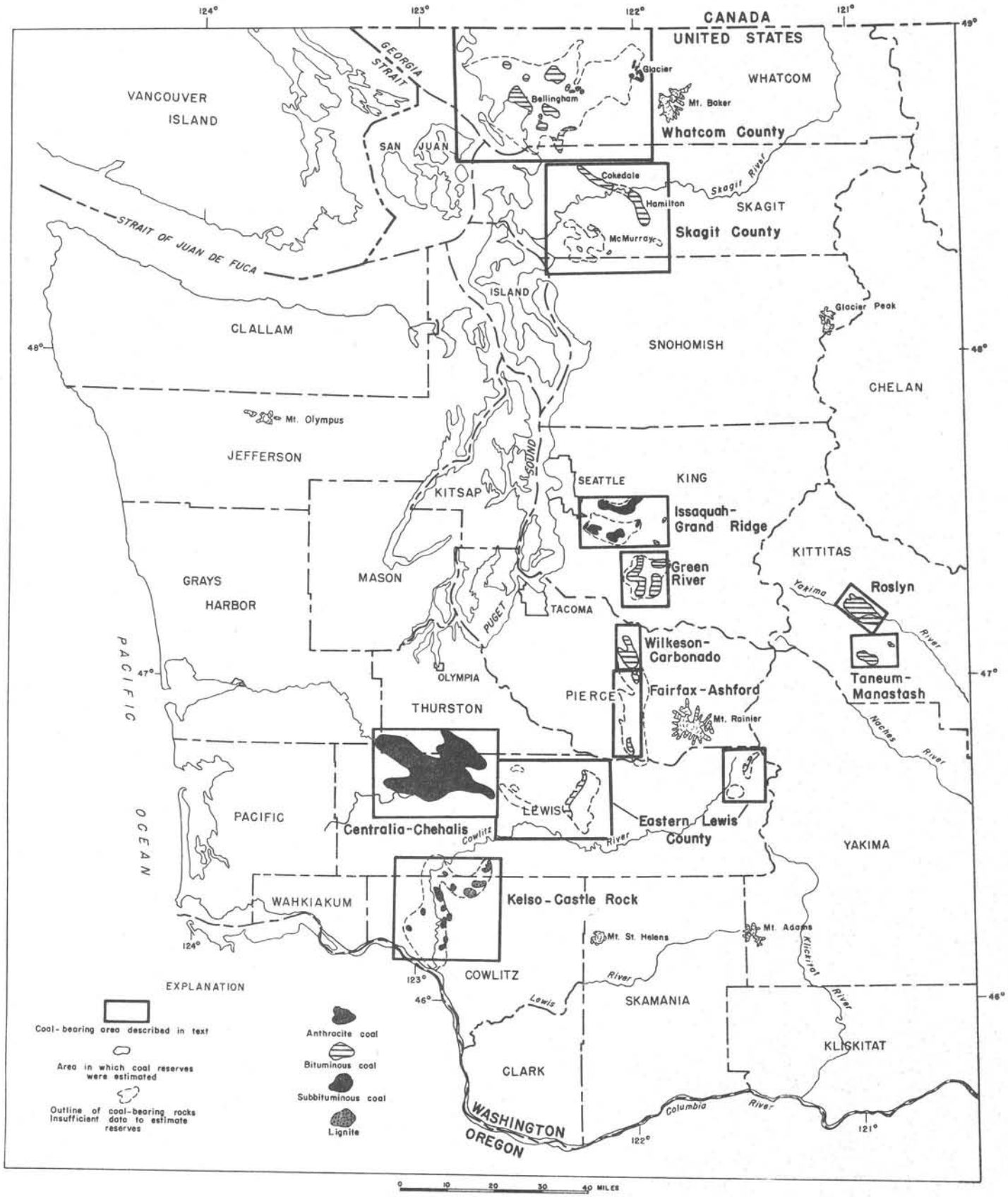


Figure 2. MAP OF WESTERN WASHINGTON SHOWING MAJOR COAL-BEARING AREAS
(modified from Belkman et. al., 1961)

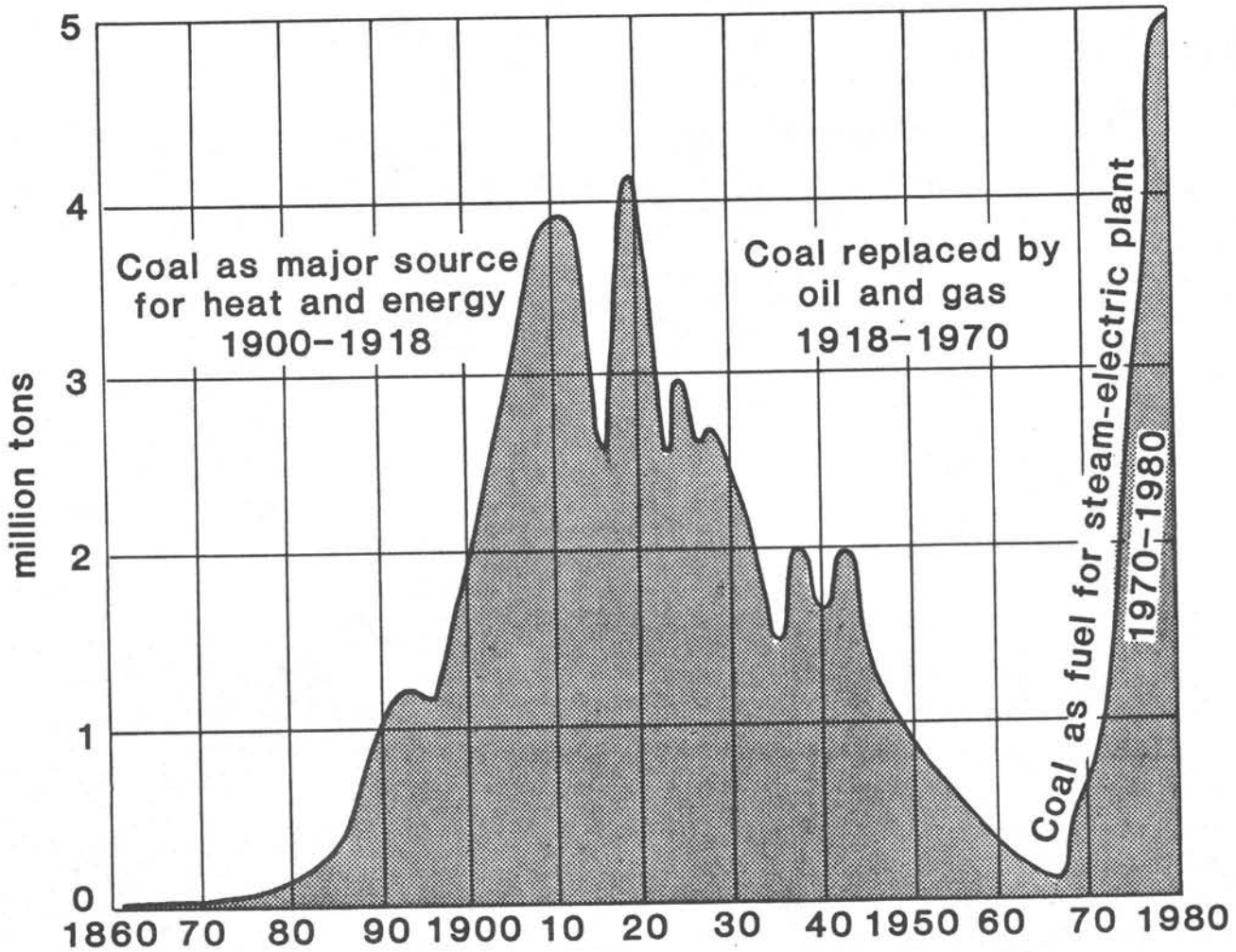


Figure 3. Coal production of Washington, 1900-1980
(Moen 1982)

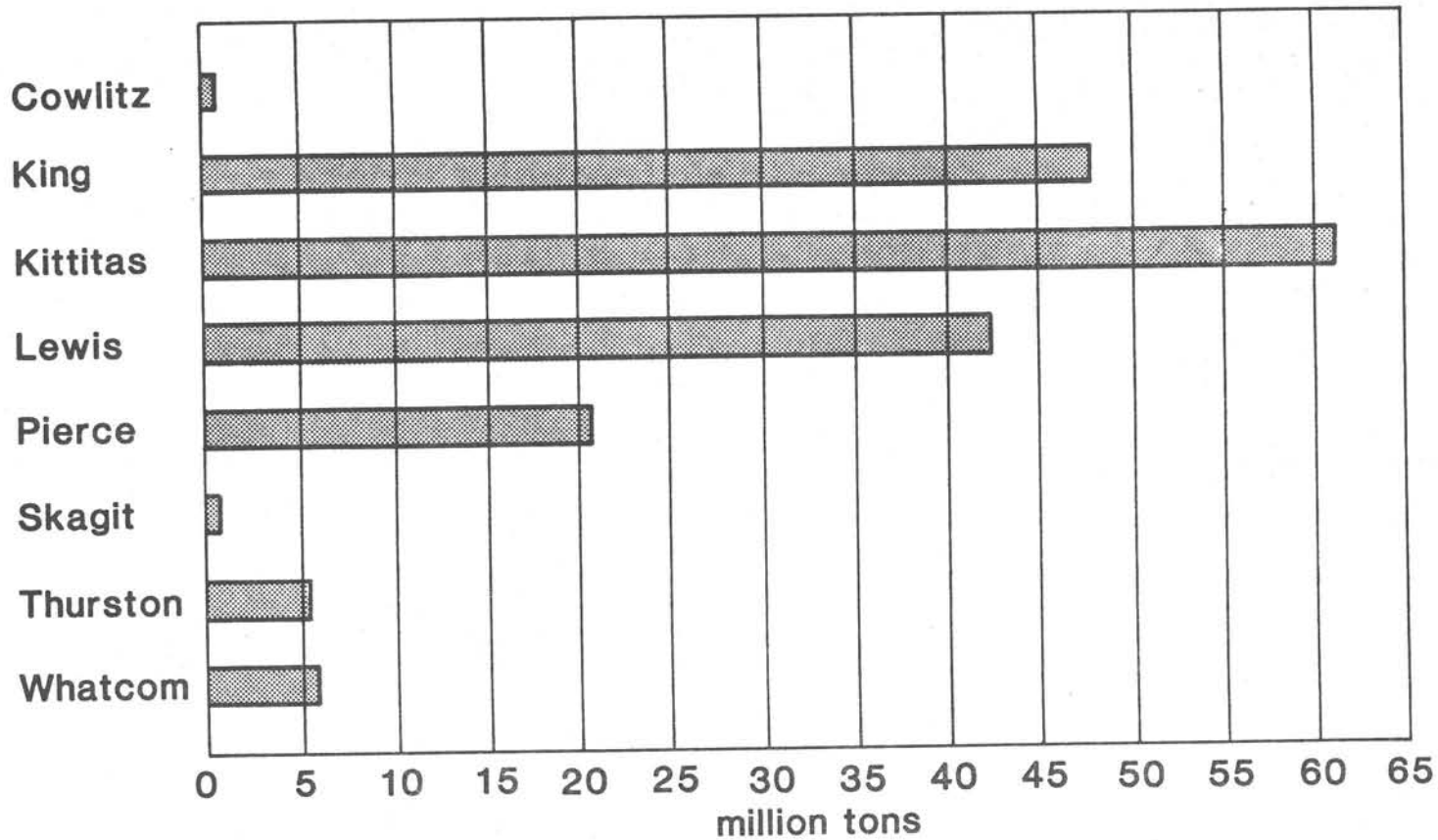


Figure 4. Cumulative coal production in Washington, by county
(Moen 1982)

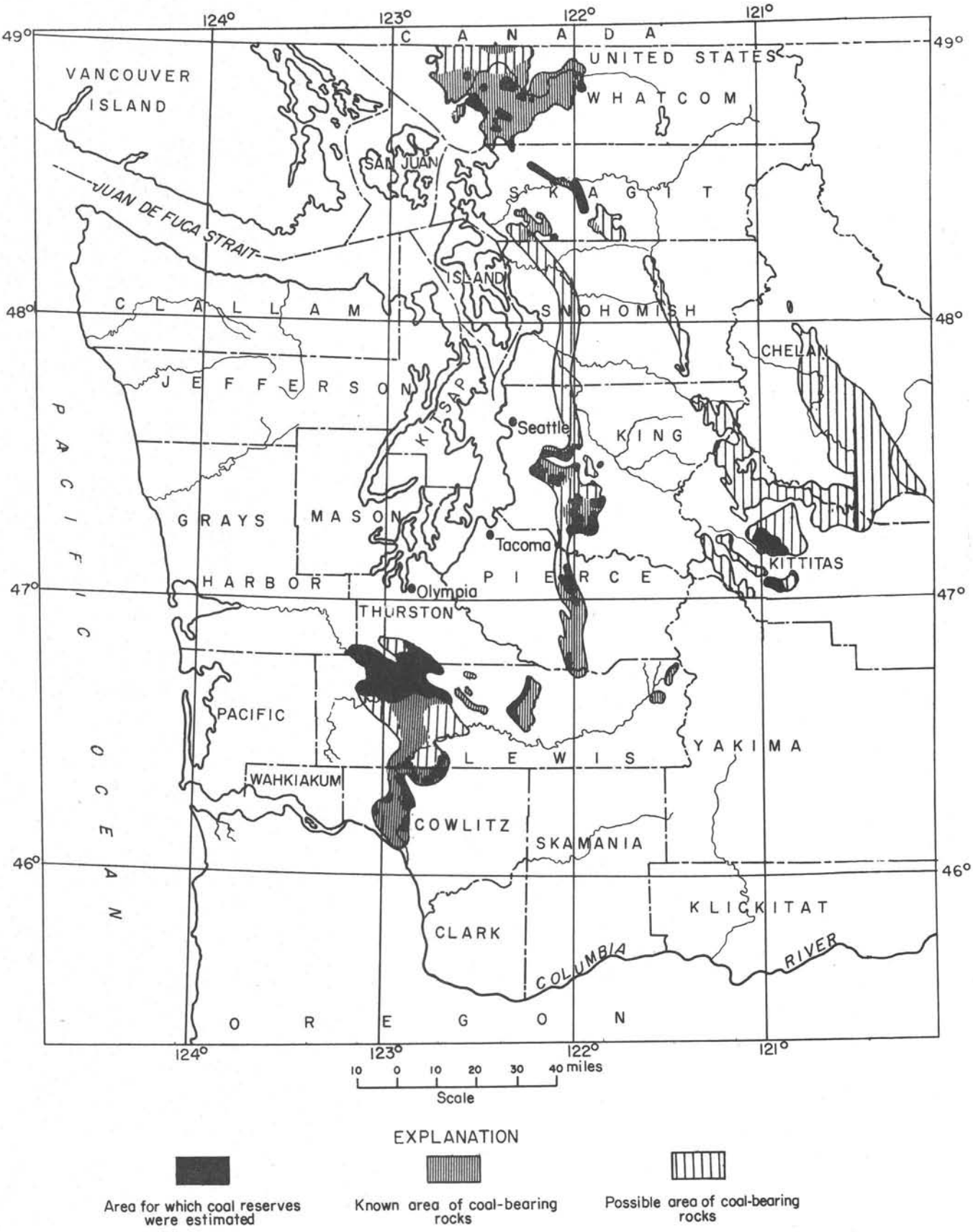


FIGURE 5. INDEX MAP OF WASHINGTON SHOWING KNOWN AND POSSIBLE AREAS OF COAL-BEARING ROCKS (After Beikman et. al., 1961)

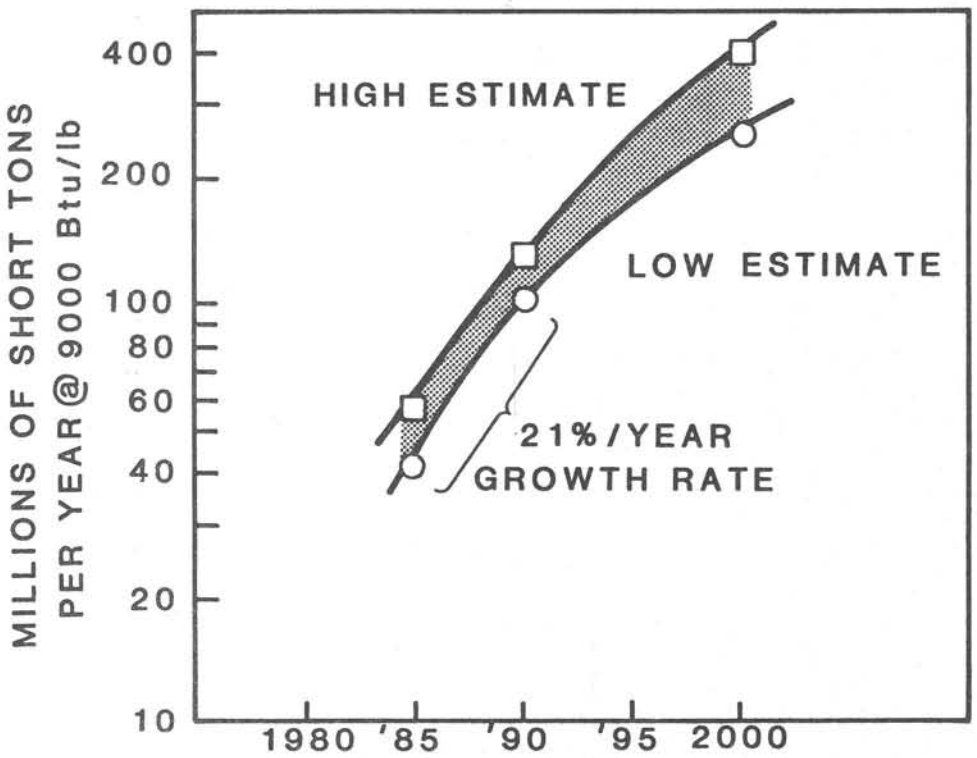


Figure 6.
East Asia Steam Coal Market Outlook

Source: (Swift et al., 1980)

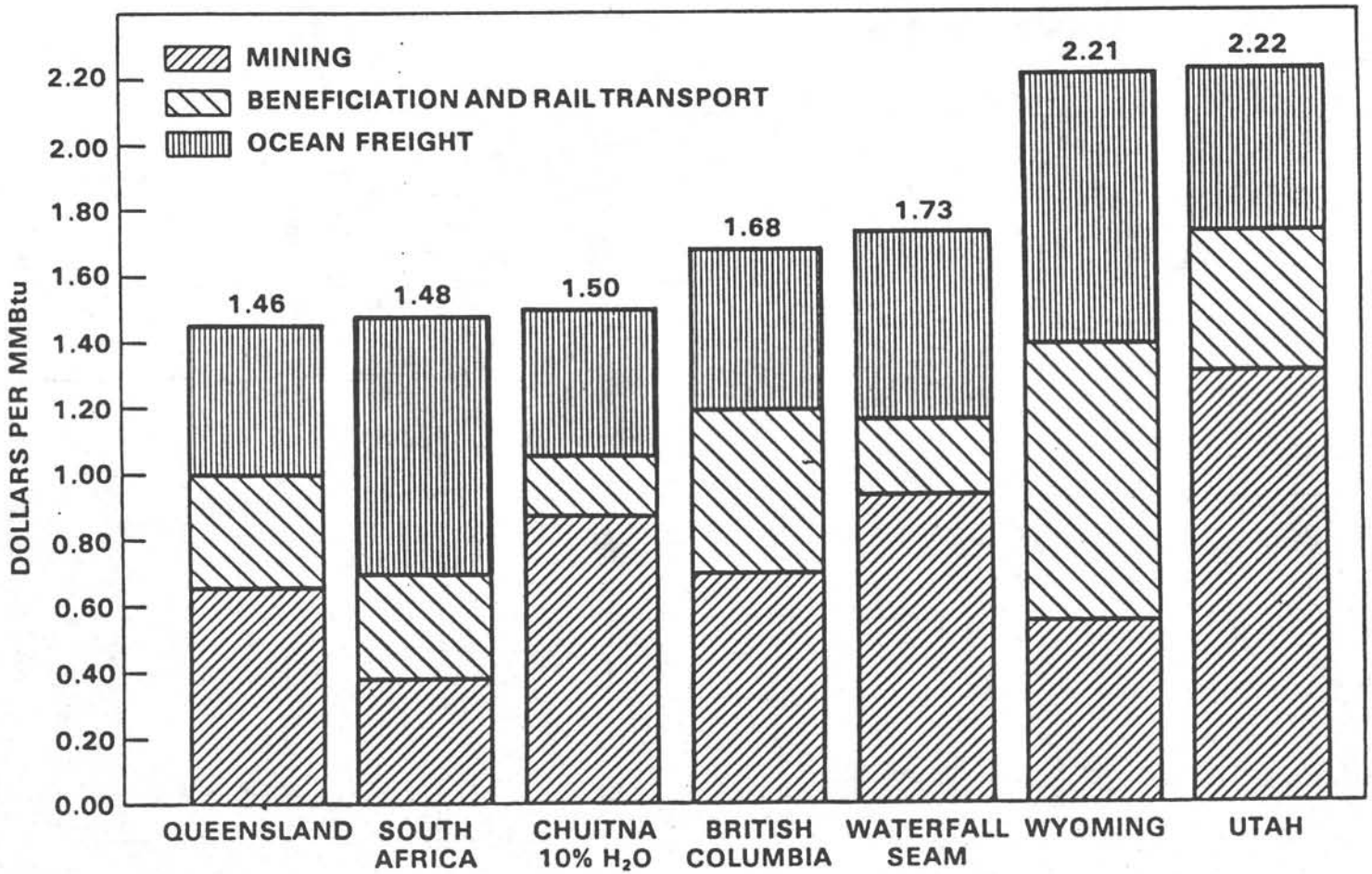
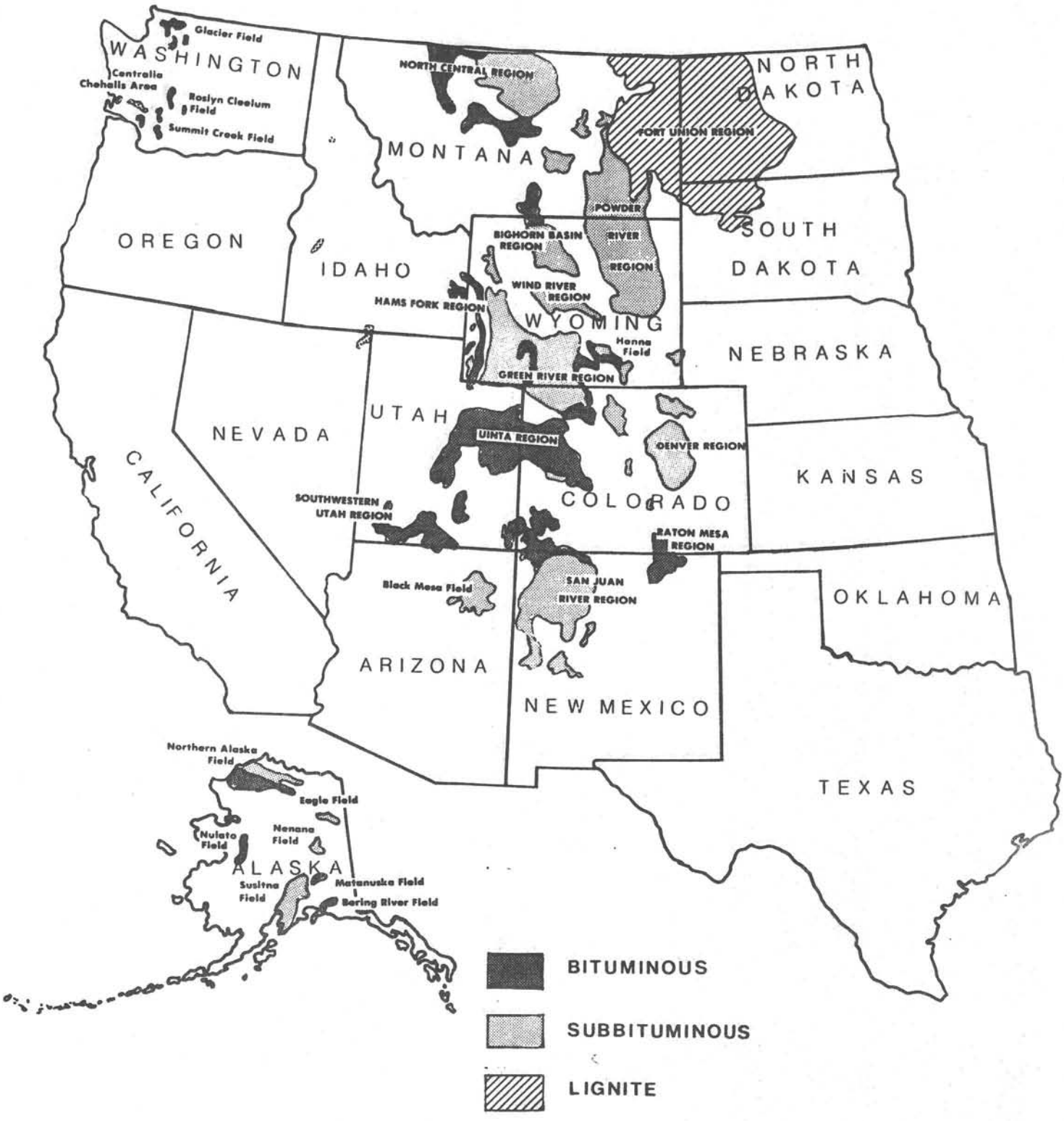


FIGURE 7. Steam Coal Prices-Cost Insurance Freight (CIF) Japan-1985 Conditions (After Swift et al, 1980)



Source: WESTPO, 1981

Figure 8. Coal Regions of the Western United States