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BULLETIN 47

COAL RESERVES OF WASHINGTON

By

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with addendum by

Henry W. Schasse, Timothy J. Walsh, and William M. Phillips

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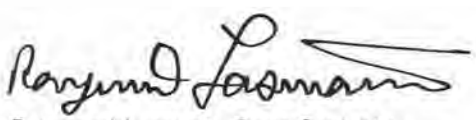
FOREWORD

The first printing of "Coal Reserves in Washington" was the result of a cooperative effort between the Fuels Branch of the U.S. Geological Survey and the Washington Department of Conservation, Division of Mines and Geology, predecessor to the Division of Geology and Earth Resources now under the Department of Natural Resources. At the time of the first printing, industry was beginning to show a renewed interest in Washington coal. That interest resulted in the opening of a large surface mine at Centralia in northwestern Lewis County in 1971. The mine supplies a mine-mouth thermo-electric power plant which accounted for over 7 percent of all electricity generated in the state in 1980.

In the past 14 years, Washington coal production has increased from a low of 37,000 tons in 1970 to an average annual production of 4.7 million tons, which surpasses the former maximum production of 4.1 million tons attained in 1918. Coal exploration efforts have also increased since 1970, but information on the new reserves discovered remains largely proprietary.

With the approaching depletion of the first printing of Bulletin 47, it was decided that the reprinted version would remain essentially in its original form. A few changes have been incorporated as an addendum which preceeds the text in this edition (1984). The changes consist of an update of coal production statistics since January 1, 1960, and changes in ASTM coal rank standards which have affected 237 million tons of coal in King County that have been reclassified from subbituminous to bituminous. Notable changes in stratigraphic nomenclature of coal-bearing formations are mentioned and referenced. Significant exploration and mining activities which have occurred since 1960 are also included. Errata noted in the first printing are presented.

We believe that this report will continue to be valuable to those requiring new sources of coal in Washington.



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ADDENDUM TO THE 1961 EDITION OF BULLETIN 47

by

Henry W. Schasse, Timothy J. Walsh, and William M. Phillips

INTRODUCTION

This section has been added to provide the reader with details which serve to update the original text. The updated information is provided in the same sequence as the original text. Page, column, and paragraph numbers (as appropriate) are cited in order to provide ready reference to the corresponding section in the original text. Errata found in the original printed version are noted at the end of the text portion of the addendum. References cited in this section are included at the end of the addendum.

RECLASSIFIED COAL RANK — KING COUNTY

Since 1961, the American Society for Testing Materials (ASTM) has revised the classification of coals by rank several times. In the classification used in the 1961 printing of Bulletin 47 (table 1, p. 3), coals with moist, mineral-matter-free Btu values of 11,000 to 13,000 were considered to be high-volatile C bituminous only if they were agglomerating or nonweathering. In the current classification, all coals with moist, mineral-matter-free Btu values of 11,500 to 13,000 are considered to be high-volatile C bituminous. Because many of the coal analyses used in determining the rank of Washington coals did not include agglomerating or weathering tests, coals in this overlap zone were considered to be subbituminous. Under the current classification (table 1A) many coals that were previously considered subbituminous are now classified as bituminous, all of them in King County. A total of 237 million tons of reserves were affected by this reclassification. These reserves are listed by township and by coal bed in table 2A.

COAL MINING FROM 1960 TO 1983

Almost 203 million tons of coal has been produced in the State of Washington. Nearly 53 million tons has been produced since 1960. Ninety-seven percent of post-1960 production has come from one mine, Washington Irrigation and Development Company's (WIDCO) Centralia mine, which has a capacity of approximately 5 million tons per year. The mine is dedicated to a mine-mouth thermo-electric power plant which came on line in 1971.

The remaining 3 percent of the coal produced since 1960 has come from several small operations which produced for limited periods. Currently only one mine besides the Centralia mine is in production, that being a small strip mining operation near Black Diamond in King County which produces 5 to 7 thousand tons per year.

Much of the state's coal production has come from Kittitas County, whose lead will soon be surpassed by Lewis County where the Centralia mine is located. The annual and cumulative coal production since 1860 is illustrated in figures 1A and 2A. Production for the period from 1960 to the present has been highlighted.

WHATCOM COUNTY COAL DEPOSITS

CHUCKANUT FORMATION

The coal-bearing rocks in Whatcom County occur in the Chuckanut Formation (p. 10, column 2, paragraph 3), which was named by McLellan (1927) and whose type sections were established later by Glover (1935) and Weaver (1937). Johnson (1984) has divided the Chuckanut Formation into members and assigned the Blue Canyon coal zone to the Bellingham Bay member. The Lake Whatcom coal zone has been assigned to the Padden member of the Chuckanut Formation.

SKAGIT COUNTY COAL DEPOSITS

GEOLOGIC MAPPING AND DRILLING FROM 1960 TO 1983

The relative age relationships between the coal-bearing rocks of the Cokedale-Hamilton-Rick Creek area and those of

TABLE 1A. — *Classification of coals by rank*[1]

[From American Society for Testing Materials (1982, p. 241)]

Class	Group	Fixed carbon limits, percent (dry, mineral-matter-free basis)		Volatile matter limits, percent (dry, mineral-matter-free basis)		Calorific value limits. Btu per pound (moist,[2] mineral-matter-free basis)		Agglomerating character
		Equal or greater than	Less than	Greater than	Equal or less than	Equal or greater than	Less than	
I. Anthracitic	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[3]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile *A* bituminous coal	...	69	31	...	14 000[4]	...	
	4. High volatile *B* bituminous coal	...	...	...	...	13 000[4]	14 000	
	5. High volatile *C* bituminous coal	...	...	...	...	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous *A* coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous *B* coal	...	...	...	...	9 500	10 500	
	3. Subbituminous *C* coal	...	...	...	...	8 300	9 500	
IV. Lignitic	1. Lignite *A*	...	...	...	...	6 300	8 300	
	2. Lignite *B*	...	...	...	...	...	6 300	

[1] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15 500 moist, mineral-matter-free British thermal units per pound.

[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3] If agglomerating, classify in low-volatile group of the bituminous class.

[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and that there are notable exceptions in high volatile *C* bituminous group.

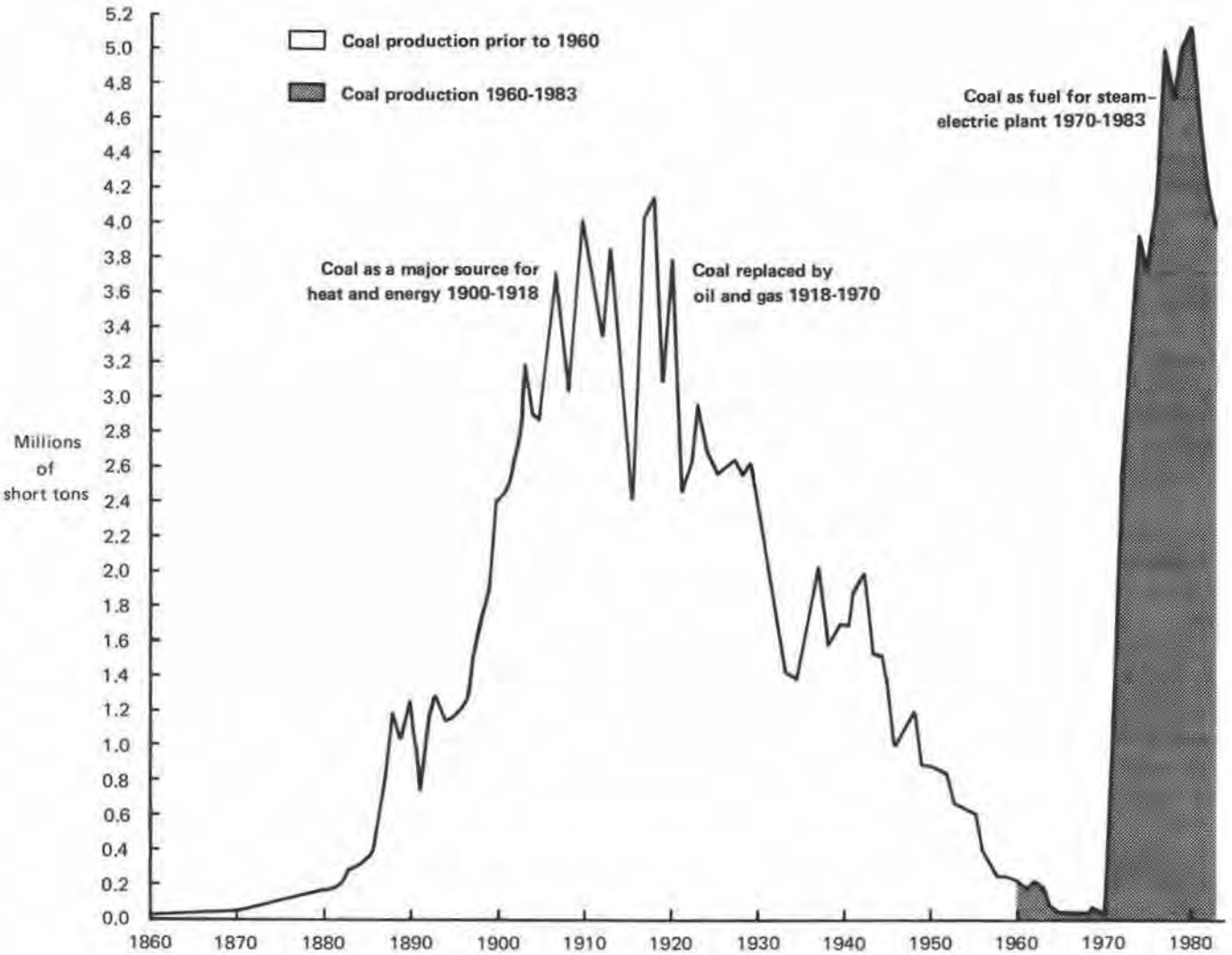

Figure 1A. Coal production in Washington, by year

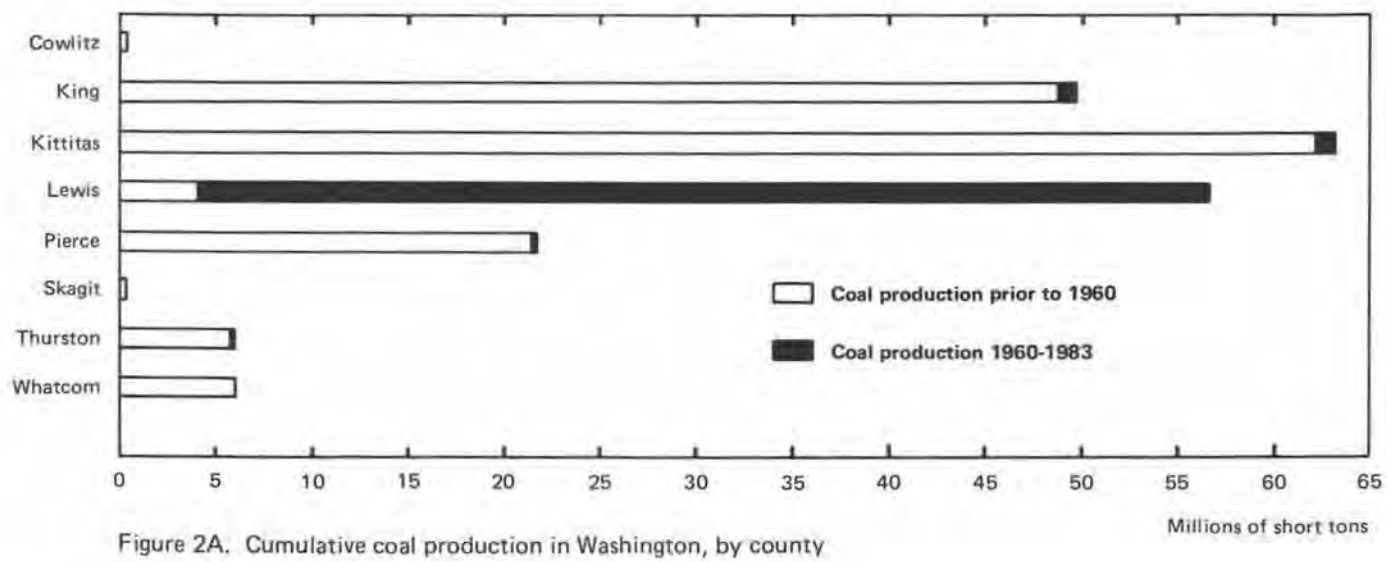

Figure 2A. Cumulative coal production in Washington, by county

TABLE 2A. — *Reserves of coal in King County, Washington, reclassified from subbituminous to high-volatile C bituminous, by township and bed*

Coal bed	Total Reserves, (millions of short tons)
	T. 24 N., R. 5 E.
Muldoon	12.37
Bagley	19.69
Dolly Varden	2.05
Jones	8.42
Township total	42.53
	T. 24 N., R. 6 E.
Bagley	41.08
Muldoon	27.02
Dolly Varden	35.89
Jones	26.70
Township total	130.69
	T. 23 N., R. 4 E.
No. 3	9.29
Springbrook	4.80
Sunbeam	7.57
Township total	21.66
	T. 23 N., R. 5 E.
Cavanaugh No. 2	5.23
Jones	6.66
Discovery	9.19
Township total	21.08
	T. 23 N., R. 6 E.
Jones	2.29
Discovery	2.81
Township total	5.10
	T. 21 N., R. 6 E.
Kummer No. 1	9.11
Kummer No. 0	6.55
Township total	15.66
Grand total	236.72

the McMurray area in northwestern Skagit County were not defined in the first printing (p. 16). Recent mapping (Loveseth, 1975; Whetten and others, 1979, 1980; Dethier and Whetten, 1980; Marcus, 1981) shows that the coal-bearing rocks in the McMurray area are younger than those of the Cokedale-Hamilton-Rick Creek area, which are attributed to the Chuckanut Formation (Bechtel Inc., 1979). The rocks of the McMurray area have been informally named the rocks of Bulson Creek (Loveseth, 1975) and are probably of late Eocene to early(?) Oligocene age (Narizian to Refugian foraminiferal stages).

To the southeast of Cokedale, drilling for the Skagit Nuclear Plant project revealed at least eight coal seams (Bechtel, Inc., 1979; Walsh, 1983). Analyses of coal from that site (Vonheeder, 1978) indicates that the coal is of high-volatile A bituminous rank and is high in ash.

KITTITAS COUNTY COAL DEPOSITS

ROSLYN COAL FIELD

GEOLOGIC MAPPING FROM 1960 TO 1983

A number of reports and maps concerned with aspects of the geology of the Roslyn area have been published since 1960. These works have largely consisted of stratigraphic and structural contributions; no new major coal resources have been defined.

Tabor and others (1983) mapped the Wenatchee 1:100,000 quadrangle for the U.S. Geological Survey. Their report places the Roslyn Formation in regional context by assigning stratigraphic correlations and defining major structural features. Additional regional data are presented in a later paper (Tabor and others, 1984).

Walker (1980) mapped the Roslyn area at a scale of 1:24,000. Using both surface data and borehole information collected since 1961 (Tuck and Boyd, 1966), Walker produced a number of detailed coal and overburden isopach maps. These data document an ancient, west-flowing fluvial system in which about 9,000 ft of nonmarine sediments were deposited. A major reverse fault is mapped by Walker along the southern part of the Roslyn coal field. Folding along the southwest margin of the field is ascribed to drag effects along the main reverse fault zone (Walker, 1980, p. 7).

COAL BEDS

Walker (1980) describes two coal beds, the "Lanigan" and the "Patrick," which were not mentioned in the 1961 printing of this bulletin. These seams occur stratigraphically below the No. 8 coal bed (p. 22, fig. 10). The Lanigan seam consists of 5 to 18.5 ft of highly brecciated coal 100 ft stratigraphically below the No. 8 coal bed. Walker (1980) did not calculate reserves for the Lanigan seam, but he did report eight coal analyses. The Patrick seam occurs about 80 ft below the Lanigan. It consists of 4 ft of coal for which

10.8 million tons of measured and indicated reserves was reported by Walker (1980). He also provided two coal analyses for this seam.

COAL RANK VARIATION

Rank increase of the Roslyn coal bed in the northwestern part of the coal field was ascribed to "regional metamorphism" rather than local differences in the amount of folding within the field (p. 23, column 1, paragraph 3; fig. 11, p. 24). Walsh and Phillips (1983) also believe the progressive increase in coal rank across the Roslyn field is due to widespread, regional intrusive activity.

COAL MINING FROM 1960 TO 1983

Mining ceased in the Roslyn coal field in 1963. At that time, approximately 64 million tons of coal had been produced — 574 thousand tons between 1960 and 1963. Tuck and Boyd (1966) and Walker (1980) describe the results of coal exploration conducted in the Roslyn coal field after 1960.

SUMMARY OF RESERVES

Walker (1980, p. 20) tabulates six estimates of coal reserves for the Roslyn area. The estimates range from 170.2 million tons to more than 270 million tons. Differences in the reserve estimates stem primarily from differing methods used by the various authors to define a "coal reserve." Walker's (1980) estimates are probably based on the greatest amount of data. He calculated 248.2 million tons of measured and indicated reserves in the Roslyn field — a figure which includes 10.8 million tons for the previously undescribed Patrick seam. Some 24.2 million tons are inferred for the field, giving a total of 272.4 million tons for all reserve categories.

TANEUM-MANASTASH AREA

As in the Roslyn field, several reports and maps dealing with the regional stratigraphy and structure of the Taneum-Manastash area have been produced since 1961. Tabor and others (1984) is among the most definitive — correlating stratigraphic units, formalizing nomenclature, and describing the regional structural setting. On the basis of fossil leaves and palynomorphs, Tabor and others (1984, p. 38) consider the Manastash Formation to be early Eocene (approximately 50 million years before present) and equivalent to the Swauk Formation.

Lewellen and others (1984) describe the Taneum-Manastash area from a structural and sedimentary-petrologic point of view. While analyses of impure, weathered coals are provided, coal reserve estimates are not attempted.

KING COUNTY COAL DEPOSITS

CENTRAL KING COUNTY

REFINED STRATIGRAPHIC NOMENCLATURE

The coal-bearing strata in the Renton, Newcastle-Grand Ridge, Cedar Mountain, and Tiger Mountain areas were considered to occur in the Puget Group of Eocene age in the 1961 printing of this bulletin. Since then the stratigraphic nomenclature has been refined, and the coals of these areas have been referred to the Renton Formation of the Puget Group (Waldron, 1962; Vine, 1969; Mullineaux, 1970).

REDEFINED RANK OF COALS

Renton area. — By the new ASTM Standards, the Springbrook, Sunbeam, and Newenham coal beds are now classified as high-volatile C bituminous instead of subbituminous A. Three of the analyses of the Renton No. 3 bed are now classified as straddling the subbituminous A/high-volatile C bituminous boundary. The Renton Nos. 1 and 2 beds are now classified as subbituminous A.

Cedar Mountain area. — In the Cedar Mountain area, the Discovery, Jones, and Cavanaugh No. 2 beds are now classified as high-volatile C bituminous; the New Lake Youngs No. 2 bed remains high-volatile C bituminous as noted on p. 33-34.

Newcastle area. — In the Newcastle area, the Jones and Bagley beds are high-volatile C bituminous while analyses of the Dolly Varden, Muldoon, and May Creek beds are approximately half high-volatile C bituminous while the other half is mixed subbituminous A and high-volatile C bituminous. The remaining seams in the area are subbituminous.

COAL MINING FROM 1960 TO 1983

Coal production in central King County since 1960 came from a single mine at Newcastle which produced 14,843 tons before terminating operations in 1962.

GREEN RIVER DISTRICT

Vine (1969) presents a comprehensive account of the geology and coal resources of the coal fields within the Maple Valley, Hobart, and Cumberland 1:24,000 quadrangles. This represents the most important published source of information on the coal resources of the Green River district since 1960.

COAL RANK TRENDS

Walsh and Phillips (1982,1983) have documented a general progressive increase in coal rank from west-to-east across the Green River coal district. They interpret this coal rank gradient to be a result of high, regional geothermal gradients induced by Eocene-Miocene igneous activity in the ancestral Cascade Mountains.

COAL MINING FROM 1960 TO 1983

Since 1960, 707,980 tons of coal have been produced in the Green River coal district. Production came from four to six small operations between 1960 and 1963. Since 1964, only one company, Palmer Coking Coal Co., has mined coal in the district. Beginning in 1975 all production has been from a series of small strip mines largely on the Gem and McKay coal seams. Average annual production during this period has been 11 to 12 thousand tons. Currently, Pacific Coast Coal Co. is in the process of securing operating permits from the Federal Office of Surface Mining for a new strip mine in secs. 11 and 12, T. 21 N., R. 6E. If approved, the mine would produce up to 250,000 tons of bituminous coal per year. The production would come from coal beds stratigraphically below the Franklin No. 9 seam.

SUMMARY OF RESERVES

Since 1960, the known coal resources of the Green River district have been increased through coal and petroleum exploratory drill holes. Exploration results are summarized in U.S. Smelting, Refining, and Mining Co. (1962), Shannon and Wilson (1977), and Morris and Ames (1980). Most of the new coal resources identified are stratigraphically below the Franklin No. 9 seam. While detailed reserve studies have not been published, Morris and Ames (1980) estimate that the new resource contains 179.2 million tons of high-volatile B bituminous coal with 3,000 ft or less of overburden.

PIERCE COUNTY COAL DEPOSITS

REFINED STRATIGRAPHIC NOMENCLATURE — WILKESON-CARBONADO COAL FIELD

The Puget Group of Eocene age referred to in the first printing of this publication has been subdivided by Gard (1968) in the Wilkeson-Carbonado area. Coals mined in the Burnett, Gale Creek, Wilkeson, and Carbonado areas have been assigned to the Carbonado Formation. Those mined at the Spiketon and South Willis areas have been assigned to the Spiketon Formation.

COAL MINING FROM 1960 TO 1983

During the period since the first printing of this bulletin, less than 10,000 tons of coal were produced from the Wilkeson-Carbonado coal fields of Pierce County. Of that total only 5,686 tons were mined from underground reserves, occurring over a 14-year period (1960 through 1973) and at an annual average production of slightly greater than 400 tons per year. The remaining 4,192 tons were reprocessed from a waste dump at Wilkeson in 1975 — the last recorded coal production in Pierce County.

Exploration drilling and sampling has occurred in the Wilkeson-Carbonado area since the early 1960's. Feasibility studies of hydraulic mining and other innovative techniques have been and are currently being conducted. To date, none of these methods has been implemented. The challenge in this structurally complex coal field is the development of a mining method for steeply dipping beds that provides acceptable productivity, meets health and safety regulations, and complies with environmental requirements.

Cooley and others (1983) have completed a feasibility study of an underground hydraulic coal mine near Wilkeson. Their mine plan was made for a 2 million (clean) ton-per-year mine using 2 shafts to provide access to the deposit to a depth of 2,500 ft. The coal quality is generally high-grade metallurgical coal. Their proposed mining method uses monitor jets to break coal by sublevel retreat mining and bring it to the surface to a preparation plant.

SUMMARY OF RESERVES

Since 1960 the known coal resources of the Wilkeson-Carbonado coal field have been increased through exploratory drilling. Most of the information is proprietary. The new coal resources identified are mainly stratigraphically below the Wilkeson No. 4 seam.

Cooley and others (1983, p. 24-38) estimate a total reserve of 244 million tons from eight coal seams ranging in thickness from 4 to 17.6 ft. The in-place reserves considered in their study lie within secs. 2, 3, 10, 11, 14, and 15, T. 18 N., R. 6 E., and also secs. 33 and 34, T. 19 N., R. 6 E. Their reserve estimates overlap a portion of the reserves estimated by the authors of Bulletin 47. The latter include reserves for the Wilkeson No. 3, No. 2, and No. 7 seams illustrated in figures 41, 42, and 45.

COAL DEPOSITS OF LEWIS AND THURSTON COUNTIES

CENTRALIA-CHEHALIS COAL DISTRICT

COAL MINING FROM 1960 TO 1983

Since the 1870's, more than 60 million tons of coal have been mined from the Centralia-Chehalis district. Prior to 1960, about 9 million tons had been produced – more than 7.5 million tons from the Tono No. 1 coal bed and most of the remainder from the Mendota bed.

Since 1960, more than 51 million tons of coal has been produced from the Centralia-Chehalis district. Nearly all of that production has come from a single, large strip mine, the Centralia mine, located 8 miles northeast of the city of Centralia. The remaining production (approximately 123,000 tons) was by three companies which operated during different periods between 1960 and 1976.

The Centralia mine is a captive strip mine dedicated solely to the mine-mouth thermo-electric generating plant located a few miles from the mining area. The mine occurs mostly within the western two-thirds of T. 15 N., R. 1 W. and the northern two-thirds of T. 14 N., R. 1 W., straddling the Thurston-Lewis County line. Most of the production has come from the Big Dirty, Little Dirty, and Smith coal seams, with lesser amounts from the Upper and Lower Thompson seams. Since 1974, the average annual production has been approximately 4.5 million tons. A maximum production of 5.1 million tons occurred in 1980. The Centralia mine commenced production in 1971 and immediately surpassed production of the Tono mine, formerly the largest strip mining operation in southwestern Washington.

UNDERGROUND COAL GASIFICATION

Research and development of the underground coal gasification process (UCG) has been continuing at the Centralia mine since 1980. Through this technique, lignite and other low-grade coals, uneconomical to mine through conventional means, could be developed as a commercial energy source. The ultimate goal of these experiments is the successful gasification of multiple seams approximately 600 ft deep in the Tono Basin, 2 miles east of the mine-power plant complex. The gas generated from this process at the Centralia mine would probably be used as a boiler feedstock for electrical power generation. A consensus of opinion indicates that the UCG process can be commercial within the next decade.

COAL DEPOSITS OF COWLITZ AND LEWIS COUNTIES

KELSO-CASTLE ROCK AREA

GEOGRAPHIC AND GEOLOGIC SETTING

May (1980) interpreted the paleoecology and depositional environment of the Toutle Formation east of the Cowlitz River, in the area mapped by Roberts (1958). May was able to refine the age assignment made by Roberts and divided the Toutle Formation into two members – a lower marine member to which he assigned latest Eocene through earliest Oligocene strata, and an upper continental member which he provisionally dated as no older than early Oligocene.

GEOLOGIC MAPPING AND EXPLORATION FROM 1960 TO 1983

The Kelso-Castle Rock area saw little exploration activity for coal reserves until the late 1970's and early 1980's. Livingston (1966) mapped the geology of the Kelso-Cathlamet area, which includes the southwest quarter of the Kelso-Castle Rock area shown in figure 60, p. 107.

Drilling was done in the Wilkes Hills area between the Toutle and Cowlitz Rivers near the Lewis-Cowlitz County line, and to the northwest between the towns of Curtis and Vader. In the Curtis-Vader area at least five minable seams of lignite have been intercepted by exploration drilling over the last 5 years. The lignite beds occur within strata which Henriksen (1956) named the Olequa Creek member of the Cowlitz Formation and which Wells (1981,1982) assigned to the Cowlitz Formation. The lignite-bearing strata are believed to be equivalent to the Skookumchuck Formation (Snavely and others, 1958) in the Centralia-Chehalis coal district. These strata were intercepted by the Shell Oil Co. Zion No. 1

well (McFarland, 1983) in sec. 15, T. 11 N., R. 2 W., located midway between Vader and Toledo in southwestern Lewis County. No less than 20 coal-bearing zones were intercepted between depths of 230 to 5,565 ft in the well.

The exploration drilling in the Curtis-Vader area has proved significant strippable reserves of lignite. It has been speculated that the deposit is large enough to supply 3.5 to 4 million tons of lignite per year for a mine-mouth thermoelectric power plant. Further information at the time of this writing is being kept proprietary by the exploration companies.

MISCELLANEOUS OCCURRENCES OF COAL IN WASHINGTON

ASOTIN COUNTY

Stoffel (1984) describes the geology of the Grande Ronde lignite field in Asotin County. Lignite beds up to 40 ft thick are intercalated with flows of the Miocene Columbia River Basalt Group. Analyses of the lignites range from 5,027 to 7,994 Btu per pound (as received) with low sulfur (0.1 to 0.4 percent) and moderate (5.7 to 16.7 percent) ash contents. Regional structural deformation during peat deposition, invasion of peats by basalt flows, post-basalt folding, and erosion of the lignite beds by the Grande Ronde River have all combined to produce complex stratigraphic relationships between Columbia River Basalt Group flows and intercalated lignite-bearing sediments. Future exploration for lignite in the Grande Ronde lignite field must be based upon a thorough understanding of these stratigraphic complexities.

ISLAND COUNTY

Coal-bearing rocks were found at a depth of 624 ft in a water well on the north end of Whidbey Island, in the NW¼SE¼ sec. 23, T. 33 N., R. 2 E. (Walsh, 1984a). An analysis of the coal indicated a probable high-volatile C bituminous rank. Walsh (1984a) tentatively correlates the coal-bearing strata with the Eocene Chuckanut Formation on the basis of coal rank.

ERRATA

On p. 2, column 1, paragraph 3, second equation: Mineral-matter-free fixed carbon (FC) should be on the dry basis (*Dry*, Mm-free FC) rather than *Moist*, Mm-free FC.

On p. 16, column 2, paragraph 2, the Cokedale, Hamilton and Rick Creek areas cover about 25 square miles rather than 250 square miles as stated. Likewise, the McMurray area covers 45 square miles rather than 450 square miles.

On p. 33, column 2, paragraph 2: Most of the Newcastle-Grand Ridge coal seams dip an average of 45° and as steep as 70° — rather than less than 35° as stated.

On p. 34, column 2, paragraph 1: Throughout most of the [Newcastle-Grand Ridge] area the coal beds strike eastward and dip 40° to 48°, not 30° to 40° as stated.

On p. 36, column 1, paragraph 1: The coals of the Newcastle-Grand Ridge area were considered as subbituminous A coal (even though some of the coals were then classified as either subbituminous A or high-volatile C). However, the rank of these coals now ranges from subbituminous B to high-volatile C as a result of changes in ASTM standards.

On p. 36, column 1, paragraph 4: The statement that the coal beds of the Renton area have not been located north of the west-trending fault proposed by Warren and others (1945) is in error. Warren and others (1945) clearly show that coal mine workings extended across this fault and that coal was mined to the north of it.

On p. 37, column 1, paragraph 2: With regard to the coal beds in the Cedar Mountain area (fig. 19) the authors of this bulletin did not think that correlations of coal beds on either side of that fault shown on figures 21 through 24 could be made. Also, they stated that the New Lake Youngs No. 2 bed (fig. 20) appears to be stratigraphically higher than the coal beds that crop out to the north (Ryan No. 1, Discovery, Jones, and Cavanaugh No. 2; figs. 21 through 24). They noted, however, because structural data were scarce, that the stratigraphic position of the New Lake Youngs No. 2 bed is uncertain. Walsh (1984b) has correlated the New Lake Youngs No. 2 bed with the Ryan No. 2 and Cedar Mountain No. 2 beds, and the Ryan No. 1 bed with the Cedar Mountain No. 1 coal bed. Walsh (1984b) bases his correlations on old coal mine maps and measured coal seam descriptions. He also shows from coal mine map data that the New Lake Youngs No. 2 bed is folded into an anticline and dips back toward the other coal beds. The map showing the New Lake Youngs No. 2 (fig. 20) does not show it as an anticline.

On p. 39 (fig. 19), the authors show 1,000 ft separating the Ryan No. 2 and Discovery coal beds. A more accurate distance of 700 ft separating these two beds has been determined from coal mine maps.

On p. 50 (table 14) the Cedar Mountain No. 2 seam is shown to be within the 2.5 to 5.0 ft category. Vine (1969, p. 54) lists its thickness as about 3.5 ft. H.D. Gower was a contributor to both this bulletin and to Vine (1969), so a thickness of 3.5 ft for the Cedar Mountain No. 2 bed was

probably used to determine the reserve figure. Evans (1912) gave a thickness of 9 ft for this bed while Landes (1903) also gave a thickness of 9 ft which included a 1-ft seam of dirt. Mine map records of the Pacific Coast Coal Co. (Schasse and others, 1983, p. 40, index no. K-41) show the thickness to be 9.75 ft and Walsh (1984b) measured a thickness of 9.5 ft. Reserves for the Cedar Mountain No. 2 seam should therefore be increased by about 2.5 times.

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COAL RESERVES OF WASHINGTON

By Helen M. Beikman, Howard D. Gower, and Toni A. M. Dana

ABSTRACT

The coal reserves of Washington remaining in the ground as of January 1, 1960 are estimated to be 6,185 million short tons. Of this total, about 5 million tons is anthracite, 1,869 million tons bituminous coal, 4,194 million tons subbituminous coal, and 117 million tons lignite. This estimate is based on all available information concerning the location, thickness, extent, and rank of the coal beds. It includes anthracite and bituminous coal in beds 14 or more inches thick and subbituminous coal and lignite in beds $2\frac{1}{2}$ or more feet thick, all less than 3,000 feet below the surface.

The coal-bearing rocks in Washington occur as areas of relatively limited extent separated by expanses of older, non-coal-bearing rocks or by a cover of younger rocks. The principal deposits in the State occur along the western margin of the Cascade Range in a discontinuous belt that extends from the Canadian border south to the Columbia River. One important exception to this is the Kittitas County coal fields, which are on the east side of the Cascades in the central part of the State.

All known deposits of commercial coal in Washington are of Tertiary age, and most of the coal-bearing rocks have been folded or faulted to varying degrees. The rank of the coal ranges from lignite to anthracite. In general the rank increases with age; early to middle Eocene deposits are bituminous coals, most late Eocene deposits are subbituminous coals, and Oligocene deposits are lignites. Anthracite occurs only in small areas of intense deformation. Volcanic ash is a constituent of the coal-bearing rocks and of most coal beds.

INTRODUCTION

This summary of the coal reserves of Washington has been prepared by the U.S. Geological Survey in cooperation with the Division of Mines and Geology of the Washington Department of Conservation. It is part of a larger study by the U.S. Geological Survey to re-estimate the coal reserves of the United States. The purpose of the study is to show the quantity and distribution of coal according to rank, thickness of beds, and thickness of overburden, based on information currently available.

The previous estimate of the coal reserves of Washington was made in 1929 by M. R. Campbell of the U.S. Geological Survey (Campbell, 1929). Much new geologic information on the Washington coal field areas has become available since that estimate was prepared, and more detailed methods of estimating reserves have been established. The new estimate of this report is based on the modern information and procedures and thus has greater reliability and utility than the older estimate.

Although the increased availability of hydroelectric power, petroleum, and natural gas have led to a decrease in the use of coal as a fuel in the past few decades, the supply of energy available from these sources may in time become inadequate to meet the increasing demand for power in Washington. It is therefore apparent that the long-term potentialities of Washington's substantial coal resources should be reappraised and their ability to supplement other sources of power in meeting the ever-increasing energy requirements of the State be considered.

Geologic mapping of coal-bearing areas in Washington is hampered by a thick mantle of soil and glacial drift and by a dense growth of vegetation. Although geologic maps have been published for many of the coal-bearing areas in the State, geologic information of the type required to make a detailed estimate of coal reserves is scarce or lacking for many areas. In addition to providing a convenient summary of what is presently known about the coal resources of the State, this report points out areas where additional geologic information is needed.

The most detailed information about coal fields in Washington is contained in reports of the Washington Division of Mines and Geology and its predecessors, in reports of the U.S. Bureau of Mines, and in those of the U.S. Geological Survey. Much information is also present in records of mining companies. These sources have provided the data on which this report is based. A small amount of field work was done by the U.S. Geological Survey in areas where information on coal was scarce.

The cooperation of numerous individuals and mining companies in furnishing information that contributed to the completeness of this study is gratefully acknowledged.

METHODS OF ESTIMATING RESERVES

An estimate of the coal reserves of a large area must be based on both factual information and assumptions concerning thickness, extent, and correlation of coal beds, and the value of the estimate to the user is dependent upon the definitions and procedures used in its preparation. The methods used in preparing this report are similar to those used by the U.S. Geological Survey in preparing other state summaries (Averitt, In press) and are briefly described here.

CLASSIFICATION ACCORDING TO CHARACTERISTICS OF THE COAL

Characteristics considered in calculating coal reserves are the rank and weight of the coal and the thicknesses of the coal beds and of the overburden.

Rank of coal.—The rank of coal is determined according to the standard classification of the American Society for Testing Materials (1951, p. 75). For classification of coals by this means (table 1) it is necessary to calculate the Btu values and the fixed carbon values of some of the bituminous coals given in the tables of coal analyses to the mineral-matter-free basis in accordance with the following formulas (ASTM, 1951, p. 78):

$$\text{Moist, Mm-free Btu} = \frac{\text{Btu}}{100-(1.1A+0.1S)} \times 100$$

$$\text{Moist, Mm-free FC} = \frac{\text{FC}}{100-(M+1.1A+0.1S)} \times 100$$

Where: Mm = mineral matter;
Btu = British thermal units;
A = percentage of ash; S = percentage of sulfur;
FC = fixed carbon; M = percentage of moisture.

Weight of coal.—For purposes of calculating reserves where precise data are not available, the values assigned as weights of coal in Geological Survey calculations are 2,000 tons per acre-foot for anthracite and semianthracite, 1,800 tons per acre-foot for bituminous coal, 1,770 tons per acre-foot for subbituminous coal, and 1,750 tons per acre-foot for lignite. These figures have been accepted for use in calculating Washington reserves, with the exception of lignite in the Kelso-Castle Rock area, where a weight of 2,000 tons was used (p. 105).

Thickness of beds.—The estimates of coal reserves in this report are divided into three bed-thickness categories called thin, intermediate, and thick. These thickness categories are based primarily on the mining characteristics of the different ranks of coal. For anthracite and bituminous coal the beds from 14 to 28 inches thick are classed as thin, those from 28 to 42 inches are classed as intermediate, and those 42 or more inches are classed as thick. For subbituminous coal and lignite the thicknesses assigned to these categories are $2\frac{1}{2}$ to 5 feet, 5 to 10 feet, and 10 or more feet, respectively. Anthracite and bituminous coal in beds less than 14 inches thick and subbituminous coal and lignite in beds less than $2\frac{1}{2}$ feet thick are generally considered too thin to be minable on any large scale; therefore, reserves have not been calculated for such beds. Partings more than three-eighths of an inch thick are subtracted from the bed total in determining thicknesses. Beds composed of alternating thin layers of coal and partings are omitted if the partings make up more than half of the total thickness.

Thickness of overburden.—Coal-reserve data are reported in several classes according to the thickness of rock overlying the coal. Thus, for coal mined underground the reserves are divided into three overburden categories: 0 to 1,000 feet, 1,000 to 2,000 feet, and 2,000 to 3,000 feet. Coal more than 3,000 feet below the surface is, for the most part, beyond the limit of present economic interest, and is not included in reserve estimates.

The overburden categories generally used for strippable coal are 0 to 60 feet, 60 to 90 feet, and 90 to 120 feet. The Cedar Creek lignite area in Lewis County is the only area in the State where the amount of drilling data available was sufficient at the time this report was being prepared to delineate strippable reserves, and here data were abundant enough to make a more definitive classification of the overburden into the following categories: 0 to 20 feet, 20 to 40 feet, and 40 to 60 feet.

CLASSIFICATION ACCORDING TO ABUNDANCE OF RELIABLE DATA

Coal-reserve estimates by the U.S. Geological Survey are divided into three categories termed "measured," "indicated," and "inferred" according to the abundance and reliability of data.

Measured reserves.—Measured reserves are those for which tonnage is computed from dimensions of coal beds revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurements are no more than half a mile apart, and the thickness and extent of the coal bed is so well defined that the computed reserve tonnage is judged to be accurate within 20 percent or less of the true tonnage.

Indicated reserves.—Indicated reserves are those for which tonnage is computed partly from specific measurements and partly from projection of reliable data for a reasonable distance on geologic evidence. In general, the points of observation are about 1 mile apart but may be as much as $1\frac{1}{2}$ miles apart for beds of known geologic continuity.

Inferred reserves.—Inferred reserves are those based largely on broad knowledge of the geologic character of the individual coal beds and on an assumed continuity of the coal for which there is geologic evidence. In general, inferred coal lies more than 2 miles from the outcrop.

Because of the paucity of exposures and the lack of drill-hole data, the reserves of coal in the State of Washington that can be assigned to the measured category are small and probably comprise less

Table 1.--Classification of coals by rank

Explanation: FC, fixed carbon; VM, volatile matter; Btu, British thermal units.

This classification does not include a few coals that have unusual physical and chemical properties and that come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[From American Society for Testing Materials (1951, p. 75)]

Class	Group	Limits of fixed carbon or Btu mineral-matter-free basis	Requisite physical properties
I. Anthracitic	1. Meta-anthracite	Dry FC, 98 percent or more (dry VM, 2 percent or less)	
	2. Anthracite	Dry FC, 92 percent or more and less than 98 percent (dry VM, 8 percent or less and more than 2 percent)	
	3. Semianthracite	Dry FC, 86 percent or more and less than 92 percent (dry VM, 14 percent or less and more than 8 percent)	Nonagglomerating 1/
II. Bituminous 2/	1. Low-volatile bituminous coal	Dry FC, 78 percent or more and less than 86 percent (dry VM, 22 percent or less and more than 14 percent)	
	2. Medium-volatile bituminous coal	Dry FC, 69 percent or more and less than 78 percent (dry VM, 31 percent or less and more than 22 percent)	
	3. High-volatile A bituminous coal	Dry FC, less than 69 percent (dry VM, more than 31 percent); and moist 3/ Btu, 14,000 4/ or more	
	4. High-volatile B bituminous coal	Moist 3/ Btu, 13,000 or more and less than 14,000 4/	
	5. High-volatile C bituminous coal	Moist Btu, 11,000 or more and less than 13,000 4/	Either agglomerating or nonweathering 5/
III. Subbituminous	1. Subbituminous A coal	Moist Btu, 11,000 or more and less than 13,000 4/	Both weathering and nonagglomerating
	2. Subbituminous B coal	Moist Btu, 9,500 or more and less than 11,000 4/	
	3. Subbituminous C coal	Moist Btu, 8,300 or more and less than 9,500 4/	
IV. Lignitic	1. Lignite	Moist Btu, less than 8,300	Consolidated
	2. Brown coal	Moist Btu, less than 8,300	Unconsolidated

1/ If agglomerating, classify in low-volatile group of the bituminous class.

2/ It is recognized that there may be noncaking varieties in each group of the bituminous class.

3/ Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

4/ Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

5/ There are three varieties of coal in the high-volatile C bituminous coal group, namely, variety 1, agglomerating and nonweathering; variety 2, agglomerating and weathering; variety 3, nonagglomerating and nonweathering.

than 10 percent of the total. This assumption is based on the results of the reserve estimate for the Centralia-Chehalis district by Snavely and others (1958), in which measured reserves were calculated separately and were found to constitute less than 7 percent of the total reserves for that area. In order to avoid disclosing measured reserves of coal on an individually owned property and also because such a small percentage of total reserves could be classed as measured, the measured reserves in that report were combined with indicated reserves. In preparing the present State-wide summary, measured reserves were not calculated separately but are included within the one category of "measured and indicated" reserves.

ORIGINAL, REMAINING, AND RECOVERABLE RESERVES

Estimates of reserves may be made on the basis of original reserves in the ground prior to mining, remaining reserves as of a certain date, or recoverable reserves as of a certain date.

Remaining reserves are reserves in the ground as of the date of appraisal and are obtained by subtracting from original reserves the past production and losses by fire, flooding, and caving.

Recoverable reserves are reserves of coal in the ground as of the date of appraisal that could be produced in the future under the present economic conditions; they are obtained by subtracting from remaining reserves the estimated future losses in mining.

In this report, reserves for fields in which there has been considerable mining are given as remaining reserves as of January 1, 1960. For fields in which coal production has been negligible, remaining reserves are practically synonymous with coal originally in the ground; therefore, reserve estimates for these fields are given as original reserves.

RECOVERABILITY IN MINING

Measurements of several mined-out areas of certain coal beds give a figure for the total coal originally in that bed in each mined-out area. This figure, when compared with the record of past production for these beds, indicates that, in southwestern Washington underground mines, about 40 percent of the coal has been recovered. In the Roslyn coal field, about 80 percent of the coal was recovered. Recoverable reserves differ from area to area but can be assumed to be at least 40 percent of the coal remaining in the ground. Improvements in mining practices could increase this recovery figure.

It is not possible at this writing to obtain a reliable figure for percentage of recoverability by strip mining in Washington; however, a much higher percentage of coal can be recovered than from underground mining. As an example, in Indiana, where 50 percent of the coal can be recovered by underground mining, 80 percent can be recovered by strip-mining methods (Spencer, 1953, p. 11).

METHODS OF RECORDING DATA AND MAKING CALCULATIONS

The tonnage estimates presented in this report are calculated by townships for individual coal beds where sufficient information was available. To prepare these estimates, a work sheet was compiled of each bed or of each coal-bearing area, showing the location of all outcrops, measured sections, mine information, and the drill holes that penetrated the coal bed or beds. On the basis of this information the thickness of the coal was determined; the areas of measured- and indicated- and inferred-reserve categories were outlined; and areas of coal under each of the overburden ranges were delineated.

The thickness of the coal in each area thus delineated was obtained by taking a weighted average of all the thickness figures from the plotted data pertaining to the coal bed. The thicknesses used were actual measured thicknesses of coal, excluding partings more than three-eighths of an inch thick; in areas of little data, reported thicknesses of coal were used. The areas outlined on the work maps by these procedures were measured with a planimeter to obtain the acreage underlain by coal in the different categories of thickness, reserve, overburden, and rank within each township. Where coal beds dip at angles greater than 18°, the true area of the coal bed is significantly greater than the surface area underlain by coal. The acreage obtained from planimeter measurements of such areas was multiplied by the secant of the angle of dip to obtain the true area of the coal bed. The tonnage was calculated by multiplying the number of acres by the weighted average thickness of the coal to the nearest tenth of a foot, and the appropriate weight factor per acre-foot for each rank of coal. The figures were then rounded to the nearest 10,000 tons, which is a very small unit for calculations of this nature, but which was used to preserve and incorporate figures for the smaller areas of coal.

COMPARISON OF RESERVE ESTIMATES

Campbell (1929, table facing p. 24) estimated the coal reserves of Washington to be about 64 billion tons. This estimate included coal to a minimum thickness of 14 inches and to a maximum depth of 3,000 feet below the surface. The present estimate, which is based on the same limits of coal thickness and depth, is slightly more than 6 billion tons, or about one-tenth of the Campbell estimate.

At the time the Campbell estimate was prepared only a few of the better known coal areas had been mapped in detail, others had been mapped only in reconnaissance, and still others were unmapped. His problem was further complicated by the fact that most areas of coal-bearing rock in Washington are concealed by thick soil, glacial drift, or by younger rocks. Thus, knowledge of the lenticular nature of the coal beds had not been fully established. Campbell's estimate for Washington, as for other states, was an attempt to estimate the total amount of coal that might ultimately be found by

exploration in all the coal-bearing areas. Consequently, he assumed wide continuity for the coal beds and made statistical allowance for coal in the concealed and unmapped areas.

Much more information was available for use in preparing this report than was available to Campbell. The additional information precluded the extension of reserves over vast areas for which data are still inadequate or entirely lacking. The present estimate of about 6 billion tons is conservative and represents only a minimal estimate of the coal reserves. Detailed geologic knowledge of many of the coal-bearing areas would most likely result in an expanded reserve estimate.

WASHINGTON COAL DEPOSITS

The coal-bearing rocks in Washington occur in many small areas (fig. 1) separated by expanses of older, non-coal-bearing rocks or by a cover of younger rocks. In this report coal-bearing areas that are surrounded by older rocks and thus are clearly defined are called fields or districts; those that are covered by younger rocks and thus are not clearly defined are called areas. The name assigned to a field or area is generally that of the largest nearby town or city. The reserve estimates are given by townships within the fields or areas.

GEOGRAPHIC AND GEOLOGIC SETTING

Most of the principal coal deposits in Washington occur in a discontinuous belt extending along the western edge of the Cascade Range from the Columbia River northward nearly to the Canadian border; notable exceptions are the Kittitas County coal fields on the east flank of the Cascades in the central part of the State. In addition, coal occurs in many small, isolated areas in other parts of the State. The locations of the major coal-bearing areas and of the isolated occurrences of coal are shown on figure 1. These coal areas are grouped for the purpose of descriptions under eight geographic headings as follows: Whatcom County, Skagit County, Kittitas County, King County, Pierce County, Centralia-Chehalis coal district, Kelso-Castle Rock coal area, and Eastern Lewis County (fig. 2).

With the exception of several thin beds of semianthracite in rocks of pre-Tertiary age on Orcas Island in San Juan County, all coal in the State is of Tertiary age. Most of the principal coal deposits occur in rocks of Eocene age and were formed in swamps that occurred along the eastern shoreline of a north-trending sedimentary basin. The coal-bearing rocks interfinger with and grade into marine non-coal-bearing rocks to the west. Local volcanism was contemporaneous with the deposition of the coal-bearing rocks, and in some places volcanic rocks are the lateral equivalents of the coal-bearing sequence. The high ash content of many of the coal beds is due to volcanic ash falls that occurred during accumulation of the coal-forming plant material.

The rocks in all coal-bearing areas have been folded and faulted, but the amount of deformation and type of structure varies greatly. In the Centralia-Chehalis district, Kelso-Castle Rock area, and Roslyn field the major structures consist of gently folded, broad anticlines and synclines with dips generally less than 30°. In the Green River district of King County, dips of 50° or more are common. In the Wilkeson-Carbonado field of Pierce County, the structure is extremely complex, consisting of a northwest-trending anticline flanked by smaller plunging anticlines and synclines, all of which have been cut by normal and high-angle reverse faults. Dips of 60° or more are common in this field.

COAL BEDS

The coal beds within a field derive their names from mines and geographic areas where they are particularly well developed. Many names are used only locally. Also, many of the beds have been referred to by more than one name, because it is a common practice of mine operators to call a coal bed by the name of the mine where it is worked. In this report, coal beds are correlated from one area to another, using, wherever possible, the name by which the bed is most widely known. Where data are too scarce to permit correlation the local names are used.

Physical and chemical properties.—The rank of the coal beds ranges from lignite in the southwestern part of the State to anthracite in the Glacier field near the Canadian border. In places the coal ranges appreciably in rank within a field. In this report the rank of coals has been determined from published analyses, from sources cited in the appropriate tables. Where several analyses are available for a particular coal bed, an average value is given. Only proximate analyses on an "as-received basis" are given, because they most closely approximate the composition of the coal in the ground. Detailed individual analyses can be found in the published sources.

COAL MINING

History.—The occurrence of coal in Washington has been known since the early days of settlement. As early as 1833, coal prospects were examined near the junction of the Cowlitz and Toutle Rivers in Cowlitz County by a Dr. Tolmie, who was employed by the Hudson's Bay Company (Roberts, 1958, p. 2). Other discoveries of coal in 1848 in the Cowlitz River valley were reported (Bancroft, 1890, p. 340), but when tested, this coal was found to be a poor quality lignite. At about this same time, coal found on the Skookumchuck River provided the incentive for building the first railroad from Seattle to the Columbia River (Bancroft, 1890, p. 340). The occurrence of coal on Bellingham Bay was known in 1849, and according to Jenkins (1923, p. 17), the first coal mine in the State was opened at Bellingham in Whatcom County about 1854. In 1877 Goodyear (p. 97-129) gave a complete description of mines in operation at

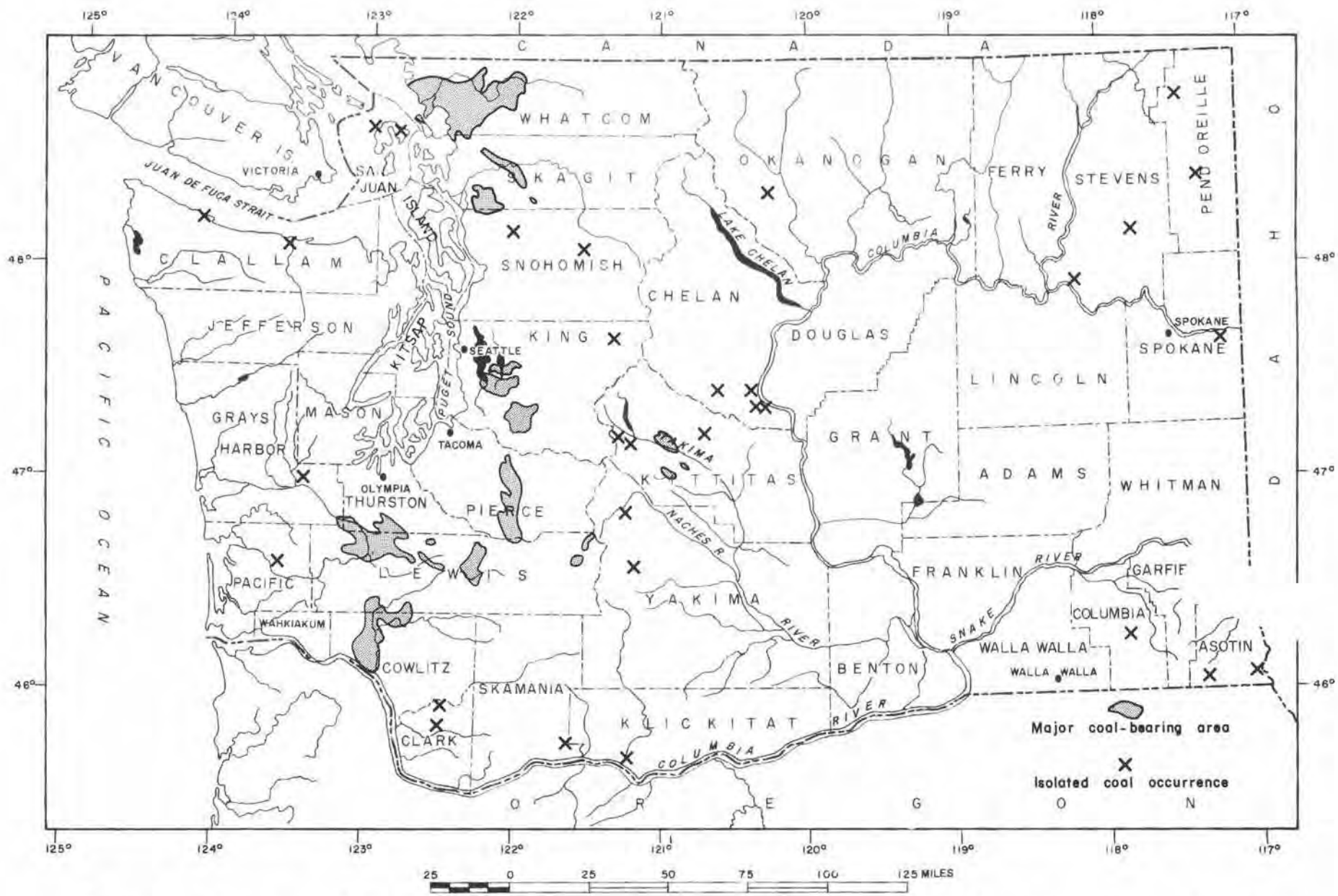


Figure 1. Index map of Washington showing major coal-bearing areas and isolated occurrences of coal.
(After Valentine, 1949, pl. 9)

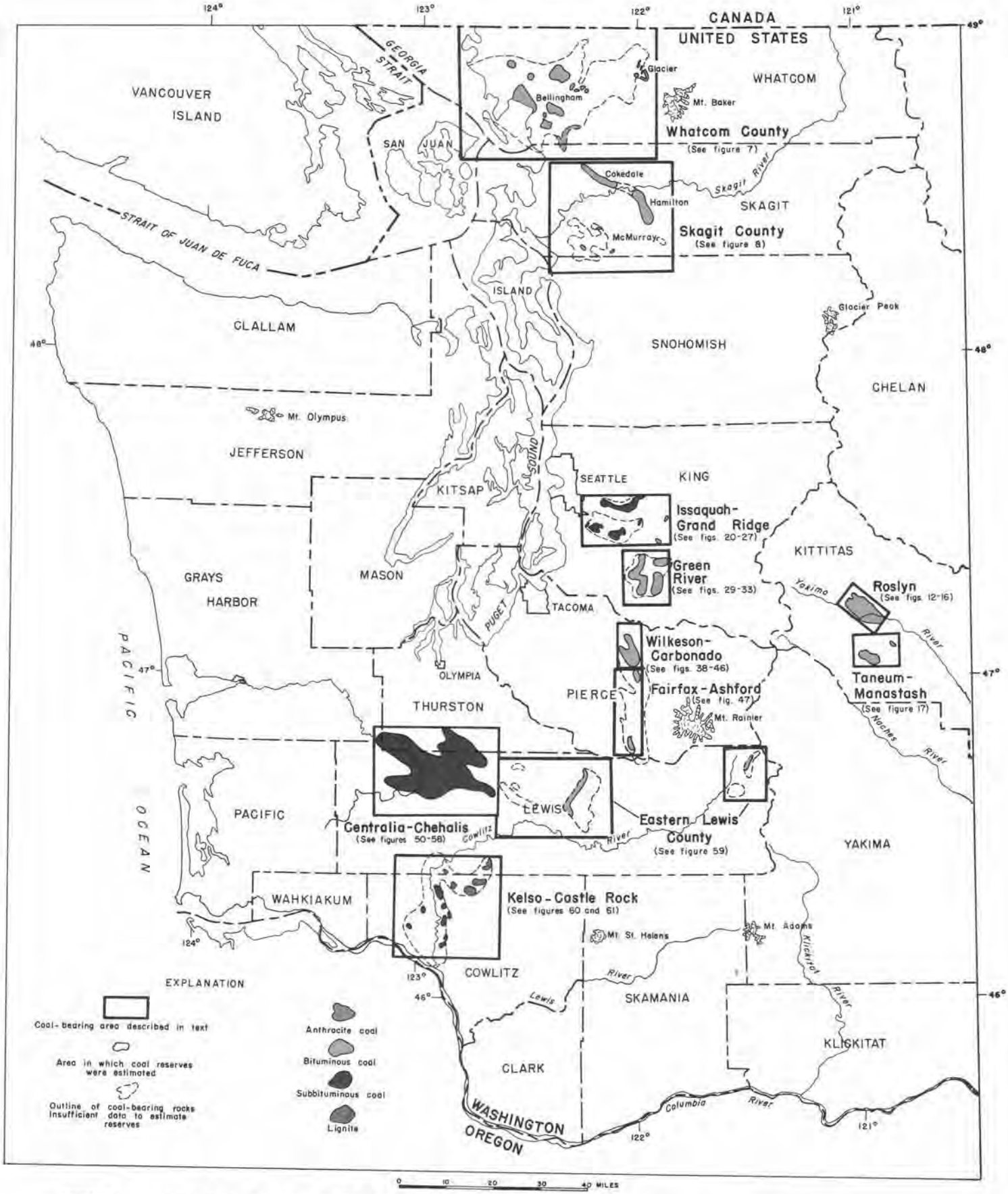


FIGURE 2 INDEX MAP OF WESTERN WASHINGTON SHOWING MAJOR COAL-BEARING AREAS

that time, including the Bellingham mine and the Renton, Talbot, and Seattle Coal and Transportation Company mines in King County southeast of Seattle.

Eavenson (1942, p. 340) gives the following account of the further development of the coal industry in Washington:

> The coal from the mines around Seattle became an important factor in the San Francisco market in 1877 as rail connection was made between the town and the Renton mines, and this road was extended to the Newcastle mine in 1878. The seam found near Tenino [Lewis County] in 1873 had stood idle after some headings had been driven, until 1878 when the sheriff of Thurston County took the Territorial prisoners there to work the mine, which has since been occasionally known as the 'Penitentiary Vein.' The Puyallup field was practically abandoned in 1880, but in years following Pierce County gained importance as a source of coal near Wilkeson, and later the Roslyn-Cle Elum field in Kittitas County was developed, and by 1890 coal mining was the principal mining industry of the State.

During the period 1850–1870, all the major occurrences of coal in the State as they are known today had been discovered, and by 1890 (Bancroft, p. 340) coal ranked second in importance to lumber as an export product from Washington.

In the first few decades of the twentieth century, coal production increased greatly owing to its use as a fuel for domestic purposes and for railroad operations, and the peak of production was reached in 1918, when more than 4 million tons of coal was mined. In the 1930's production began to decline because of the increased use of oil as a fuel, availability of low-cost hydroelectric power, and increased imports of coal from Wyoming and Utah. In 1959, production from the State was only about 200,000 tons.

Almost 150 million tons of coal has been produced in the State, primarily from Kittitas, King, and Pierce Counties. The annual and cumulative coal production since 1860 is shown on figures 3 and 4.

Mining methods.—Coal in Washington is mined chiefly by underground methods, although at several localities in King, Kittitas, and Thurston Counties coal has been mined by stripping methods.

In the past, most of the underground mines were "water level" or "drift" mines in which the lowest point in the mine was at the portal. The workings were driven slightly up the dip of the coal bed so that the mine was self-draining. As coal above the level of the portal was mined out, the mine was either abandoned or, as frequently happened, slopes were then driven down the dip of the coal bed and pumps installed to remove excess water. Gangways along the strike of the bed would be made off the main slope at different levels. At the present time, the majority of the mines are slope mines, and room and pillar mining is most often used.

Strip mining of coal is done in a few areas where the coal is flat lying or gently dipping and the overlying rocks are thin enough to be removed economically, and along the outcrop of steeply dipping thick coal beds. This method has advantages over underground mining in that mining costs are lower, a higher percentage of the coal bed can be removed, and more coal can be produced per man-day.

Large-scale strip mining is not feasible in most of Washington because the coal beds dip rather steeply and the thickness of overburden increases rapidly down dip. However, a few scattered areas where the coal beds are close to the surface and have low dips are suitable for stripping operations. In view of the economic advantages of mining by this method, areas that may be suitable for potential strip mine operations are discussed separately for each coal district.

Mining problems.—In many areas in Washington the coal-bearing strata have been both folded and faulted. Thus the coal beds dip at angles ranging from moderate to steep, and in some mines more than one method of mining may be necessary to remove the coal. Where the coal is faulted it is often necessary to change the grade of the slope when the faulted bed is relocated.

The roof rock of many of the coal beds is structurally incompetent siltstone or friable sandstone, and in some mines extensive timbering is necessary or several feet of coal must be left in place to support the roof. As most of the mines now operate below the level of the water table, almost continual pumping is necessary to remove the water that accumulates.

COKING COAL AND COKE

Coking coal occurs in the Pacific Coast of the United States only in Washington and Alaska. Because of the importance of coke in many West Coast industries and in the export market, the coking coal in Washington is of especial interest. The following paragraphs, summarized in part from reports of Daniels (1920, 1941) and Yancey and others (1943), give the salient facts concerning the Washington coking coal deposits.

Properties of coking coal.—A coking coal is a coal that will fuse or become semiliquid during destructive distillation and form a residue consisting of a hard cellular mass of carbon and inert constituents with certain physical and chemical properties that make it suitable for metallurgical and industrial uses. The properties of a coke determine the use to which it is put.

According to Berryhill and Averitt (1951, p. 4) it has not been possible to devise a satisfactory set of standards for the identification of a good coking coal by its physical and chemical properties. Most coke has been manufactured from high-volatile A bituminous coal, and lesser amounts from low-volatile and medium-volatile bituminous coal. Although rank is an important criterion for determining whether a coal is a good coking coal, variants such as ash content, agglutinating value, amount of vitrain (coalified wood) present, as well as other factors, play a part in the determination of the coking quality of a coal. Many bituminous coals will coke or fuse when heated in a closed oven, but a coking coal must produce a coke that meets

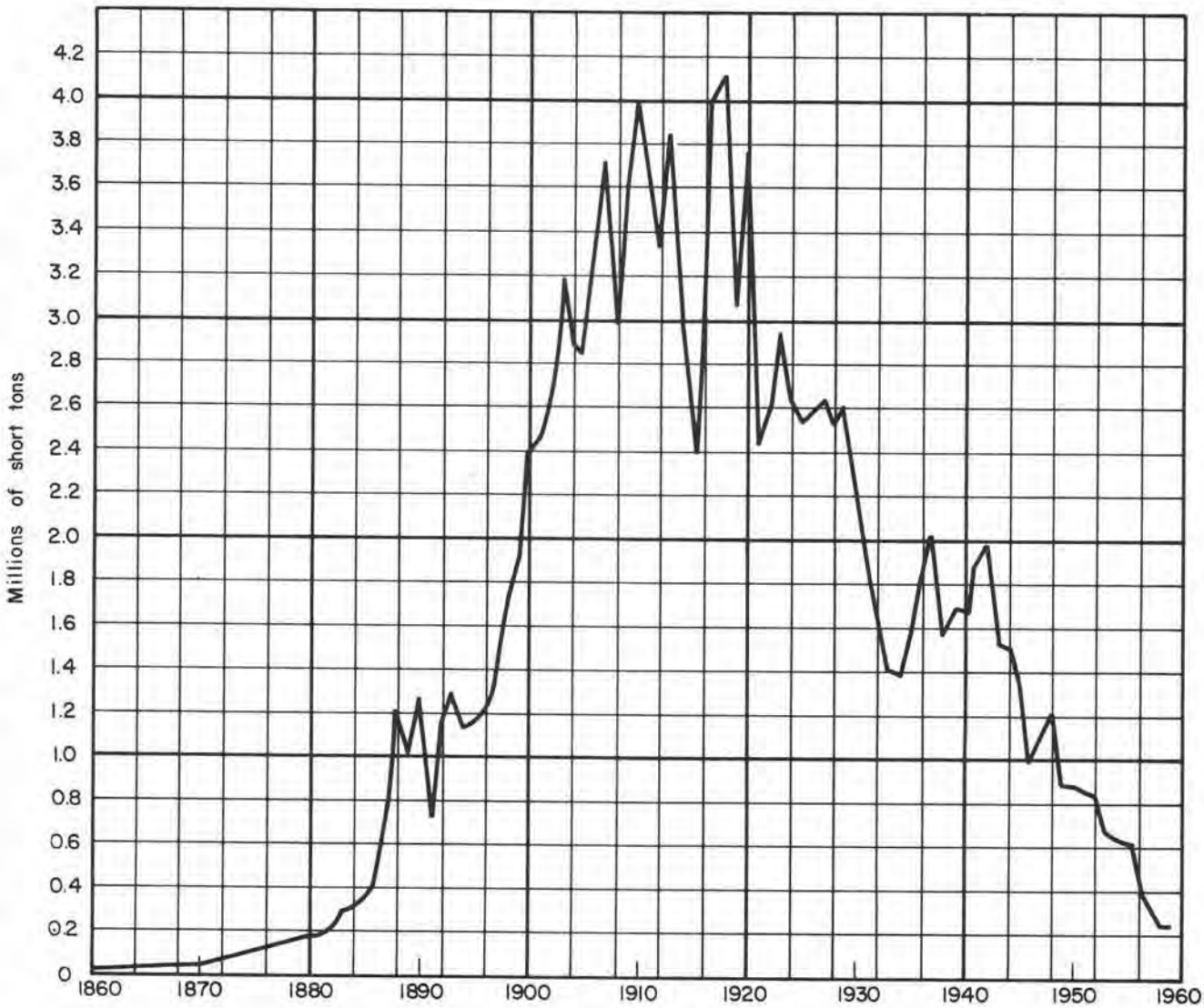


Figure 3. Coal production in Washington, by year

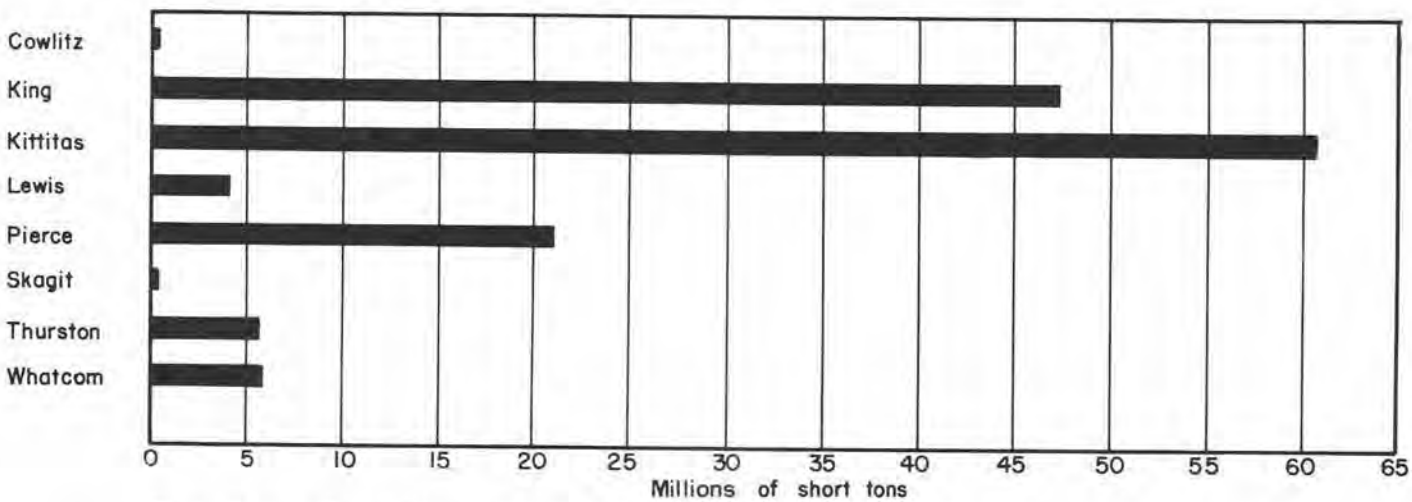


Figure 4. Cumulative coal production in Washington, by county

specific requirements for use in blast furnaces, in foundries, in the manufacture of water-gas, or as a domestic fuel.

History of coke production.—The first coke made in Washington was pit coke made at Wilkeson in Pierce County about 1880, and the earliest reported production was 400 tons of pit coke in 1884. The building of two beehive ovens at Wilkeson in 1885 marked the beginning of the coking industry in the State. From 1885 to 1937, when most coke manufacturing ceased, beehive ovens were built at Wilkeson, Carbondale, Crocker, Fairfax, and South Willis in Pierce County; at Cokedale in Skagit County; and at Snoqualmie in King County. The operations at Cokedale and Snoqualmie were ephemeral, and most of the coke manufacturing was centered in Pierce County. At the end of 1921, nearly 500 beehive ovens had been built in the State, of which more than 400 were in Pierce County. From 1884 to 1937, about 2½ million tons of coke was produced in the State (fig. 5).

Beehive ovens, which used coal from nearby mines, were the only type used in coke manufacturing until 1914, when five byproduct ovens were built at Seattle. These ovens were used primarily for the manufacture of gas; however, the coke was used for domestic and metallurgical purposes. After certain modifications had been made in the coking method, the coke was also suitable for copper smelting and foundry purposes.

During World War II (H. F. Yancey, written communication, March 1, 1961) a coke plant was built in Tacoma, which started operating in May 1943 and, with some interruptions, was shut down in December 1944. Coal to supply the plant was mined at the Skookum slope at Wilkeson. During the 18 months in which the plant was in operation, about 75,000 tons of coal was used to produce 51,000 tons of coke, some of which was used for metallurgical purposes, but most of which was used for domestic heating.

Coking coal areas.—The most important coking coal areas in Washington are the Wilkeson-Carbonado field and Fairfax area in Pierce County. Coking coal occurs in the Roslyn field in Kittitas County, and some of the coals in eastern King County may also have coking qualities, but these have not been adequately tested. Other coking coal deposits are present in Whatcom and Skagit Counties, near Ashford in the southern part of Pierce County, and in the eastern part of Lewis County.

The coking properties of coals in Washington, except those at Roslyn, seem to be due to physical and chemical changes brought about by the folding and faulting of the rocks containing the coal beds. The coking properties of the coal at Roslyn are related to a change in rank and differences in composition.

Quality of coking coal.—Information regarding the properties of Washington coke and a comparison with physical and chemical properties of coke from other areas is contained in U.S. Bureau of Mines Technical Paper 597 (Yancey and others, 1939). In general, the results of tests show that cokes made from Washington coal are resistant to shatter degradation and withstand breakage when handled. The cokes are resistant to degradation by abrasion, are fairly combustible (their ignition temperature ranges from 460° to 570°C), and the sulfur content is low enough to meet the requirements of foundry use. In order to keep the ash content of Washington cokes at an acceptable percentage, it is necessary to use washed coal.

WHATCOM COUNTY COAL DEPOSITS

GEOGRAPHIC AND GEOLOGIC SETTING

In Whatcom County, in the northwestern part of Washington, the coal-bearing rocks are found only on the west side of the Cascade Mountains. A spur of the mountain range extends westward to Bellingham Bay in the southern part of the county, separating the coal-bearing strata here from those in Skagit County.

The coal-bearing rocks, which underlie an area of over 500 square miles, occur in the Chuckanut Formation of Eocene age and have been considered to be part of the Puget Group according to McLellan (1927, p. 136). Most of these rocks appear to lie in a northwest-plunging basin bounded on the southwest, south, and east by pre-Tertiary metamorphic and igneous rocks and concealed on the northwest and north by a mantle of glacial drift. The strata in the southern part of the area have been tightly folded into a series of northwest-plunging structures. The limbs of most of these folds dip 45° to 60°. The meager available data indicate that the amount of deformation decreases toward the northwest where the strata appear to dip at low angles. The coal-bearing rocks have been faulted, but the extent or magnitude of the faulting has not been determined.

According to Jenkins (1923, p. 47-49; 1924, pl. 1), the coal-bearing rocks in Whatcom County are about 12,000 feet thick (fig. 6). Stratigraphically, the two principal coal beds are more than 10,000 feet apart, with the Blue Canyon coal at the base of the coal-bearing sequence and the Bellingham coal near the top. Several coal beds occur in the rocks that separate the Blue Canyon and Bellingham coal beds and also in the strata above the Bellingham.

The Glacier coal field is in the north-central part of Whatcom County and contains many steeply dipping coal beds that have been fractured and crushed by intense folding and faulting. At one time this field attracted considerable attention because it contains anthracite, but although much prospecting has been done, the reported production from the field is less than 1,000 tons.

COAL BEDS

Many coal outcrops and openings on coal beds in Whatcom County have been described in detail by Jenkins (1923, p. 88-123) and Woodruff (1914, p. 393-398). The areal extent of the various beds has not been determined and only the approximate correlation by Jenkins (fig. 6) has been made. According to this correlation,

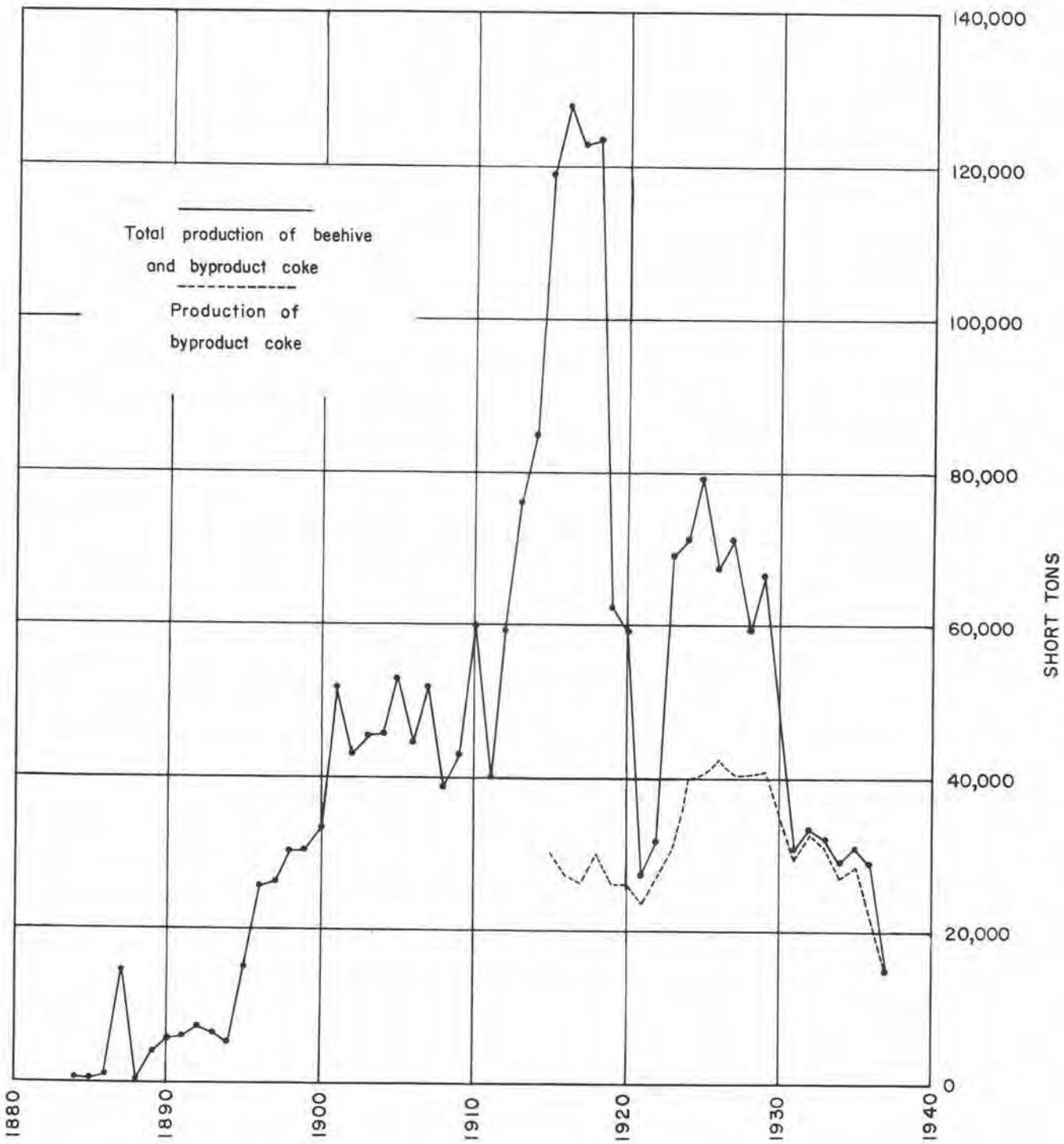
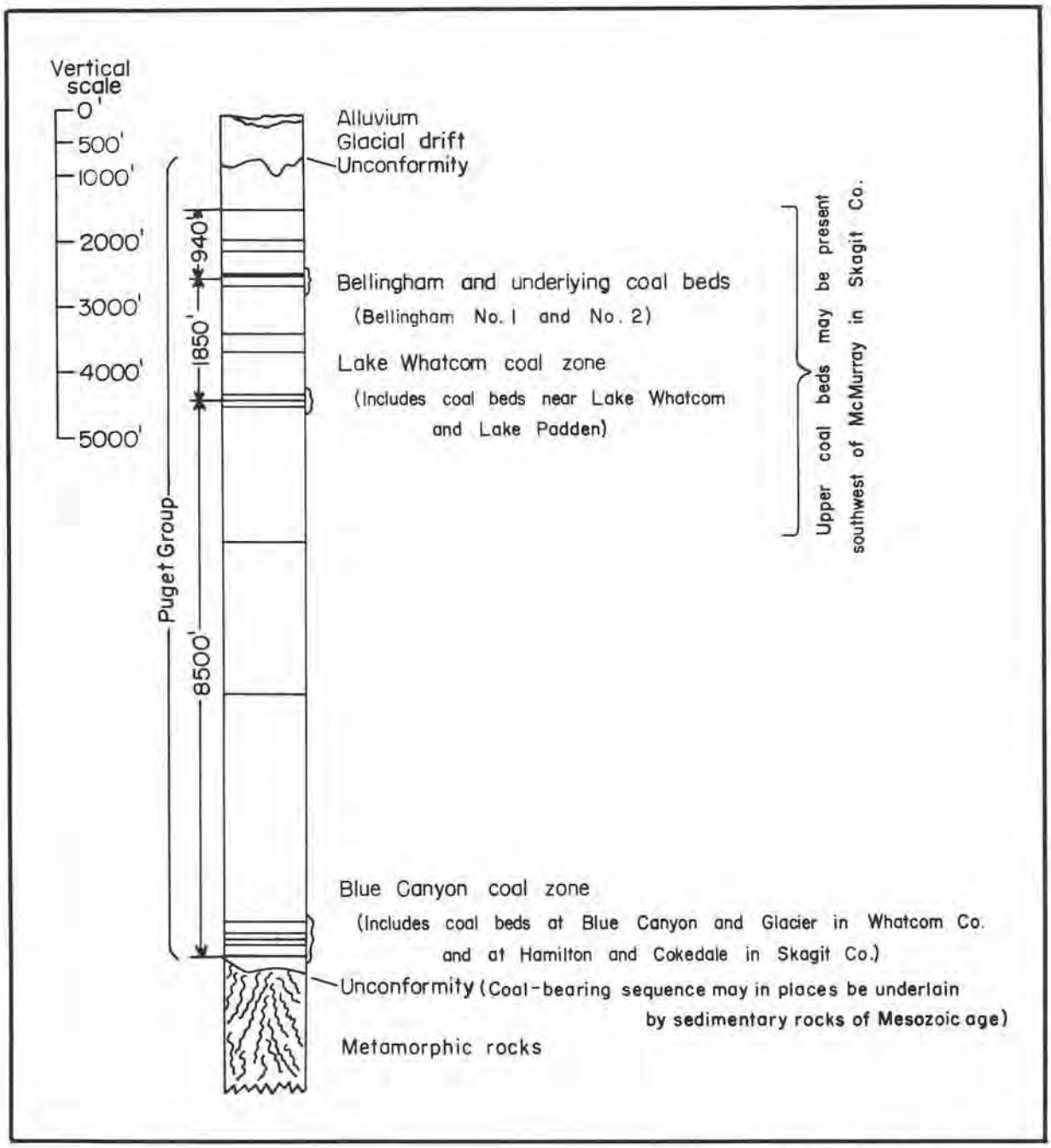


FIGURE 5. CHART SHOWING PRODUCTION OF BEEHIVE AND BYPRODUCT COKE IN WASHINGTON
(Data from Daniels, 1941, table 1)



(After Jenkins, 1924, pl. I.)

Figure 6. Diagrammatic section of coal-bearing rocks in Whatcom and Skagit Counties, Washington

more than 15 coal beds, ranging in thickness from a few inches to 14 feet, occur in the county.

The coal at the Blue Canyon mine in sec. 15, T. 37 N., R. 4 E., that in the Glacier field, and that at Cokedale and Hamilton in Skagit County all occur near the base of the coal-bearing sequence and apparently are at the same geologic horizon. The coal beds that occur at this horizon are herein referred to the Blue Canyon coal zone. The coal bed mined at Blue Canyon ranged in thickness from 0 to 12 feet and is reported to average 7 feet where there was no structural disturbance in the coal-bearing rocks. Three other coal beds, each reported to be about 2 feet thick, were found overlying this main bed. In the Glacier field the coal beds range in thickness from 0 to several feet and range greatly in thickness within a short distance.

Data are lacking on the continuity and areal extent of coal beds in the Blue Canyon coal zone, as well as on beds that occur between this zone and the zone exposed in the vicinity of Lake Whatcom (fig. 7); therefore, reserves have been calculated around only the known exposures.

Jenkins (1923) has tentatively correlated the coal beds that occur in several outcrops and mines near Lake Whatcom. The general extent of this zone, which is here called the Lake Whatcom coal zone, has been delineated around the lake on the basis of the synclinal structure mapped by Jenkins. As many as five coal beds, ranging in thickness from 2 to 9 feet, have been reported in this zone, but reserves have been calculated for only three, as little is known about the continuity of the individual beds.

The coal that has been prospected east of Lake Padden and north of Samish Lake was thought by Jenkins to represent the same zone as that around Lake Whatcom. By using the structure as mapped by Jenkins, the probable extent of this horizon has been delineated and is shown on figure 7, but reserves have been estimated only around the prospects.

The Bellingham No. 1 coal bed has been mined extensively in and near the town of Bellingham. The outcrop of this coal bed is covered in most places by glacial drift; however, several core holes have been drilled in the search for coal, and the probable position of the concealed outcrop as determined from these holes is shown on figure 7. The dip of the bed is about 10° SW. and, according to Jenkins (1923, p. 90), it ". . . has an average total thickness of 14 feet, but only the upper 7 or 8 feet are being worked at the present time, as this contains the better quality of coal." An underlying bed (Bellingham No. 2), 2 feet thick, was found 100 feet below the Bellingham No. 1 bed in an underground prospect shaft and in several of the core holes.

Jenkins (1923, p. 126) noted the possibility that the Bellingham coal bed may underlie an area that is about 5 miles northeast of Bellingham and extends as far north as the town of Enterprise, where a coal bed 15 feet thick has been reported in a well. The presence of the Bellingham coal bed in this area has not been substantiated.

Coal beds have been found in isolated outcrops and drill holes throughout Whatcom County. Little is known about them, and in this report the beds are unnamed and reserves have been calculated around reported occurrences only.

Physical and chemical properties.—Most of the coal in Whatcom County is of high-volatile C bituminous rank; however, the only known occurrence of anthracite in the State is in the Glacier field in the north-central part of the county. Only four analyses of the coal in the Glacier field were available, and these were all of coal that occurs very near the base of the coal-bearing sequence. Although all the coal in the field has been assumed to be anthracite, the coal higher in the sequence may be of bituminous rank.

The Blue Canyon coal bed has low moisture, ash, and sulfur content, and, according to Jenkins (1923, p. 105), is said to possess coking qualities. The Bellingham coal bed, because of its thickness and accessibility, is presently (1961) the most commercially significant coal bed in the county. It has a moisture content ranging from 6.9 to 8.4 percent and averaging 7.4 percent; an ash content ranging from 11.7 to 19.9 percent and averaging 15.1 percent; and a sulfur content ranging from 0.2 to 0.4 percent and averaging 0.3 percent. Analyses of coals in Whatcom County are given in table 2.

Table 2.—Averages of analyses (as-received basis) of coal samples from Whatcom County, Washington.

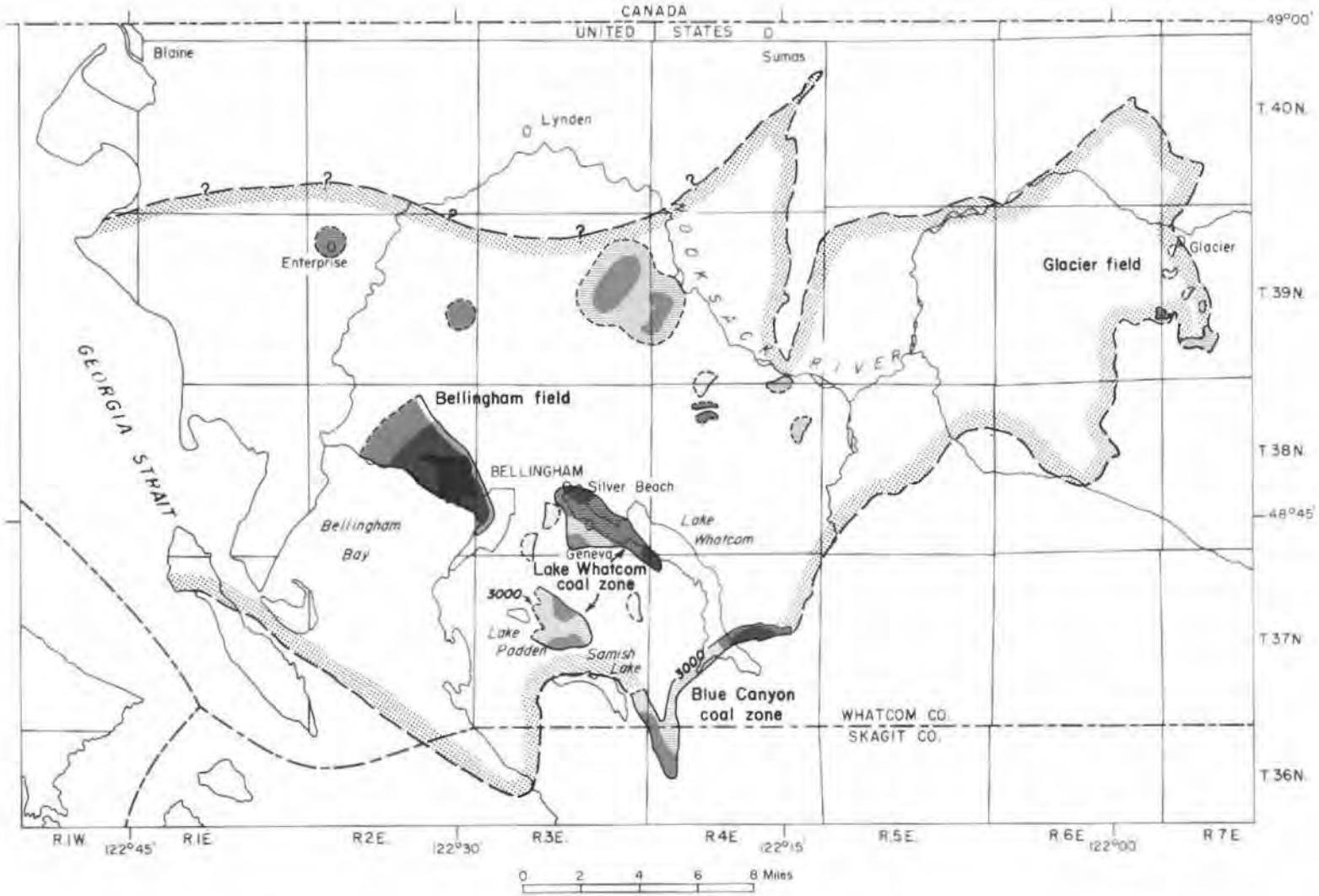
(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Campbell and Clark, 1916; Jenkins, 1924; Fieldner and others, 1931; and Cooper and Abernethy, 1941.)

Location			Mine or prospect	Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
Sec.	T.	R.			M	VM	FC	Ash			
13	38 N.	2 E.	Bellingham ---	Bellingham No. 1	7.3	35.8	41.3	15.7	0.3	10,542	15
24	38 N.	2 E.	--- do-------	Bellingham No. 2	5.5	40.0	43.4	11.2	—	11,048	1
15	37 N.	4 E.	Blue Canyon --	Blue Canyon -----	1.6	41.3	55.0	2.2	1.1	11,919	1
34	38 N.	3 E.	Geneva ------	Unnamed --------	5.5	32.7	24.8	37.0	1.1	7,161	1
5	38 N.	4 E.	Glen Echo ---	-- do ----------	8.4	37.9	40.3	18.5	.4	9,715	2
31	38 N.	4 E.	Rocky Ridge --	-- do ----------	5.0	31.5	23.7	39.8	.9	7,232	1
35	39 N.	4 E.	Deming ------	-- do ----------	6.5	24.2	30.9	38.4	1.9	7,541	1
24	39 N.	6 E.	Prospect------	-- do ----------	4.3	9.0	77.2	9.5	1.1	13,350	1
					10.7	13.1	68.7	7.5	.9	11,900	1
30	39 N.	7 E.	Discovery ----	-- do ----------	5.0	7.2	76.8	11.1	1.0	12,660	2

Table 3.—Estimated remaining reserves of coal in Whatcom County, Washington, as of January 1, 1960, by township and bed.

Coal bed or coal zone	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 36 N., R. 4 E.													
Blue Canyon----	0-1,000	-----	2.43	-----	2.43	0.67	1.01	-----	1.68	0.67	3.44	-----	4.11
	1,000-2,000	-----	1.62	-----	1.62	.63	.94	-----	1.57	.63	2.56	-----	3.19
	2,000-3,000	-----	1.31	-----	1.31	.45	.67	-----	1.12	.45	1.98	-----	2.43
Bed total---		-----	5.36	-----	5.36	1.75	2.62	-----	4.37	1.75	7.98	-----	9.73
T. 37 N., R. 3 E.													
Lake Whatcom --	0-1,000	-----	2.82	1.03	3.85	0.48	2.57	0.34	3.39	0.48	5.39	1.37	7.24
	1,000-2,000	-----	2.19	-----	2.19	.26	3.06	-----	3.32	.26	5.25	-----	5.51
	2,000-3,000	-----	1.47	-----	1.47	-----	4.56	-----	4.56	-----	6.03	-----	6.03
Bed total---		-----	6.48	1.03	7.51	0.74	10.19	0.34	11.27	0.74	16.67	1.37	18.78
Blue Canyon----	0-1,000	-----	0.24	-----	0.24	-----	0.32	-----	0.32	-----	0.56	-----	0.56
	1,000-2,000	-----	.16	-----	.16	-----	.40	-----	.40	-----	.56	-----	.56
	2,000-3,000	-----	-----	-----	-----	-----	.20	-----	.20	-----	.20	-----	.20
Bed total---		-----	0.40	-----	0.40	-----	0.92	-----	0.92	-----	1.32	-----	1.32
Township total --		-----	6.88	1.03	7.91	0.74	11.11	0.34	12.19	0.74	17.99	1.37	20.10
T. 37 N., R. 4 E.													
Lake Whatcom --	0-1,000	-----	0.90	3.10	4.00	-----	-----	-----	-----	-----	0.90	3.10	4.00
Blue Canyon----	0-1,000	2.44	0.20	2.85	5.49	2.45	2.42	0.99	5.86	4.89	2.62	3.84	11.35
	1,000-2,000	2.82	.40	3.29	6.51	3.23	3.15	1.32	7.70	6.05	3.55	4.61	14.21
	2,000-3,000	1.50	.72	1.75	3.97	4.62	3.82	2.41	10.85	6.12	4.54	4.16	14.82
Bed total---		6.76	1.32	7.89	15.97	10.30	9.39	4.72	24.41	17.06	10.71	12.61	40.38
Township total --		6.76	2.22	10.99	19.97	10.30	9.39	4.72	24.41	17.06	11.61	15.71	44.38
T. 38 N., R. 2 E.													
Bellingham No. 1	0-1,000	-----	-----	29.43	29.43	-----	-----	22.97	22.97	-----	-----	52.40	52.40
Bellingham No. 2	0-1,000	12.27	-----	-----	12.27	6.35	-----	-----	6.35	18.62	-----	-----	18.62
Township total --		12.27	-----	29.43	41.70	6.35	-----	22.97	29.32	18.62	-----	52.40	71.02
T. 38 N., R. 3 E.													
Bellingham No. 1	0-1,000	-----	-----	4.53	4.53	-----	-----	-----	-----	-----	-----	4.53	4.53
Bellingham No. 2	0-1,000	1.86	-----	-----	1.86	-----	-----	-----	-----	1.86	-----	-----	1.86
Lake Whatcom --	0-1,000	1.32	3.35	5.32	9.99	2.07	8.16	18.58	28.81	3.39	11.51	23.90	38.80
	1,000-2,000	.55	1.13	3.39	5.07	1.21	8.44	22.26	31.91	1.76	9.57	25.65	36.98
	2,000-3,000	.06	.09	.36	.51	.17	2.96	10.69	13.82	.23	3.05	11.05	14.33
Bed total---		1.93	4.57	9.07	15.57	3.45	19.56	51.53	74.54	5.38	24.13	60.60	90.11
Township total --		3.79	4.57	13.60	21.96	3.45	19.56	51.53	74.54	7.24	24.13	65.13	96.50
T. 38 N., R. 4 E.													
Unnamed-------	0-1,000	0.44	1.16	1.64	3.24	0.74	2.22	1.09	4.05	1.18	3.38	2.73	7.29
	1,000-2,000	.44	1.16	1.64	3.24	.76	.90	1.09	2.75	1.20	2.06	2.73	5.99
	2,000-3,000	.44	1.16	1.64	3.24	.65	.90	1.09	2.64	1.09	2.06	2.73	5.88
Bed total---		1.32	3.48	4.92	9.72	2.15	4.02	3.27	9.44	3.47	7.50	8.19	19.16
Lake Whatcom --	0-1,000	-----	0.06	0.22	0.28	-----	-----	-----	-----	-----	0.06	0.22	0.28
Township total --		1.32	3.54	5.14	10.00	2.15	4.02	3.27	9.44	3.47	7.56	8.41	19.44
T. 39 N., R. 2 E.													
Unnamed-------	0-1,000	-----	-----	-----	-----	3.58	2.68	15.65	21.91	3.58	2.68	15.65	21.91
T. 39 N., R. 3 E.													
Unnamed-------	0-1,000	-----	8.17	-----	8.17	-----	18.55	-----	18.55	-----	26.72	-----	26.72
T. 39 N., R. 4 E.													
Unnamed-------	0-1,000	-----	2.93	-----	2.93	0.42	5.89	-----	6.31	0.42	8.82	-----	9.24
	1,000-2,000	-----	-----	-----	-----	.48	-----	-----	.48	.48	-----	-----	.48
	2,000-3,000	-----	-----	-----	-----	.55	-----	-----	.55	.55	-----	-----	.55
Bed total---		-----	2.93	-----	2.93	1.45	5.89	-----	7.34	1.45	8.82	-----	10.27
T. 39 N., R. 7 E.													
*Glacier-------	0-1,000	-----	-----	-----	-----	0.67	1.81	0.50	2.98	0.67	1.81	0.50	2.98
	1,000-2,000	-----	-----	-----	-----	.33	1.49	-----	1.82	.33	1.49	-----	1.82
Bed total---		-----	-----	-----	-----	1.00	3.30	0.50	4.80	1.00	3.30	0.50	4.80
Grand total-----		24.14	33.67	60.19	118.00	30.77	77.12	98.98	206.87	54.91	110.79	159.17	324.87

*Anthracite



EXPLANATION

COAL RESERVES

All reserves are of bituminous coal, except for a small amount of anthracite in the Glacier field

MEASURED AND INDICATED

- Coal 14 to 28 inches thick
- Coal 28 to 42 inches thick
- Coal 42 or more inches thick

INFERRED

- Coal 14 to 28 inches thick
- Coal 28 to 42 inches thick
- Coal 42 or more inches thick

Mined-out area

Concealed or inferred coal outcrop

3000

Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

Approximate limit of coal-bearing rocks. Queried where covered by younger rocks

FIGURE 7. MAP OF WHATCOM COUNTY COAL DEPOSITS

COAL MINING

The Bellingham coal bed in Whatcom County was discovered in about 1849 and the first coal mine in the State was subsequently opened on it. From 1891 to 1955, when production ceased, about 5½ million tons, or 94 percent of the total coal produced in Whatcom County, was taken from this bed. Two other mines, at Blue Canyon and at Glen Echo, have a recorded production of about 280 thousand and 65 thousand tons, respectively. According to production records, less than 1,000 tons of anthracite has been mined in the Glacier field.

SUMMARY OF RESERVES

The total reserves of coal remaining in the ground in Whatcom County as of January 1, 1960, are estimated to be 325 million tons. Of this total, about 5 million tons is anthracite in the Glacier field; more than 50 million tons is bituminous coal in the Bellingham coal bed, which is the most commercially important one in the county; and 270 million tons is bituminous coal in other coal beds found in the county. Approximately 36 percent of these reserves is classified as measured and indicated, and 64 percent as inferred. The reserve figures by township and bed are shown in table 3, on page 14.

At several places reserves have been calculated for coal beds that overlie each other. As the extent of only one bed could be shown on figure 7, the thickest bed has been selected.

Although as many as 15 coal beds were reported by Jenkins (fig. 6) in Whatcom County, this reserve estimate is based on very sparse information, and additional data regarding the thickness and extent of the coal beds, based on detailed geologic mapping, would increase it.

As a result of his geologic investigation of Whatcom County, Jenkins (1923, p. 12, 126-127) specifically recommended that the area north and northeast of the Bellingham mine be examined by core drilling to determine whether the main Bellingham bed, as well as other coal beds, is present.

SKAGIT COUNTY COAL DEPOSITS

GEOGRAPHIC AND GEOLOGIC SETTING

The coal-bearing rocks in Skagit County occur in several different areas, herein called the Cokedale, Hamilton, Rick Creek, and McMurray areas (fig. 8). The coal-bearing rocks in the extreme northwest part of the county are contiguous with those in Whatcom County and were included in the discussion of the Whatcom County coal fields. The rest of the coal deposits of Skagit County are separated from those of Whatcom County by an east-trending belt of pre-Tertiary metamorphic rocks. The coal-bearing sequence in Skagit County is probably of the same age as the lowermost few hundred feet of the sequence in Whatcom County (fig. 6).

The Cokedale and Hamilton areas probably connect beneath alluvial deposits in the Skagit River valley and are thought to comprise a troughlike belt of structurally disturbed sandstone, with dips ranging from vertical to as little as 10°. These beds are unconformable on, or at places in fault contact with, the underlying metamorphic rocks (Jenkins, 1924, p. 24). The coal area to the southeast near Rick Creek may be a continuation of those at Cokedale and Hamilton. The three areas cover about 250 square miles.

The McMurray area is larger, more irregular, and more complex structurally than the Cokedale-Hamilton-Rick Creek area. The coal-bearing rocks in the McMurray area cover about 450 square miles. In the northeast and east part of the area they are complexly folded and faulted and are both unconformable on and in fault contact with the older metamorphic rocks. About 5 miles north of McMurray the coal-bearing rocks have been intruded by rhyolite. In the south and southwest part of the McMurray area the coal-bearing rocks are relatively undisturbed and dip gently in a southwest direction under an alluvial cover.

COAL BEDS

The Cokedale and Hamilton areas contain several coal beds ranging in thickness from a few inches to more than 10 feet. According to Jenkins (1924, p. 30), a tunnel at the Cokedale mine ". . . intersected seven coal seams, the last three of which proved to be of economic interest." The thicknesses of these three coal beds, starting with the lowest, were reported by Jenkins as being from 10 to 30 feet (half of which was coal); a few inches to 8 feet; and a few inches to 2 feet. The lowermost coal bed at the Cokedale mine is thought to be the same as the bed at the Blue Canyon mine in Whatcom County. In a section along Coal Creek to the southeast of Cokedale, eight coal beds are present, ranging in thickness from 1 foot 2 inches to 2 feet 10 inches. Other occurrences of coal in these areas are described by Jenkins (1924, p. 26-42). In each of these localities, from one to more than four coal beds of varying thicknesses have been reported, but the exact number and correlation of coal beds present at Cokedale and Hamilton have not been determined nor has their continuity been established. The coal reserves for these areas were estimated by making a statistical evaluation of the volume of coal present in each of the different categories of coal bed thickness. This evaluation was based on the number of coal beds and their thicknesses as reported at various points of observation. Although the Rick Creek area is known to contain coal-bearing rocks, sufficient data on which to base a coal reserve estimate are lacking.

In the McMurray area, coal beds have been found in only a few places, including Walker Valley, the region around McMurray and along Pilchuck Creek, and south of Mount Vernon. Most of the beds at these localities were reported to be less than 3 feet thick, although coal more than 5 feet thick has been reported in a few places. In this area, as in the Cokedale and Hamilton areas, it is not possible to trace an individual bed for any distance.

The structure and areal extent of the coal-bearing rocks in the McMurray area are not so well known as those in the Cokedale and Hamilton areas, and coal has been reported to occur at fewer and more widely separated localities. Therefore, it was not feasible to estimate reserves for the total area of coal-bearing rocks; instead, inferred reserves have been estimated only around reported occurrences.

Physical and chemical properties.—Only a few analyses of the coals in Skagit County are available (table 4), and most of these do not include the sulfur content, which is a factor needed in determining the rank of the coal, nor do they include the Btu values. The few complete analyses indicate that the coal is of bituminous rank. It has a relatively low ash content, ranging from 1.8 to 17.7 percent and averaging about 8 percent. The moisture content is extremely low, ranging from 0.3 to 4.0 percent and averaging a little more than 1 percent. The coal from the Cokedale mine and that near Hamilton is of coking quality, and during the years that the mine was in operation a large part of the coal mined was made into coke.

COAL MINING

The Cokedale mine in sec. 4, T. 35 N., R. 5 E., is the only mine in Skagit County with a record of sustained production. It first started producing coal in 1891, and operations were finally suspended in 1922. The total production of coal was about 180,000 tons, a part of which was made into coke. The Blumont mine in sec. 33, T. 34 N., R. 5 E., was opened in 1916, but no coal was shipped from it (Jenkins, 1924, p. 43).

SUMMARY OF RESERVES

The total reserves of coal in Skagit County are estimated to be 507 million tons, of which 18 percent is classified as measured and indicated. Individual coal beds could not be correlated and named, thus the reserves in table 5 are given only by township and thickness. The reserves are grouped into one category of 0 to 3,000 feet, as overburden categories of 1,000-foot intervals could not be delineated. Where coal beds overlie each other, only the thickest coal bed has been shown on figure 8.

The Cokedale, Hamilton, and Rick Creek areas apparently are isolated exposures of a continuous northwest-trending belt of coal-bearing rocks. If the continuity of these rocks were established and the exact number and thicknesses of the coal beds in these areas were determined through geologic mapping, the coal reserves of Skagit County would be substantially increased. Rocks of continental origin occur northeast and east of the Rick Creek area. It is probable that these are a continuation of the coal-bearing rocks that were prospected along Rick Creek and that they also are coal-bearing.

KITTITAS COUNTY COAL DEPOSITS

Kittitas County is located almost in the center of Washington. Coal has been found in the Roslyn field in the northwest part of the county and in the Taneum and Manastash areas in the south-central part. The Roslyn field is a major coal-producing area,

Table 4. Analyses (as-received basis) of coal samples from Skagit County coal areas, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Smith, 1911, and Jenkins, 1924)

Location			Mine or prospect	Proximate (percent)				Sulfur (percent)	Btu
Sec.	T.	R.		M	VM	FC	Ash		
4	35 N.	5 E.	Cokedale	3.0	35.0	60.0	2.0	0.2	------
				.5	26.7	64.5	8.3	---	------
				1.0	30.8	59.3	8.9	---	------
23	35 N.	6 E.	Cumberland Creek	.3	9.0	79.7	11.0	.4	------
				.5	19.4	68.3	----	.6	------
				.5	19.3	68.4	11.9	---	------
				1.2	18.8	71.7	8.4	---	------
26	35 N.	6 E.	Conner	.5	18.7	70.2	9.6	1.0	------
				.5	12.1	80.2	7.3	---	------
13	34 N.	6 E.	Day Creek	2.0	33.0	63.3	1.8	---	------
				2.3	40.5	55.3	2.0	---	------
33	34 N.	5 E.	Blumont	4.0	42.7	35.6	17.7	---	9,830
				1.0	30.8	59.3	8.9	---	13,850

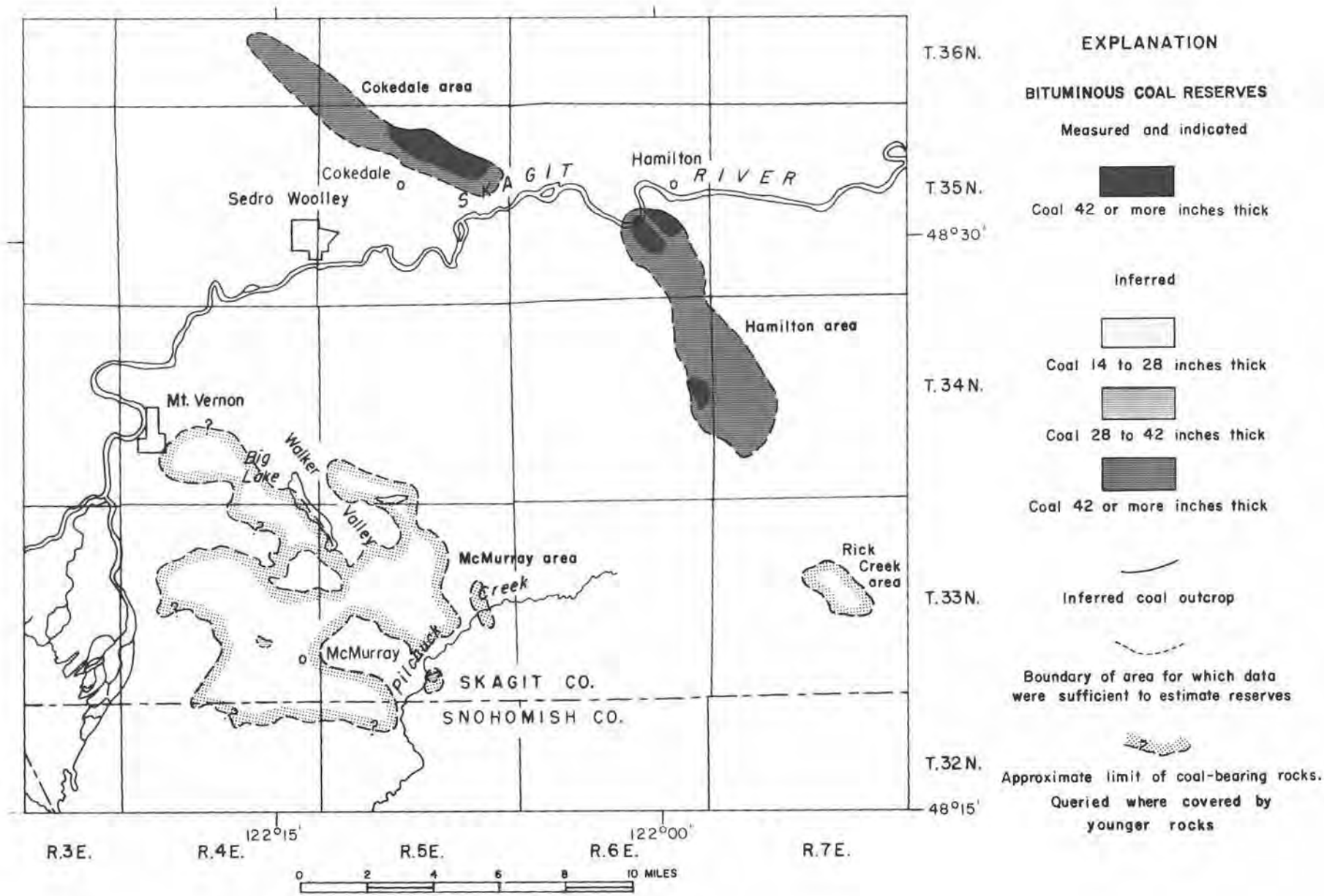


FIGURE 8. MAP OF SKAGIT COUNTY COAL DEPOSITS

Table 5.—Estimated remaining reserves of coal in the Skagit County coal areas, Washington, as of January 1, 1960, by township

(In millions of short tons)

Township and range	Measured and indicated				Inferred				All categories			
	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
33 N., 4 E.	------	------	------	------	------	0.37	------	0.37	------	0.37	------	0.37
33 N., 5 E.	------	------	------	------	------	.33	------	.33	------	.33	------	.33
34 N., 5 E.	------	------	------	------	0.78	------	------	.78	0.78	------	------	.78
34 N., 6 E.	------	------	11.06	11.06	19.64	------	59.65	79.29	19.64	------	70.71	90.35
34 N., 7 E.	------	------	------	------	30.85	------	93.71	124.56	30.85	------	93.71	124.56
35 N., 4 E.	------	------	------	------	.40	.16	.34	.90	.40	.16	.34	.90
35 N., 5 E.	24.94	10.33	21.38	56.65	34.15	14.15	29.27	77.57	59.09	24.48	50.65	134.22
35 N., 6 E.	1.15	------	21.63	22.78	1.77	------	53.78	55.55	2.92	------	75.41	78.33
36 N., 4 E.	------	------	------	------	23.64	9.79	20.26	53.69	23.64	9.79	20.26	53.69
36 N., 5 E.	------	------	------	------	10.32	4.27	8.84	23.43	10.32	4.27	8.84	23.43
Total	26.09	10.33	54.07	90.49	121.55	29.07	265.85	416.47	147.64	39.40	319.92	506.96

whereas the Taneum and Manastash areas have had little or no development and are considered to be of minor economic importance. Other scattered coal localities in the county have been described by Saunders (1914, p. 146-152), but the information on these areas is insufficient to warrant discussion in this report.

ROSLYN COAL FIELD

Geographic and Geologic Setting

The Roslyn field is the only coal field of importance in Washington that is located on the east side of the Cascade Mountains. This field is southeast of Lake Cle Elum and north of the confluence of the Cle Elum and Yakima Rivers, which cross the southwestern and southern parts of the field.

The Roslyn coal field covers an area of about 30 square miles. Although small, it has produced more coal than any other area in the State. The coal occurs in the Roslyn Formation of middle and (or) late Eocene age (Foster, 1960, p. 109), which is more than 6,500 feet thick. According to C. T. Bressler (written communication, 1951), the coal-bearing sequence is limited to the upper 1,560 feet, which contains 8 major beds of coal ranging in thickness from 2 to 21 feet interbedded with medium- to very fine grained sandstone and siltstone. The formation occupies a northwest-trending basin bounded on three sides by the older Teanaway Basalt and on the fourth, or southeast, side by the younger Yakima Basalt. The bedrock in the southern part of the field is covered by alluvium and glacial gravels.

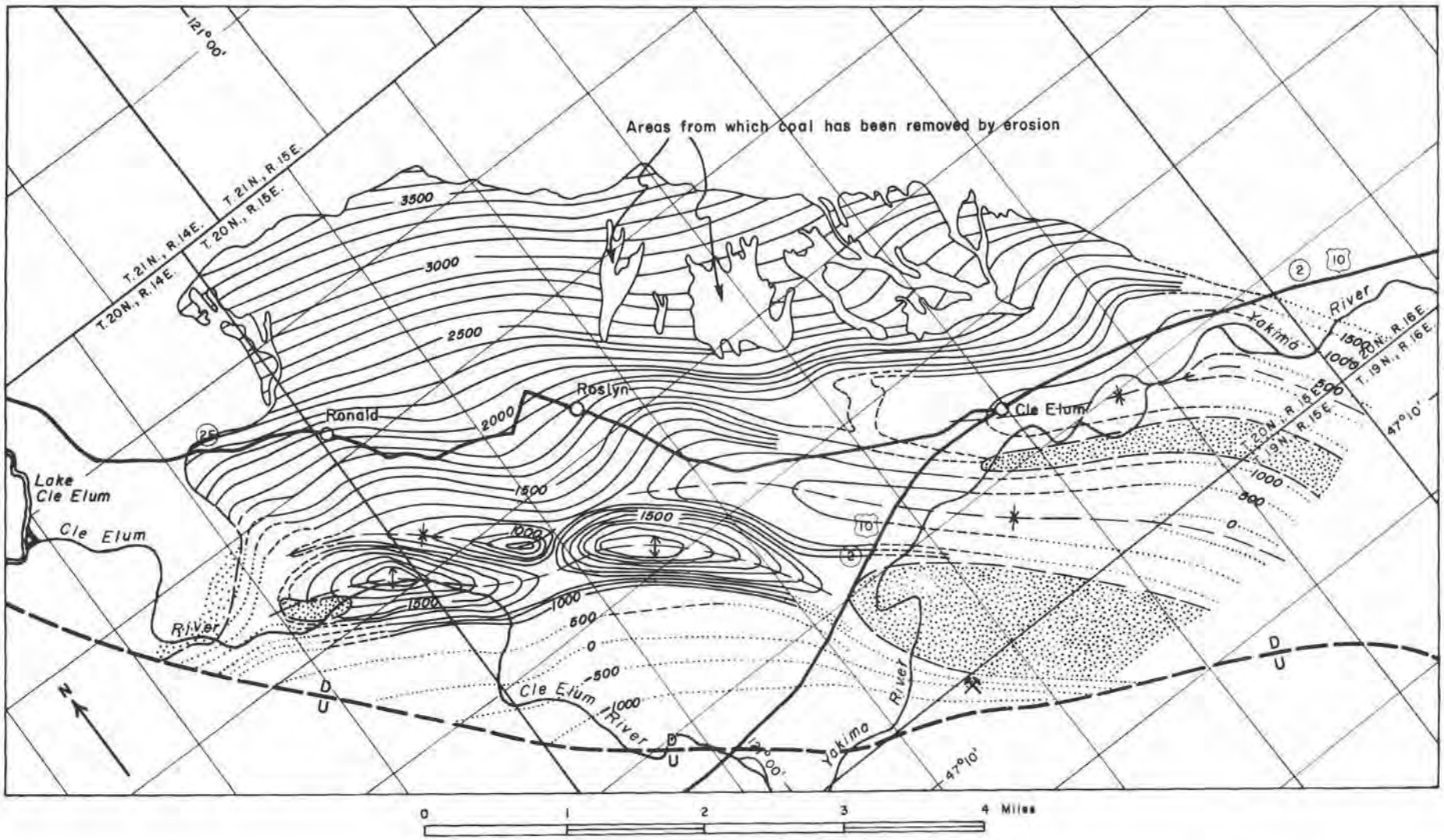
The major structure of the Roslyn coal field is a syncline that plunges to the southeast (fig. 9). The northern flank of the syncline dips about 10° to the southwest. Along the southwest margin of the field the structure is more complex and consists of a linear series of anticlines having a trend parallel to that of the major syncline. The flanks of some of these anticlines dip as much as 40°. In the southeastern part of the major syncline the structure also consists of a series of rather tightly folded anticlines and synclines.

Where the Roslyn coal bed has been mined, it was relatively uniform in thickness and, with few exceptions, was undisturbed by faulting. Local variations in this bed, called warpings or rolls, are described by Daniels (in Saunders, 1914, p. 62-83).

The structure contour map (fig. 9) is based on numerous elevations along slopes and gangways and in core holes obtained from a company mine map showing in detail the mine workings on the Roslyn coal bed. Very little information is available on the structure of the southwest and southeast parts of the field beyond the mine workings on the Roslyn coal bed. Therefore, the structures shown by dotted lines on figure 9 are conjectural and constitute extensions of structural features observed in nearby areas in which data were abundant. The inferred fault shown in the southern part of the field is based on reconnaissance mapping by R. D. Brown, Jr.

The only area in the southern part of the Roslyn coal basin in which coal was found, except in core holes and except within the limits of mine workings on the Roslyn coal bed, was in the Rothlisberger prospect in sec. 4, T. 19 N., R. 15 E. (fig. 9). This prospect consisted of a slope opened on a coal bed dipping 77° to the southwest. Some coal was mined from this bed, and a horizontal tunnel 700 feet in length was extended in a northeast direction across the dip of the strata. Several beds of coal and of interbedded coal and shale were encountered in the tunnel. An exact correlation of the coal beds found in this tunnel with those present in the main part of the Roslyn field is not possible. Some faulting has taken place in the general area of this prospect, and the coal beds found in this tunnel possibly have been overturned and are in reverse stratigraphic order.

Inasmuch as the information concerning the coal beds found in this tunnel is meager and the geology of the surrounding area is unknown, these coal beds have been assumed to be in a normal stratigraphic sequence, and the geologic structure in this area was interpreted to be as shown on figure 9. Detailed geologic mapping



EXPLANATION

Outcrop of Roslyn coal bed
Dashed where approximately located; dotted where inferred

1000

Structure contour drawn on top of Roslyn coal bed
Dashed where approximately located; dotted where indefinite
Contour interval 100 and 500 feet
Datum mean sea level

D
U

Inferred fault
U, upthrown side
D, downthrown side

Axis of anticline

Axis of syncline

Area from which coal may have been removed by glacial channeling

Prospect

FIGURE 9. STRUCTURE CONTOUR MAP OF THE ROSLYN COAL FIELD, KITTITAS COUNTY, WASHINGTON

and core drilling would be necessary to determine accurately the structure and the continuity of the coal beds beyond the area in which mining and drilling have been done.

The valleys of the Yakima and Cle Elum Rivers, which cross the southern parts of the Roslyn coal field, are filled with alluvium and terraced gravels that conceal the Roslyn Formation. The channels of these rivers are believed to follow essentially the same courses that they did throughout a period of glaciation during which they were cut more deeply than at present and subsequently were filled with glacial outwash. Based on the depth of the glacial drift reported in a few core holes and at one place in the mine workings, it has been assumed that these former glacial channels reached a maximum depth of about 700 feet below the present surface. Areas in which coal would have been removed during the cutting of these channels have been shown on the individual coal bed maps.

Coal Beds

The Roslyn coal field contains at least 8 coal beds (fig. 10), 5 of which have been mined to greater or lesser extent. Numerous thin, shaly, impure beds of coal occur in the strata separating these 5 principal beds.

The Big Dirty (No. 1) coal bed is the uppermost bed in the field and economically is second in importance only to the Roslyn coal bed. It is so named because it is 15 to 19 feet thick (Saunders, 1914, p. 103) and is relatively high in ash. Only the lower part of the coal bed, which contains an average of 4.6 feet of coal, is sufficiently clean to be minable.

In some areas the Big Dirty coal bed is close enough to the surface to be mined by stripping methods. These areas are not shown on figure 12 because the topographic control and the structural control on the coal bed were not considered to be within the limits of accuracy necessary for outlining the overburden categories of 0 to 60, 60 to 90, and 90 to 120 feet used for delineating strippable coal. The areas in which the coal probably underlies less than 120 feet of overburden are the SE¼ of section 8, the NW¼ of section 17, part of the NE¼ of section 18, and the isolated area in the northeastern part of the field, all of which are in T. 20 N., R. 15 E. These are all areas in which the slope of the coal bed seems to be approximately the same as that of the topographic surface.

The Roslyn (No. 5) coal bed is the one that has been most extensively mined. It ranges in thickness from about 4.5 to 7 feet (Saunders, 1914, p. 57) and contains an average of 4.4 feet of clean coal. The coal changes in character from the eastern to the western end of the field (fig. 11). Near Cle Elum, the coal has a higher ash content and a lower Btu or heating value and is of high-volatile B bituminous rank. The heating value and the rank gradually increase in a westward direction, and the coal is of high-volatile A bituminous rank throughout most of the field. This slight change in rank is significant because the high-volatile A bituminous coal in the western part of the field has coking characteristics.

Much less is known about the remaining three minable coal beds in the field. As shown on figure 10, the Plant (No. 6) coal bed is 2.9 feet thick and is about 410 feet below the Roslyn coal bed; the Green (No. 7) coal bed is 1.8 feet thick and is about 90 feet below the Plant coal bed; and the Wright coal bed (No. 8), the lowest in the stratigraphic section, is 3.0 feet thick and is about 150 feet below the Green coal bed. The location and classification of coal reserves by individual beds are shown in figures 12 though 16 on pages 26 through 30.

Reserves for the Big Dirty, Roslyn, and Plant coal beds have been inferred as far south as T. 19 N., R. 15 E., whereas reserves for the Green and Wright coal beds have been inferred only 1½ miles from the areas in which they were mined (figs. 12-16). Sufficient data on the upper three coal beds were available from mine workings and core holes—together with the fact that several coal beds are known to be present in the Rothlisberger prospect in section 4 described on p. 19—to allow for this extension of inferred reserves. However, even though it is possible that the two lower coal beds are represented in this prospect, the absence of information concerning them over the large area that separates the actual mine workings on these beds, which are in the extreme northwestern part of the coal field, and the prospect, which is in the extreme southeastern part, did not allow for the extension of these beds throughout the entire field.

For the purpose of estimating reserves, the average thicknesses of the various coal beds were determined by using the measurements made by the U.S. Bureau of Mines at the time samples were taken for analyses. It should be emphasized that these thicknesses are of the coal with partings excluded. Furthermore, the relative accuracy of the averages is in direct relation to the number of thickness measurements that were available. Whereas 88 samples were used in determining the average thickness of the Roslyn coal bed, only 6 each were available for the Big Dirty and Plant coal beds, and 2 each for the Green and Wright coal beds.

In calculating the coal reserves, each bed was assumed to have a constant thickness throughout the field. When the 88 thickness measurements for the Roslyn coal bed were plotted on a map of the coal field, only a small variation in the thickness of the bed was apparent and there was no definite indication of a trend of thinning or thickening of the bed in any one direction. For this reason the assumption of uniform tabular bodies was considered reasonable.

Reserves were not calculated for the three thin coal beds that occur in the interval between the Big Dirty and Roslyn coal beds because data on their extent and true thicknesses are inadequate. The bed called No. 3 has been sampled in sec. 7, T. 20 N., R. 15 E., and in sec. 12, T. 20 N., R. 14 E. Of the measurements made, the maximum thickness was 2.5 feet in section 7 and the minimum was 1.8 feet in section 12, with an average thickness of 2.2 feet based on five closely spaced measurements. It is possible that one or more of these intervening coal beds may be of sufficient thickness and continuity to constitute additional reserves in the Roslyn coal field.

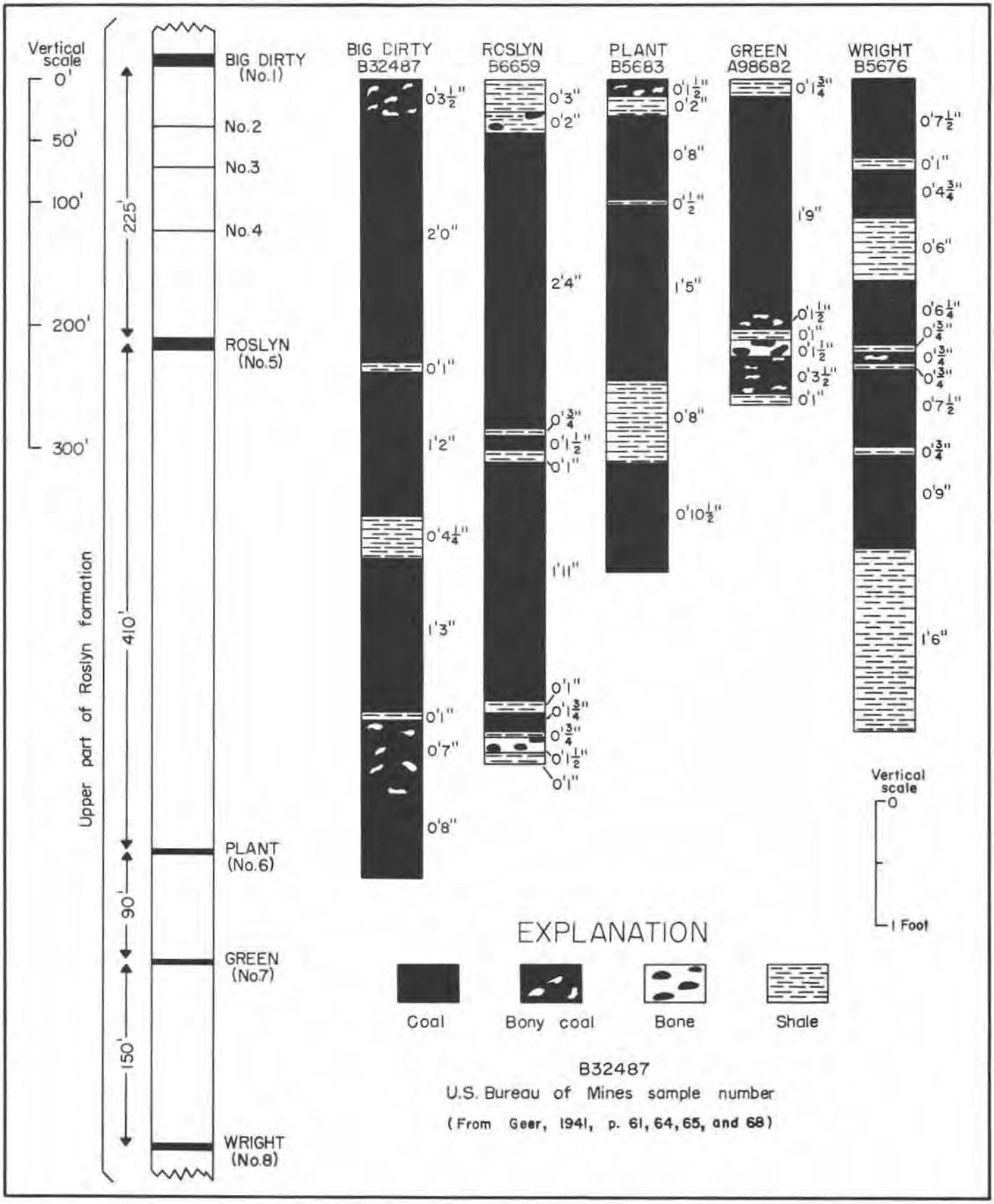


Figure 10. Generalized section showing principal coal beds in the Roslyn field and detailed sections of individual coal beds

Physical and chemical properties.—The coal beds in the Roslyn field are of high-volatile A bituminous rank, with the exception of the Roslyn coal bed, which, in the southeastern part of the field, is of slightly lower high-volatile B bituminous rank. A summary of the important constituents in the individual coal beds, given in terms of percentages of the minimum, maximum, and average content, are given in table 6. The ash, moisture, and sulfur content of these coals is within the general range of suitability for industrial or domestic use. Detailed sections of the coal beds in the Roslyn field are shown on figure 10. These were plotted from measurements made by the U.S. Bureau of Mines at sample localities.

Coking coal.—The coal in the Roslyn coal bed gradually increases in rank from high-volatile B bituminous in the southeast to high-volatile A bituminous in the northwest. The Btu value of the coal near Cle Elum is about 13,500 and increases gradually to a maximum of about 15,000 to the northwest (fig. 11). Unlike coking coal in other areas, whose coking properties seem to be due to physical and chemical changes brought about by the folding and faulting of the rocks containing the coal beds, in the Roslyn field no relation between the amount of folding and the rank of the coal is apparent. The ash content of the Roslyn bed decreases slightly in a northwest direction and the agglutinating value increases in that direction. The change in the rank and coking properties is therefore probably related to differences in the composition of the coal.

The difference in rank of the Roslyn coal bed in the northwestern part of the coal field seems to result, not from local differences in the amount of folding within the field, but, more probably, from regional metamorphism. Foster (1960, pl. 1) has mapped a small outcrop of Snoqualmie Granodiorite of Oligocene or younger age in an area about 6 miles northwest of the Roslyn field. Similar granodiorite forms Snoqualmie and Granite Mountains to the northwest and also the Denny Mountains, about 25 miles distant. If the granodiorite near the Roslyn field is part of a much larger intrusive at depth near the northwest part of the field, the heat from the intrusion may have been sufficient to cause the increase in the rank of the coal.

According to Yancey and others (1943, p. 3 and 44), the coal from the Roslyn coal bed that has been used for coking purposes has been used largely for bench-gas manufacture and occasionally in blends with other coals in byproduct coke ovens. Tests made of the Roslyn coal indicated that, when used alone, the resulting coke has a high phosphorous content, but that the coal could be blended with other coal to make satisfactory domestic cokes. Coking tests have also been performed on the Plant (No. 6) coal bed (Daniels, 1941, p. 27 and 29) and it "produced exceptionally good coke for a high-volatile coal."

Changes in rank and composition similar to those in the Roslyn coal bed may occur in other coals in the field, but this cannot be substantiated because available analyses of the other coals are confined to samples from the northwest end of the field.

Coal Mining

The Big Dirty coal was the first bed to be mined in the Roslyn field (Saunders, 1914, p. 17). A mine was opened on this bed as early as 1882, and soon thereafter a mine was opened on the Roslyn coal bed just north of the town of Roslyn. Most of the prospecting and developmental work was then concentrated on the Roslyn coal bed, and by the early 1900's several mines were working this bed.

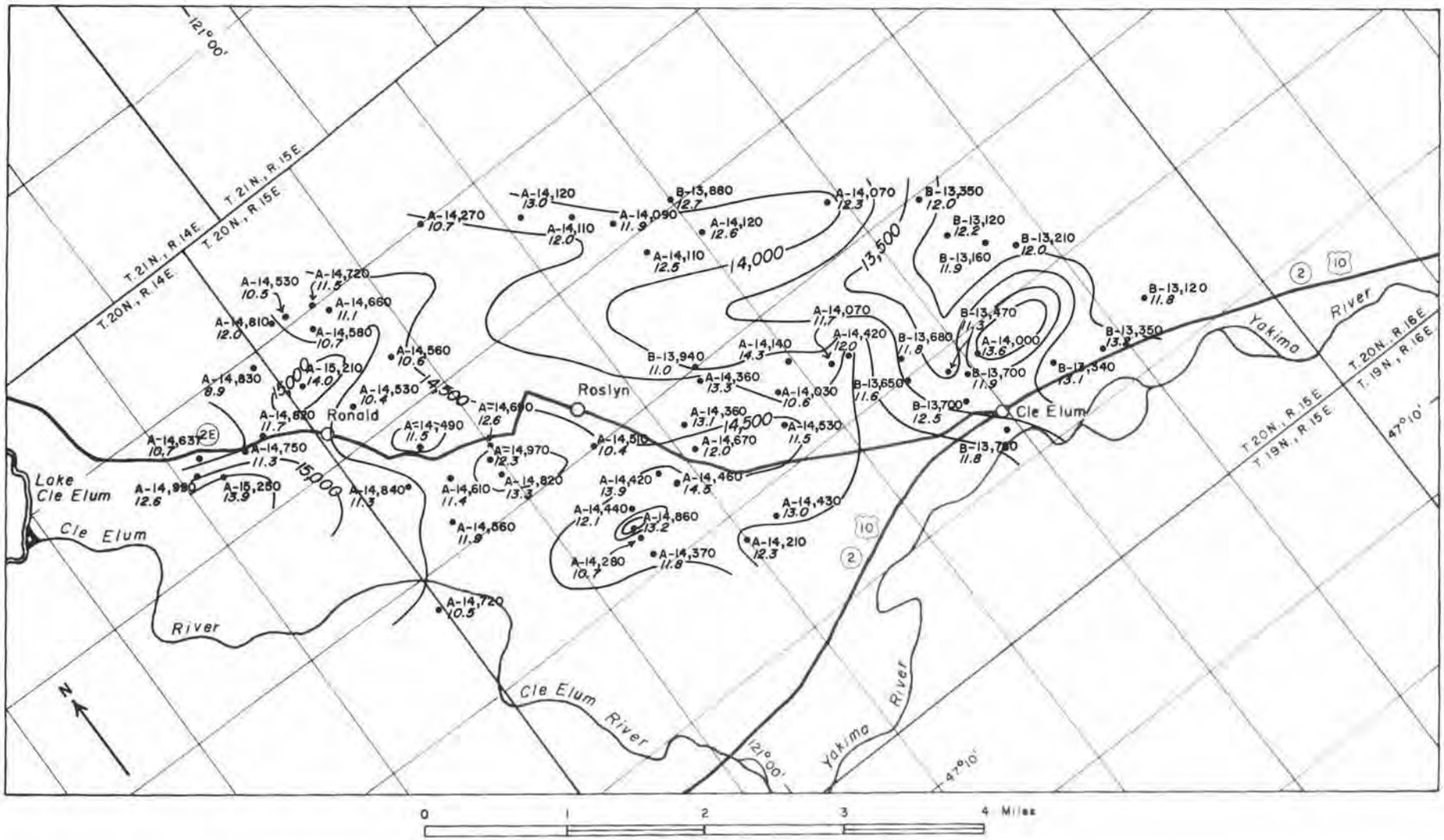
The total production of coal from the Roslyn coal field has been about 63 million tons, of which about 57 million tons has been from the Roslyn coal bed, 4 million tons from the Big Dirty coal bed, and the remainder from the three underlying beds.

The recovery of coal from the Roslyn coal bed has been about 80 percent, which is well above the average of most underground coal mining operations. This recovery figure was arrived at by comparing the total tonnage of coal reported to have been mined with the total amount estimated to have been present originally in the area now mined out.

Table 6.—Averages of analyses (as-received basis) of coal samples from the Roslyn coal field, Kittitas County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Coal bed	Proximate (percent)						Sulfur (percent)		Btu	Number of analyses used in obtaining average
	M		VM	FC	Ash					
	Range	Average			Range	Average	Range	Average		
Big Dirty (No. 1) ------	2.5-4.7	3.6	35.8	45.9	11.5-18.5	14.6	0.3-0.4	0.3	12,097	6
No. 3 ----------	-------	3.7	34.0	48.8	---------	13.4	-------	.5	12,250	5
Roslyn (No. 5)---------	2.3-9.9	4.5	36.5	47.0	9.7-14.5	12.0	.3- .6	.4	12,078	88
Plant (No. 6)----------	3.4-5.4	4.2	34.1	46.1	13.3-17.4	15.6	.4- .8	.5	11,960	6
Green (No. 7)---------	3.4-4.2	3.8	32.8	46.6	8.8-24.6	16.7	.3- .4	.3	12,035	2
Wright (No. 8)---------	-------	4.5	31.8	47.0	13.7-21.5	17.6	-------	.4	11,840	2



EXPLANATION

A-14,420

Heating value of coal sample in British thermal units, mineral-matter-free basis

A indicates coal is of high-volatile A bituminous rank (coking coal);
B indicates coal is of high-volatile B bituminous rank (non coking coal)

•

Location of coal sample analyzed by the U.S. Bureau of Mines

12.3

Ash content of coal, in percent

14000

Btu contours
Contour interval 250 Btu

FIGURE 11. MAP SHOWING CHANGES IN HEATING VALUE AND ASH CONTENT OF THE ROSLYN COAL BED

Summary of Reserves

The total reserves of coal remaining in the Roslyn coal field as of January 1, 1960, are estimated to be about 240 million tons, all classified as bituminous. Of the total, 74 million tons is contained in the Big Dirty coal bed, 54 million tons in the Roslyn coal bed, and 93 million tons in the Plant coal bed. Because of lack of information concerning the extent of the Green and Wright coal beds, the estimated reserves for them are small. Approximately 33 percent of the total estimated coal in the field is classified as measured and indicated, and about 67 percent as inferred. The reserve figures by township and bed are shown in table 8, on page 32, and a summary by township is shown in table 36, on page 112.

The reserve estimates of the known coal beds could probably be increased by core drilling in the area southeast of the present field. The Roslyn coal field may contain additional coal reserves, because reserves have been estimated for only the upper part of the Roslyn Formation. The lower part of the formation, which crops out over a wide area north of the Roslyn coal field, may also contain coal beds and should be examined. In addition, much of northern Kittitas County is underlain by the early Tertiary and (or) Cretaceous (Foster, 1960, p. 104) continental sedimentary rocks of the Swauk Formation and, although they are in many places highly deformed and intruded by igneous rocks, they should be examined for possible coal reserves.

Comparison of coal reserve estimates.—Estimates of the coal reserves in the Roslyn field were prepared for the Washington State Power Commission by Ford, Bacon & Davis, Incorporated (written communication, 1956) and for Public Utility District No. 1 of Kittitas County by Resources Research, Incorporated (written communication, 1958). A comparison of these estimates with the present estimate is shown in table 7.

Table 7.—Comparison of estimates of coal reserves in the Roslyn coal field, Kittitas County, Washington
(In millions of short tons)

Coal bed	Ford, Bacon & Davis, Inc.	Resources Research, Inc.	This report
Big Dirty (No. 1)---	34.13	47.13	74.35
Roslyn (No. 5)-----	22.61	12.61	54.12
Plant (No. 6)------	61.45	90.73	93.11
Green (No. 7)-----	43.84	-----	7.07
Wright (No. 8)-----	64.70	80.00	12.68
Total ---------	226.73	1/ 230.42	241.33

1/ For the purpose of making this comparison, estimates by Resources Research, Incorporated, were recalculated and deductions that had been made for mining and washing losses were included to obtain the amount of coal remaining in the ground, which is the basis on which the other two estimates were prepared.

As shown in table 7, the totals of the remaining reserves in the Roslyn field are approximately the same in each of the three estimates; however, the totals for the individual coal beds vary considerably. The reserves for the upper three beds as estimated in this report are larger than those estimated in the other two reports, whereas the reserves for the lower two beds are smaller. The increase in reserves for the upper three beds is due to an assumed larger area of extent for each bed. Most of the additional reserves are in the inferred category. As no data were available on the lower two coal beds beyond the limits of mine workings, reserves for these beds were restricted to a belt a mile and a half beyond the mine workings, which resulted in a decrease in the total reserves for these beds. As has been previously mentioned, it is likely that these two lower coal beds extend throughout the field, in which case, the reserves would be much larger than shown in this report.

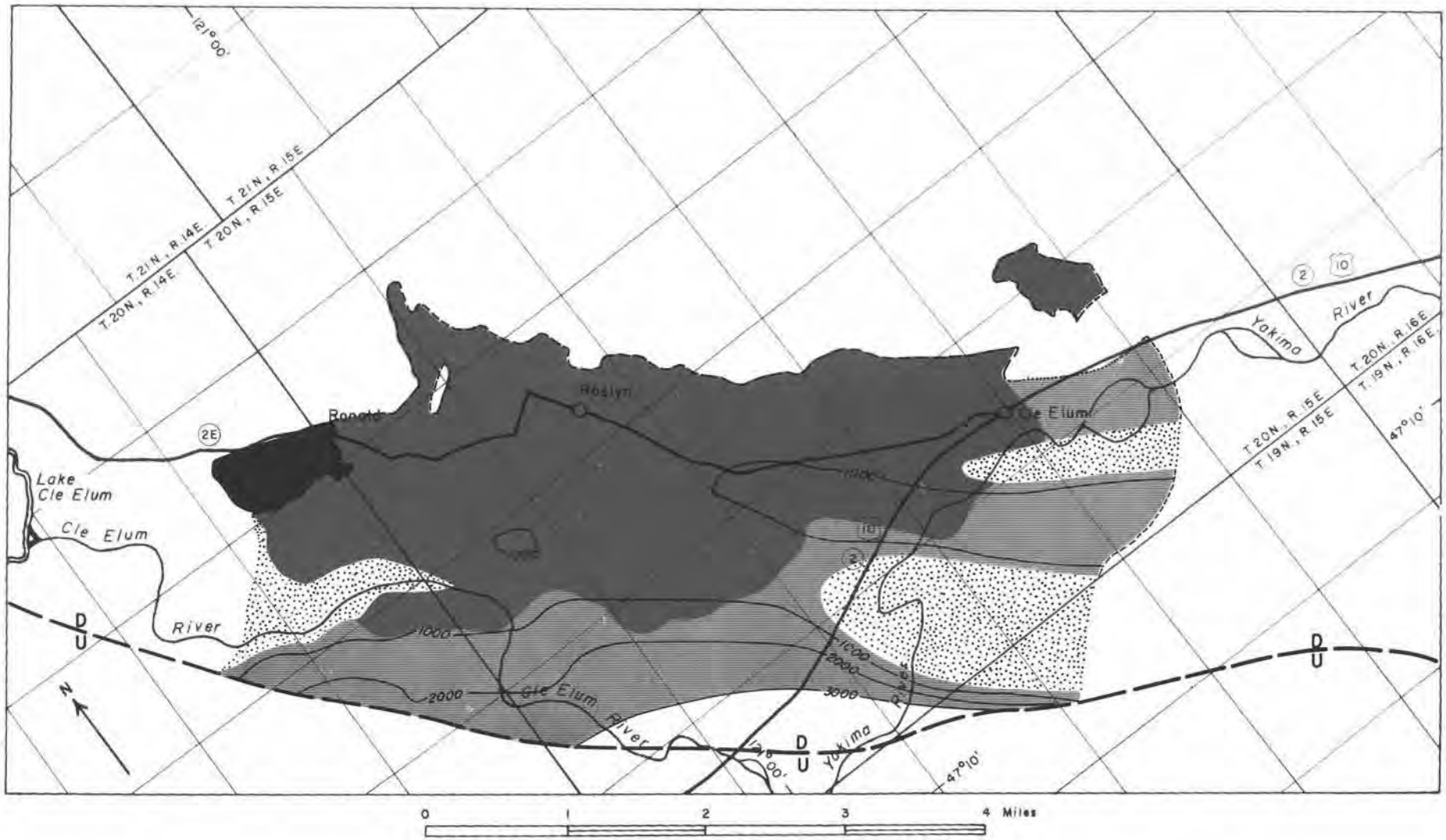
TANEUM AND MANASTASH AREAS

The Taneum and Manastash areas (fig. 17) are south of the Roslyn coal field (fig. 2) and both are believed to be areas exposed by the erosion of overlying volcanic rocks. The Taneum area may represent a continuation of the Roslyn field, and the Manastash area, in part, may also be a continuation of the Roslyn basin or may constitute a separate basin of deposition. The Taneum and Manastash areas have been described by Saunders (1914, p. 119-129, 133-136), and much of the information presented here has been taken from that report.

In the Taneum area, which covers less than a square mile, prospect tunnels were driven on coal beds cropping out on the south side of Taneum Creek. One of these, called the Wilson mine, was developed to a limited extent prior to 1925. The coal bed mined here was found to vary considerably in quality and thickness and to be interrupted by rolls and faults. An analysis of a sample from a good lens within the bed shows the coal to have a heating value of 12,220 Btu and to have the following percent composition: moisture, 6.15; volatile matter, 44.80; fixed carbon, 44.75; and ash, 4.30. The coal is of high-volatile A bituminous rank.

A drill hole half a mile northwest of the mine cut through two beds of dirty coal, one of which may be the same as the bed at the Wilson mine. On the basis of evidence presented by the mine and drill hole, coal has been inferred throughout the Taneum area south of Taneum Creek. Because of the uncertain thickness of the bed, the minimum thickness of 14 inches was used in estimating reserves.

The Manastash area covers about 7 square miles. It was mapped on a reconnaissance basis by R. D. Brown, Jr., for use in this report. The presence of several coal beds in the area was indicated by coal and carbonaceous shale found near openings of several slumped open cuts and tunnels. The number of coal beds present and their thickness could not be determined. However, from the position of the slumped



EXPLANATION

BITUMINOUS COAL RESERVES

All reserves are 42 inches or more thick

Measured and indicated

Inferred

Coal outcrop

Dashed where approximately located; dotted where inferred

1000

Thickness of overburden, in feet

Mined-out area

Area from which coal may have been removed by glacial channeling

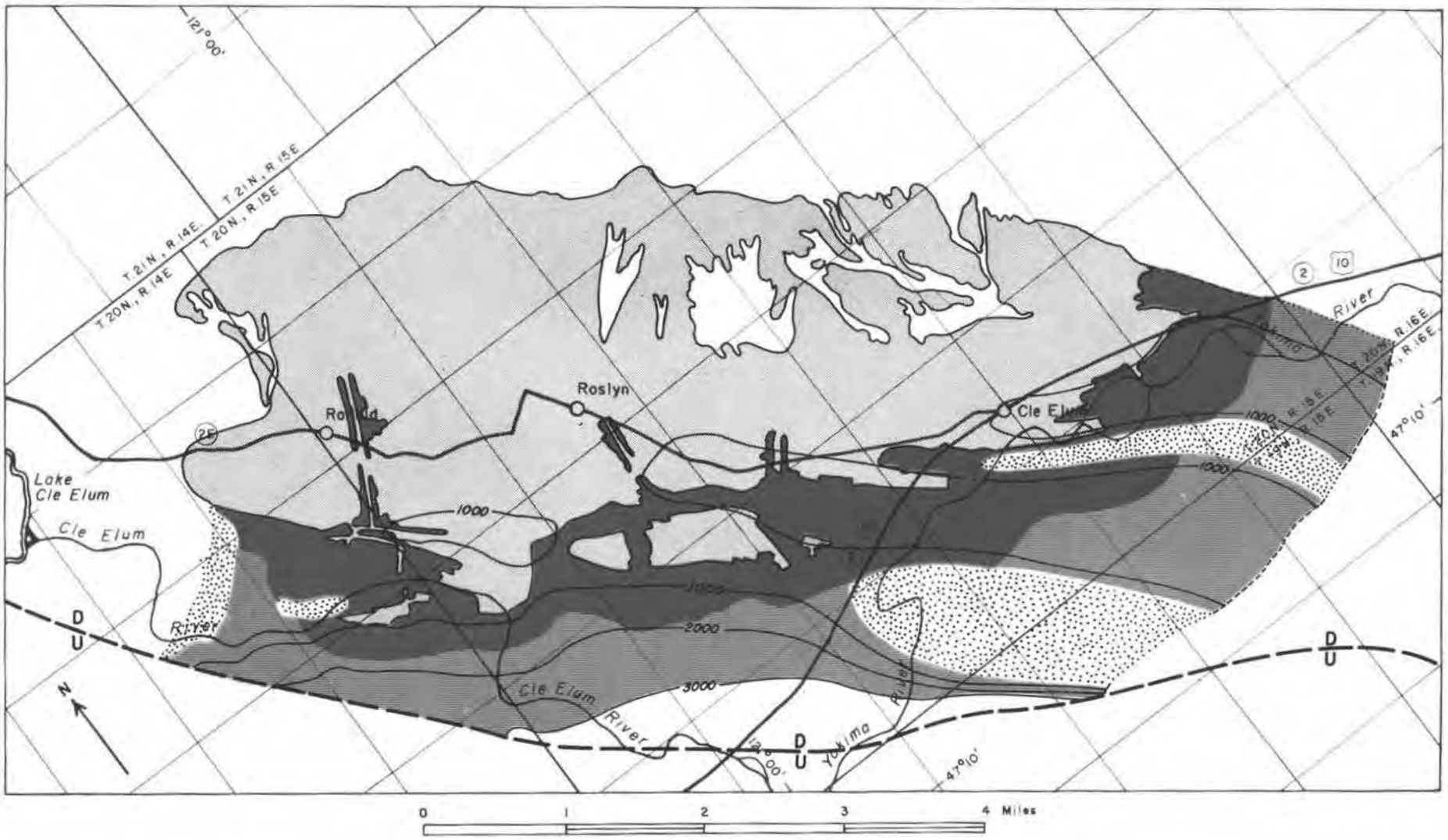
Boundary of area for which data were sufficient to estimate reserves

D
U

Inferred fault

U, upthrown side; D, downthrown side

FIGURE 12. GENERALIZED MAP OF THE BIG DIRTY (NO.1) COAL BED



EXPLANATION

BITUMINOUS COAL RESERVES

All reserves are 42 inches or more thick

Measured and indicated

Inferred

Coal outcrop

Dashed where approximately located; dotted where inferred

1000

Thickness of overburden, in feet

Mined-out area

Area from which coal may have been removed by glacial channeling

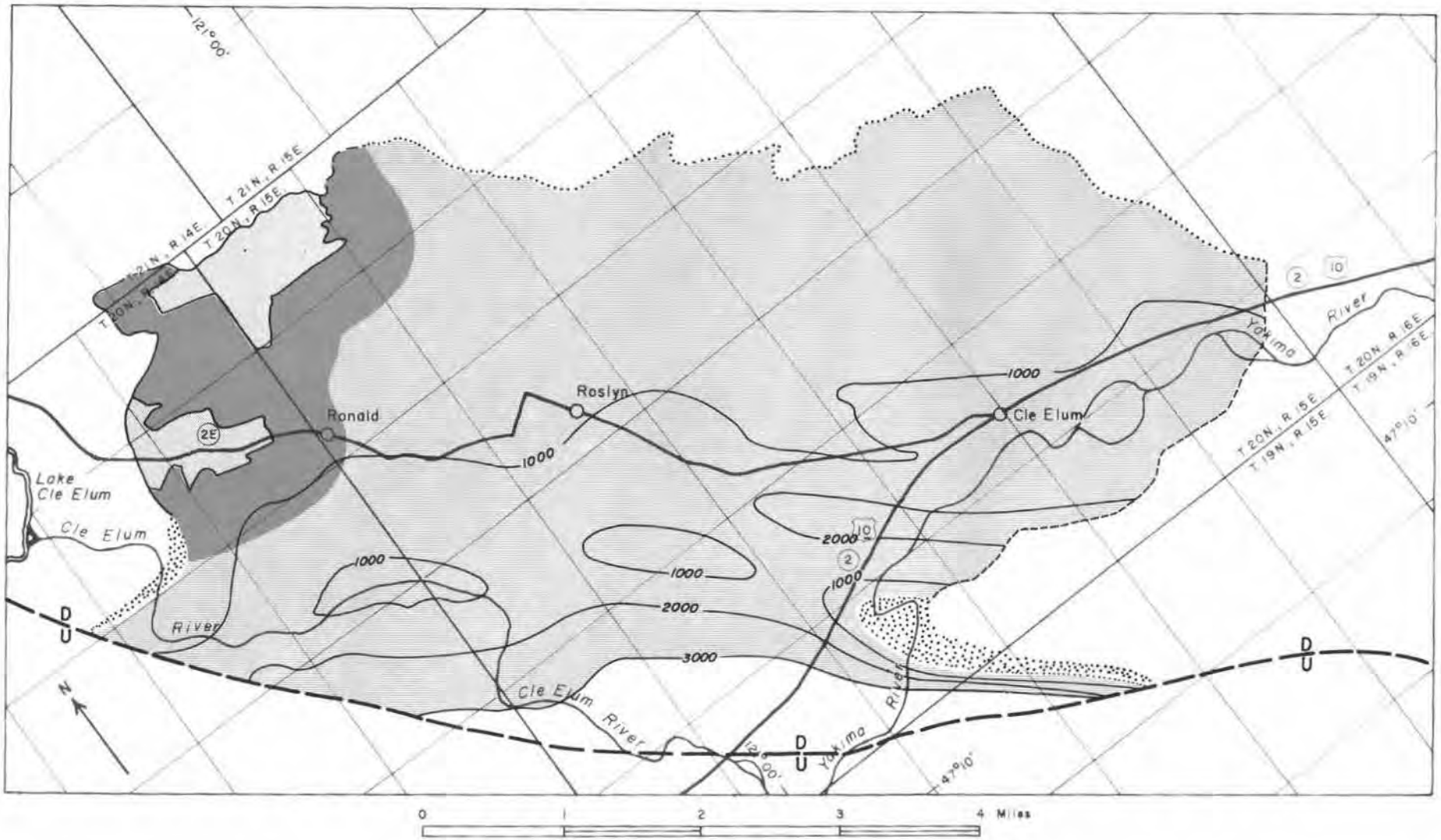
Boundary of area for which data were sufficient to estimate reserves

D
U

Inferred fault

U, upthrown side; D, downthrown side

FIGURE 13. GENERALIZED MAP OF THE ROSLYN (NO. 5) COAL BED



EXPLANATION

BITUMINOUS COAL RESERVES

All reserves are 28 to 42 inches thick

Measured and indicated

Inferred

Coal outcrop
Dashed where approximately located; dotted where inferred

1000
Thickness of overburden, in feet

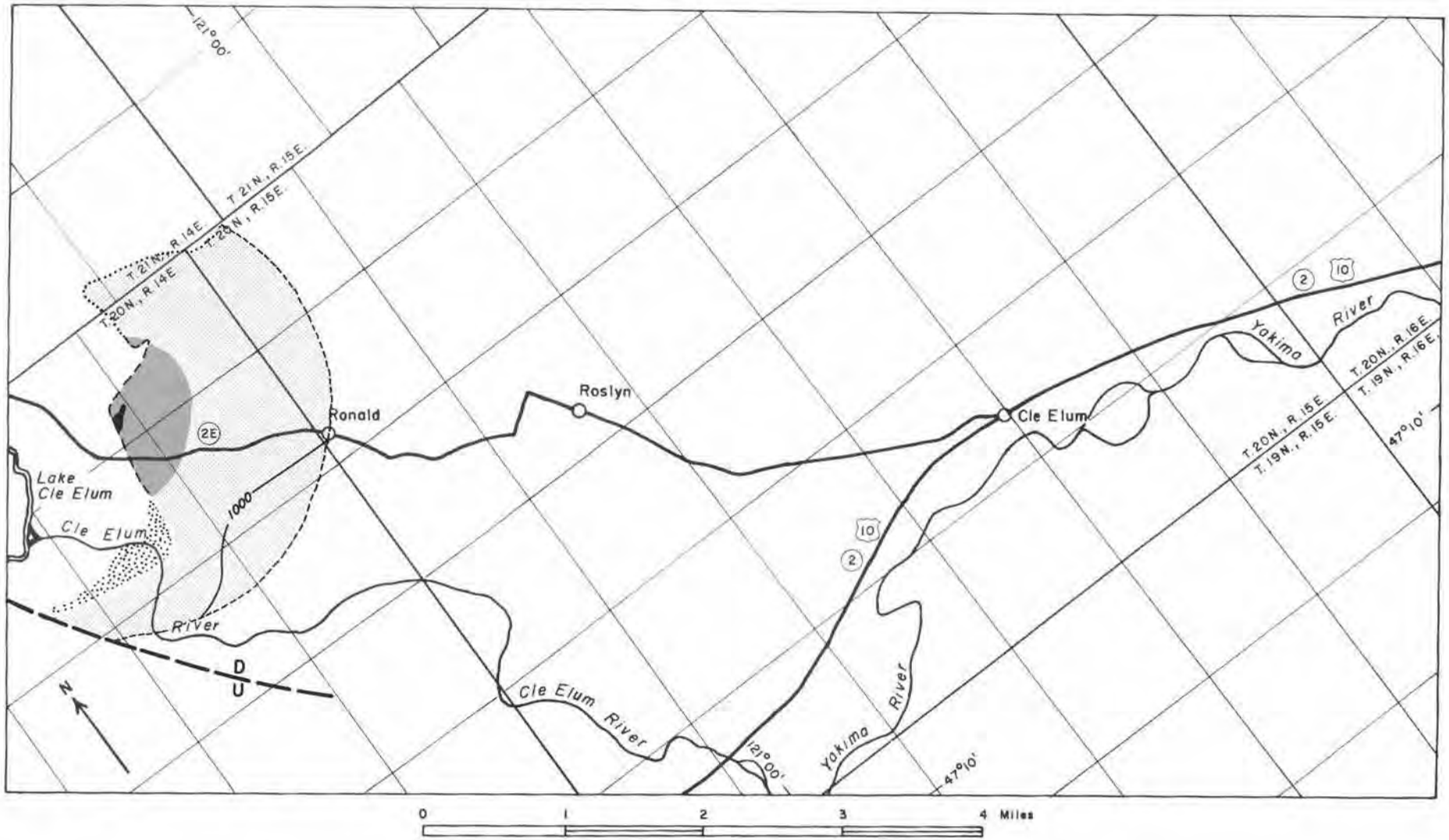
Mined-out area

Area from which coal may have been removed by glacial channeling

Boundary of area for which data were sufficient to estimate reserves

D
U
Inferred fault
U, upthrown side; D, downthrown side

FIGURE 14. GENERALIZED MAP OF THE PLANT (NO. 6) COAL BED



EXPLANATION

BITUMINOUS COAL RESERVES

All reserves are 14 to 28 inches thick

Measured and indicated

Inferred

Coal outcrop
Dashed where approximately located; dotted where inferred

1000
Thickness of overburden, in feet

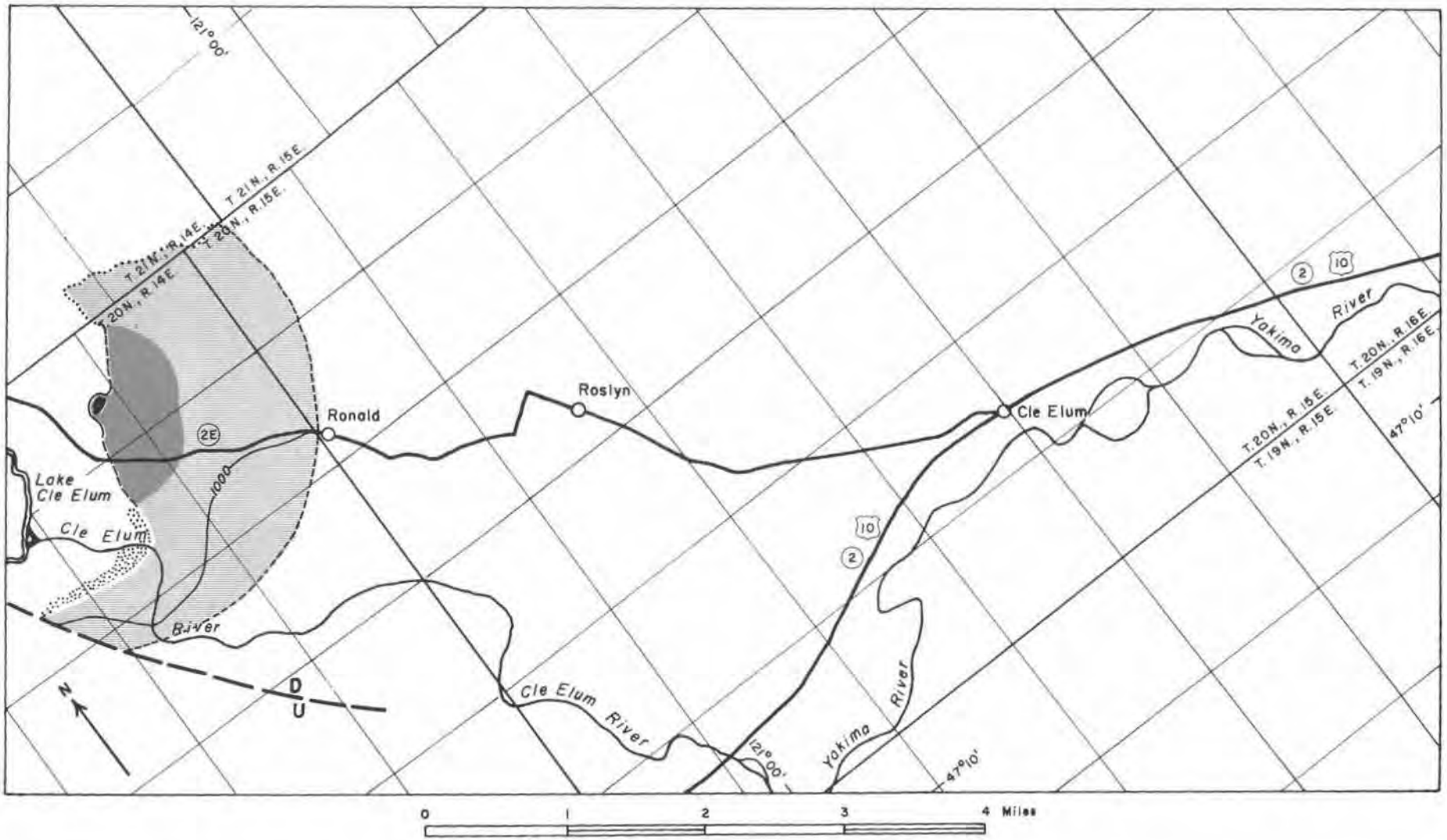
Mined-out area

Area from which coal may have been removed by glacial channeling

Boundary of area for which data were sufficient to estimate reserves

D
U
Inferred fault
U, upthrown side; D, downthrown side

FIGURE 15. GENERALIZED MAP OF THE GREEN (NO.7) COAL BED



EXPLANATION

BITUMINOUS COAL RESERVES

All reserves are 28 to 42 inches thick

Measured and indicated

Inferred

Coal outcrop
Dashed where approximately located; dotted where inferred

1000
Thickness of overburden, in feet

Mined-out area

Area from which coal may have been removed by glacial channeling

Boundary of area for which data were sufficient to estimate reserves

D
U
Inferred fault
U, upthrown side; D, downthrown side

FIGURE 16. GENERALIZED MAP OF THE WRIGHT (NO. 8) COAL BED

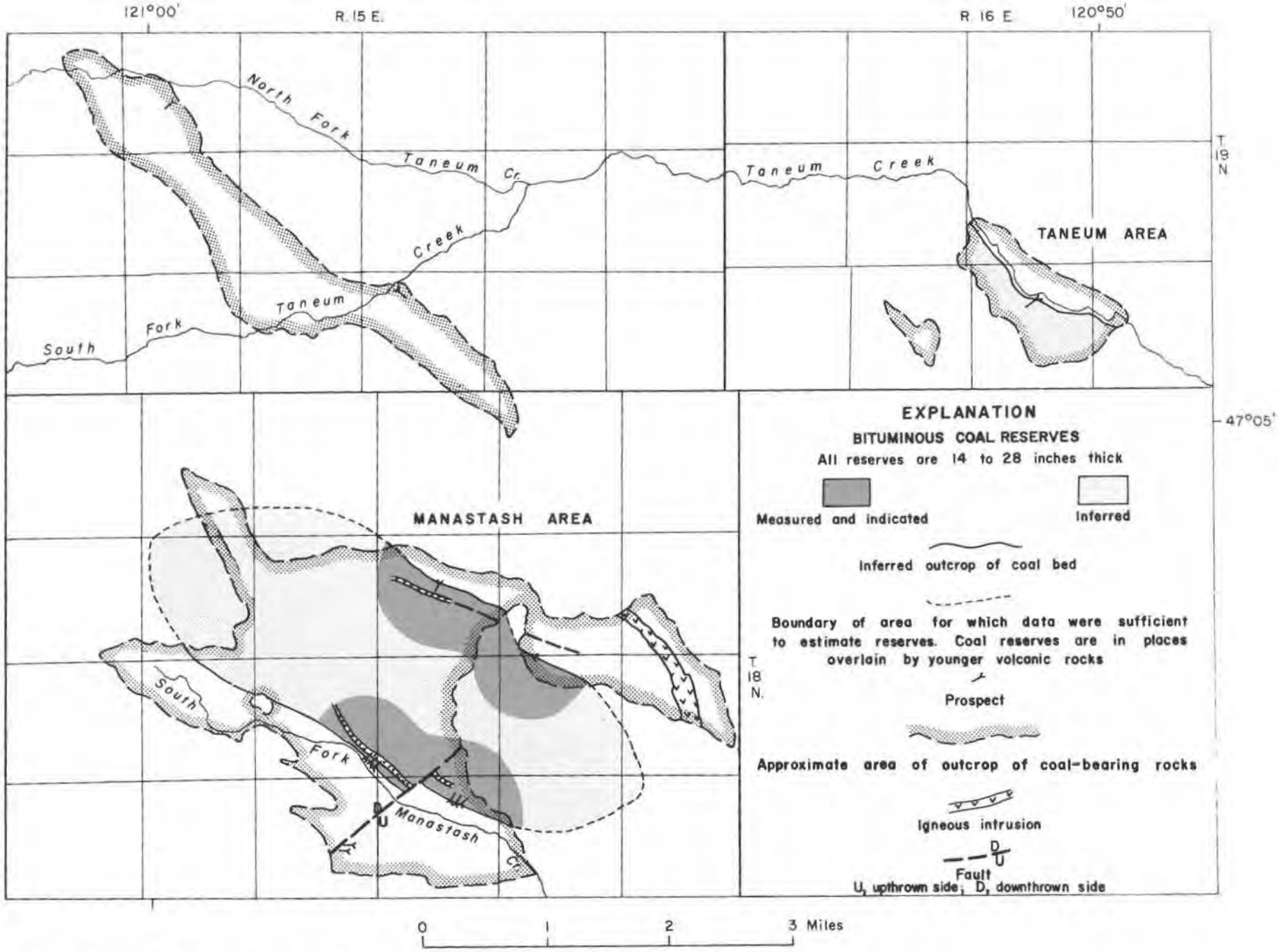


FIGURE 17. MAP OF THE TANEUM AND MANASTASH AREAS

Table 8.— Estimated remaining reserves of coal in the Roslyn coal field, Washington, as of January 1, 1960, by township and bed
(Includes reserves in the Taneum and Manastash areas)

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 18 N., R. 15 E.													
Unnamed	0-1,000	10.81	------	------	10.81	28.56	------	------	28.56	39.37	------	------	39.37
T. 19 N., R. 15 E.													
Big Dirty (No. 1)	0-1,000	------	------	------	------	------	------	0.97	0.97	------	------	0.97	0.97
	1,000-2,000	------	------	------	------	------	------	.97	.97	------	------	.97	.97
	2,000-3,000	------	------	------	------	------	------	.97	.97	------	------	.97	.97
Bed total		------	------	------	------	------	------	2.91	2.91	------	------	2.91	2.91
Roslyn (No. 5)	0-1,000	------	------	------	------	------	------	1.58	1.58	------	------	1.58	1.58
	1,000-2,000	------	------	------	------	------	------	5.51	5.51	------	------	5.51	5.51
	2,000-3,000	------	------	------	------	------	------	.95	.95	------	------	.95	.95
Bed total		------	------	------	------	------	------	8.04	8.04	------	------	8.04	8.04
Plant (No. 6)	0-1,000	------	------	------	------	------	0.75	------	0.75	------	0.75	------	0.75
	1,000-2,000	------	------	------	------	------	.75	------	.75	------	.75	------	.75
	2,000-3,000	------	------	------	------	------	.75	------	.75	------	.75	------	.75
Bed total		------	------	------	------	------	2.25	------	2.25	------	2.25	------	2.25
Township total		------	------	------	------	------	2.25	10.95	13.20	------	2.25	10.95	13.20
T. 19 N., R. 16 E.													
Roslyn (No. 5)	0-1,000	------	------	------	------	------	------	0.15	0.15	------	------	0.15	0.15
	1,000-2,000	------	------	------	------	------	------	.28	.28	------	------	.28	.28
Bed total		------	------	------	------	------	------	0.43	0.43	------	------	0.43	0.43
Unnamed	0-1,000	------	------	------	------	1.10	------	------	1.10	1.10	------	------	1.10
Township total		------	------	------	------	1.10	------	0.43	1.53	1.10	------	0.43	1.53
T. 20 N., R. 14 E.													
Big Dirty (No. 1)	0-1,000	------	------	3.42	3.42	------	------	0.57	0.57	------	------	3.99	3.99
	1,000-2,000	------	------	------	------	------	------	3.27	3.27	------	------	3.27	3.27
	2,000-3,000	------	------	------	------	------	------	1.63	1.63	------	------	1.63	1.63
Bed total		------	------	3.42	3.42	------	------	5.47	5.47	------	------	8.89	8.89
Roslyn (No. 5)	0-1,000	------	------	3.07	3.07	------	------	1.76	1.76	------	------	4.83	4.83
	1,000-2,000	------	------	.09	.09	------	------	1.86	1.86	------	------	1.95	1.95
	2,000-3,000	------	------	------	------	------	------	2.49	2.49	------	------	2.49	2.49
Bed total		------	------	3.16	3.16	------	------	6.11	6.11	------	------	9.27	9.27
Plant (No. 6)	0-1,000	------	4.72	------	4.72	------	2.21	------	2.21	------	6.93	------	6.93
	1,000-2,000	------	.43	------	.43	------	4.91	------	4.91	------	5.34	------	5.34
	2,000-3,000	------	------	------	------	------	2.30	------	2.30	------	2.30	------	2.30
Bed total		------	5.15	------	5.15	------	9.42	------	9.42	------	14.57	------	14.57
Green (No. 7)	0-1,000	0.88	------	------	0.88	3.82	------	------	3.82	4.70	------	------	4.70
	1,000-2,000	------	------	------	------	.92	------	------	.92	.92	------	------	.92
Bed total		0.88	------	------	0.88	4.74	------	------	4.74	5.62	------	------	5.62
Wright (No. 8)	0-1,000	------	1.85	------	1.85	------	5.65	------	5.65	------	7.50	------	7.50
	1,000-2,000	------	------	------	------	------	2.85	------	2.85	------	2.85	------	2.85
Bed total		------	1.85	------	1.85	------	8.50	------	8.50	------	10.35	------	10.35
Township total		0.88	7.00	6.58	14.46	4.74	17.92	11.58	34.24	5.62	24.92	18.16	48.70
T. 20 N., R. 15 E.													
Big Dirty (No. 1)	0-1,000	------	------	38.87	38.87	------	------	12.15	12.15	------	------	51.02	51.02
	1,000-2,000	------	------	1.10	1.10	------	------	4.81	4.81	------	------	5.91	5.91
	2,000-3,000	------	------	------	------	------	------	5.62	5.62	------	------	5.62	5.62
Bed total		------	------	39.97	39.97	------	------	22.58	22.58	------	------	62.55	62.55
Roslyn (No. 5)	0-1,000	------	------	8.43	8.43	------	------	1.78	1.78	------	------	10.21	10.21
	1,000-2,000	------	------	13.38	13.38	------	------	6.44	6.44	------	------	19.82	19.82
	2,000-3,000	------	------	------	------	------	------	5.18	5.18	------	------	5.18	5.18
Bed total		------	------	21.81	21.81	------	------	13.40	13.40	------	------	35.21	35.21
Plant (No. 6)	0-1,000	------	3.82	------	3.82	------	39.97	------	39.97	------	43.79	------	43.79
	1,000-2,000	------	.01	------	.01	------	25.79	------	25.79	------	25.80	------	25.80
	2,000-3,000	------	------	------	------	------	6.44	------	6.44	------	6.44	------	6.44
Bed total		------	3.83	------	3.83	------	72.20	------	72.20	------	76.03	------	76.03
Green (No. 7)	0-1,000	------	------	------	------	1.25	------	------	1.25	1.25	------	------	1.25
Wright (No. 8)	0-1,000	------	------	------	------	------	1.75	------	1.75	------	1.75	------	1.75
Township total		------	3.83	61.78	65.61	1.25	73.95	35.98	111.18	1.25	77.78	97.76	176.79

Table 8.—Estimated remaining reserves of coal in the Roslyn coal field, Washington, as of January 1, 1960, by township and bed - Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 20 N., R. 16 E.													
Roslyn (No. 5)	0-1,000	------	------	------	------	------	------	1.05	1.05	------	------	1.05	1.05
	1,000-2,000	------	------	------	------	------	------	.12	.12	------	------	.12	.12
Bed total		------	------	------	------	------	------	1.17	1.17	------	------	1.17	1.17
Plant (No. 6)	0-1,000	------	------	------	------	------	0.05	------	0.05	------	0.05	------	0.05
Township total		------	------	------	------	------	0.05	1.17	1.22	------	0.05	1.17	1.22
T. 21 N., R. 14 E.													
Plant (No. 6)	0-1,000	------	0.21	------	0.21	------	------	------	------	------	0.21	------	0.21
Green (No. 7)	0-1,000	------	------	------	------	0.20	------	------	0.20	0.20	------	------	0.20
Wright (No. 8)	0-1,000	------	------	------	------	------	0.58	------	0.58	------	0.58	------	0.58
Township total		------	0.21	------	0.21	0.20	0.58	------	0.78	0.20	0.79	------	0.99
Grand total		11.69	11.04	68.36	91.09	35.85	94.75	60.11	190.71	47.54	105.79	128.47	1/281.80

1/ Includes 39.37 million tons in the Manastash area and 1.10 million tons in the Taneum area. The total for the Roslyn field alone is 241.33 million.

open cuts and tunnels it has been assumed that two beds are present. The thicknesses of 23 inches and 27 inches used in estimating reserves are averages of figures reported by Saunders (1914).

The coal-bearing rocks in the Manastash area have been intruded in several places by dikes that cut across the coal beds, and to the northwest and southeast the strata are overlain by volcanic rocks. The continuity of the coal beds has been interrupted in several places by faults. Analyses of two samples from the area show the coal to have a heating value of 8,978 and 12,062 Btu and to have the following percent composition: moisture, 10.42 and 7.45; volatile matter, 30.33 and 37.52; fixed carbon, 36.43 and 47.88; and ash, 22.82 and 7.5. This coal is also of high-volatile A bituminous rank.

In addition to the Taneum and Manastash areas, coal-bearing rocks have been exposed by erosion of overlying volcanic rocks in T. 19 N., R. 15 E. (fig. 17). Two prospects have been opened in this area, and several carbonaceous zones were found to contain thin beds of low-grade coal. According to Saunders (1914, p. 140, 144), the coal-bearing rocks here have been squeezed and crushed by folding or by igneous intrusions, and the coal beds are thin and irregular. Coal reserves have not been estimated for this area.

Summary of Reserves

The reserves of coal in the Taneum area total about 1 million tons, all classified as inferred. The reserves in the Manastash area total about 40 million tons, of which 10 million tons is classified as measured and indicated, and 30 million tons is classified as inferred. These reserves are incorporated with those in the Roslyn field and are shown in table 8.

KING COUNTY COAL DEPOSITS

Geographic and Geologic Setting

The coal deposits of King County are located in the central and south-central part of the county (fig. 2). The central part of the county contains six principal coal-bearing areas: the Renton, Newcastle-Grand Ridge, Cedar Mountain, Tiger Mountain, Taylor, and Niblock areas (fig. 21). Near these areas are several isolated mines and prospects, which are shown on figure 27 (p. 47), but which are not included in the reserve estimates because the data concerning them is insufficient. Green River district, the largest and most extensively mined coal-bearing area of King County, includes all the coal deposits in the south-central part of the county.

The King County coals occur in the Puget Group of Eocene age. The coal-bearing strata have been folded and faulted. In most parts of the Renton, Newcastle-Grand Ridge, and Cedar Mountain areas, deformation has been moderate and most of the coal beds dip less than 35°. In the other coal-bearing areas, particularly those in the Green River district, the deformation of the rocks has been more intense, and dips of 50° or more are common.

The two most important published sources of information on King County coals are reports by Evans (1912) and by Warren and others (1945), and much of the information presented on subsequent pages was taken from them.

Coal Beds

The coals of King County range in rank from subbituminous B to high-volatile A bituminous coal. All the coals of the Renton, Cedar Mountain, Newcastle-Grand Ridge, and Tiger Mountain areas are of subbituminous rank except the New Lake Youngs No. 2 coal bed of the Cedar Mountain district, which is classified as

high-volatile bituminous C. Most of the coal beds of the Green River district and all the coal beds of the Niblock and Taylor areas are of bituminous rank. Locally, some of the bituminous coals have coking qualities, but they have not been adequately tested.

Coal Mining

In King County, coal was first discovered and mined near Renton in 1853. Coal production rose to a record high of nearly 1.5 million tons in 1907. Production declined thereafter, and by 1943 it had decreased to about 500 thousand tons annually. In 1959 only about 100 thousand tons of coal was mined. The total recorded coal production for King County is about 47 million tons, more than half of which has come from the Green River district.

Summary of Reserves

As currently estimated, the reserves of coal remaining in the ground in King County as of January 1, 1960, total about 828 million tons, of which 435 million tons is subbituminous coal and 394 million is bituminous coal. Approximately 32 percent of the total is classified as measured and indicated, and 68 percent as inferred. The reserve figures by township are shown in table 36, on page 112. Many of the King County coal-bearing strata are concealed beneath a thick cover of glacial drift, and the stratigraphic and structural relations between isolated areas are poorly known; as a result, these reserve figures are probably low. A detailed geologic study supplemented by core drilling in the covered areas is needed before the true reserves can be accurately estimated.

NEWCASTLE-GRAND RIDGE AREA

Geographic and Geologic Setting

The Newcastle-Grand Ridge area is located about 5 miles east of Seattle and is the northernmost coal-bearing area in King County. The coal beds occur in sedimentary rocks of the Puget Group of Eocene age which, in this area, overlie volcanic rocks of Eocene age and are overlain by marine sedimentary rocks of Oligocene age (Warren and others, 1945). The structure is relatively simple. Throughout most of the area the coal beds strike eastward and dip 30° to 40° northward. At Issaquah the strike swings to the northeast toward Grand Ridge. At Grand Ridge the strike is nearly north. In the vicinity of the Reynolds mine the strike swings back to the east, and the dip of the coal beds increases to about 75°. The rocks have been broken locally by small cross faults. Near Issaquah Creek the mine workings encountered glacial gravels, but the extent to which the coal beds have been removed by erosion is unknown.

Coal Beds

Coal reserves have been estimated for eight coal beds in the Newcastle-Grand Ridge area. Some of the coal beds have been called by different names in different mines, and the correlation of beds from one mine to another is difficult and sometimes uncertain. The correlations used to estimate reserves for this area are shown on figure 18. The location and classification of reserves by individual beds are shown on figures 20 through 27, on pages 40 through 47.

Table 9.—Averages of analyses (as-received basis) of coal samples from the Newcastle-Grand Ridge area, King County, Washington

(Coal bed names are those used at Newcastle. M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Coal beds	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average.
	M	VM	FC	Ash			
No. 4	16.1	30.5	42.2	9.0	0.5	9,920	5
No. 3	16.1	31.9	40.6	11.3	.8	9,665	4
No. 2[a/]	13.8	32.5	36.0	17.7	.5	9,140	1
Bagley	12.7	35.1	40.2	11.9	.4	10,227	10
May Creek	15.0	34.3	40.2	10.3	.6	10,047	4
Muldoon	14.4	33.0	38.1	14.3	.7	9,537	7
Dolly Varden	14.2	32.3	40.4	13.0	.7	9,986	6
Jones	13.8	35.2	36.2	14.8	.6	9,890	1

a/Present only in Grand Ridge area.

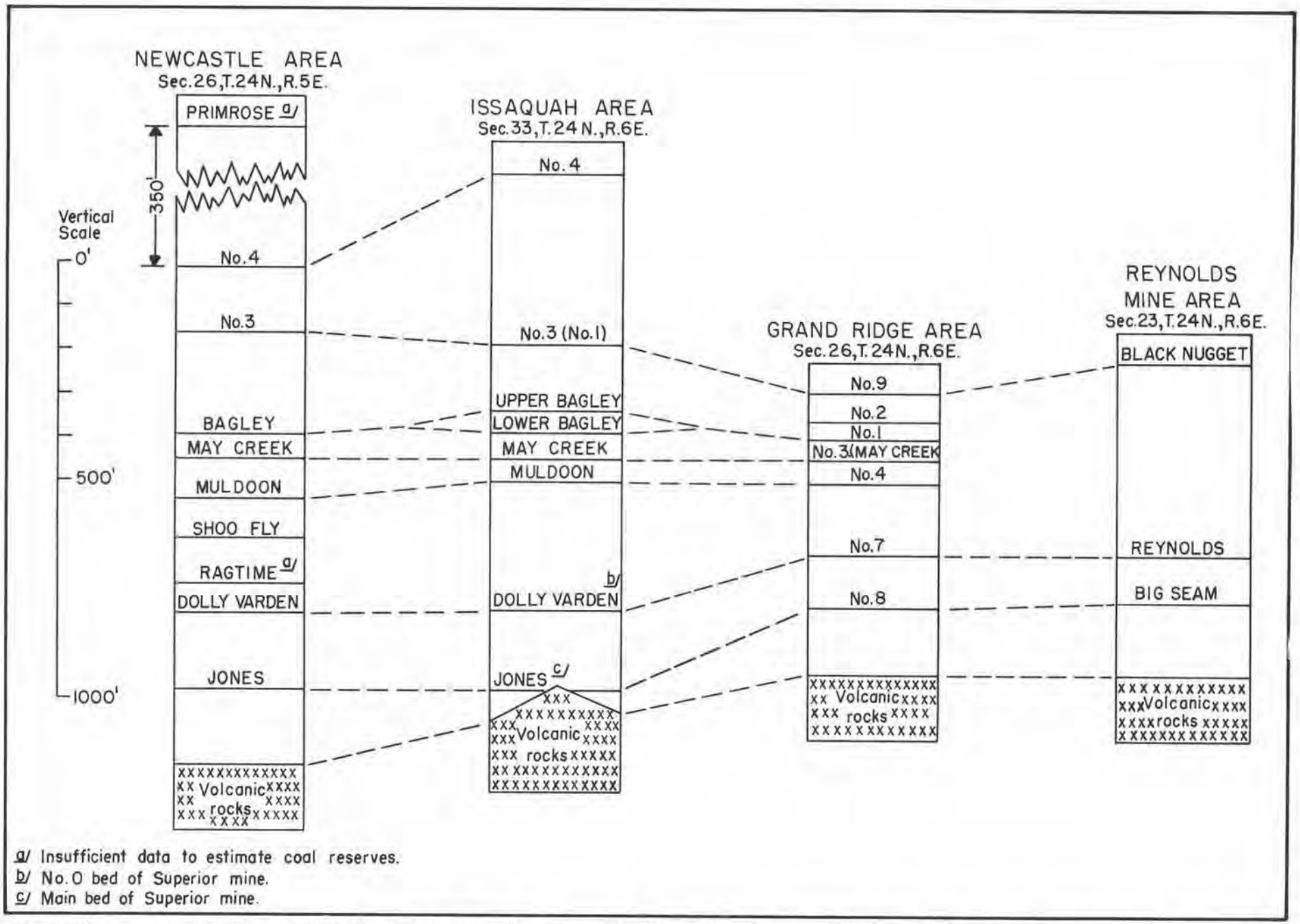


Figure 18. Generalized columnar sections in the Newcastle-Grand Ridge area showing coal beds and correlations used in estimating coal reserves

Physical and chemical properties.—The coals of the Newcastle-Grand Ridge area are here considered as subbituminous A coal. However, some of these coals may be classified as either subbituminous A or high-volatile C bituminous in rank. The ash content of the coal ranges from 7.2 to 20.6 and averages about 13 percent. The moisture content ranges from 9.3 to 18.2 and averages about 14 percent. The sulfur content ranges from 0.3 to 2.3 percent and averages 0.6 percent. Average analyses of the Newcastle-Grand Ridge coals are given in table 9.

Coal Mining

In the Newcastle-Grand Ridge area coal was first discovered and mined in 1863 near Issaquah (Green, 1947, p. 8). From that date to 1961 about 13 million tons of coal has been produced. The highest annual production in the area was reached in 1942, when about 250 thousand tons was produced. Production has decreased since that date, and in 1958 only 8,991 tons was mined.

Summary of Reserves

The total reserves of coal remaining in the ground in the Newcastle-Grand Ridge area are estimated to be about 310 million tons. Approximately 41 percent of this total is classified as measured and indicated, and 59 percent is classified as inferred. The reserve figures by township and bed are shown in table 11, on page 48.

RENTON AREA

Geographic and Geologic Setting

The Renton area is about 5 miles southwest of Newcastle. It includes the prospects and small mines located between Renton and the Duwamish River. The coal-bearing rocks in the Renton area are probably of the same age as those in the Newcastle-Grand Ridge area (Warren and others, 1945). Most of the rocks in the Renton area have been gently folded, and dips of 10° to 20° are common, but in the southern part of the area deformation has been more intense and the strata dip as much as 65°. The rocks of the Renton area have been cut by several west- to northwest-trending faults. The displacements of the two faults shown on figure 22 are unknown, but they appear to be major faults. According to Warren and others (1945), a west-trending fault with a throw of 300 feet or more is concealed beneath the alluvium of the Cedar River in the Renton area. The coal beds of the Renton area have not been located north of this proposed fault.

Coal Beds

The stratigraphic position of most of the coal beds in the Renton area is shown on figure 19, on page 39. Reserves were estimated for seven coal beds in this area, two of which, the Newenham and Springbrook coal beds, are not shown on figure 19. The exact position of the Newenham coal bed is uncertain, but is probably equivalent either to the Senior or the Pilot coal bed. The Springbrook coal bed also may be equivalent to one of the coal beds shown on figure 19, but its stratigraphic position is unknown.

The Pilot coal bed and the higher unnamed bed shown on figure 19 may contain coal reserves, but data were insufficient to include these beds in the reserve estimates. The location and classification of reserves by individual bed are shown on figures 20 through 26.

Physical and chemical properties.—The coals of the Renton area are here considered to be of subbituminous rank; however, some of the coals can be classified as either of subbituminous A or high-volatile C bituminous rank. The ash content of the coal in the Renton area is less than that of coal in other areas in King County. It ranges from 5.6 to 14.9 percent and averages about 9 percent. The moisture content of the coal is greater than that of other King County coal, however, having a range of 13.2 to 18.0 percent and an average of about 15 percent. The sulfur content ranges from 0.3 to 2.3 percent and averages about 0.6 percent.

Coal Mining

In King County coal was first mined in 1853 on the Black River near the present site of Renton, but only a small amount of coal was produced initially (Green, 1947, p. 8). Most of the coal production in the Renton area was much later, during the period from 1900 to 1920. About 4 million tons of coal has been produced in the area, most of which was from the No. 3 bed of the Renton mines. The last recorded production in the Renton area was in 1957, when 290 tons was produced.

Summary of Reserves

The total reserves remaining in the ground in the Renton area are estimated to be about 50 million tons. Approximately 20 percent of these reserves is classified as measured and indicated, and 80 percent as inferred. The reserve figures by township and bed are shown in table 12, on page 49.

CEDAR MOUNTAIN AREA

Geographic and Geologic Setting

The Cedar Mountain area is about 4 miles southeast of Renton. The coal beds of this area are probably of the same age as those in

the Renton and Newcastle-Grand Ridge areas (Warren and others, 1945). Although the Cedar Mountain and Renton areas are only a few miles apart, no correlation of coal beds between the two areas can be made. The principal structure of the Cedar Mountain area is a southwest-plunging anticline in the vicinity of the Cedar River. Several northwest-trending faults cut the coal-bearing strata. The most important fault is shown on figures 21 through 24. The magnitude of displacement along this fault is unknown. Southwest of this fault the coal-bearing rocks have been intruded by andesite (Warren and others, 1945). The nature of this intrusive and its effect on the coal beds in unknown.

Coal Beds

Reserves have been estimated for five coal beds southwest of the fault shown on figures 21 through 24 and for two coal beds northeast of the fault. Correlations of coal beds on opposite sides of the fault could not be made. The New Lake Youngs No. 2 coal bed appears to be stratigraphically higher than the coal beds that crop out to the north; however, because structural data are scarce the stratigraphic position of this bed is uncertain. The stratigraphic positions of the principal coal beds of the Cedar Mountain area are shown on figure 19.

Physical and chemical properties.—The coals of the Cedar Mountain area range in rank from subbituminous A to high-volatile C bituminous. In this report the New Lake Youngs No. 2 coal bed is the only one classified as high-volatile C bituminous coal. All other coals of the Cedar Mountain area are considered to be of subbituminous A rank, although some of them are in a range that the U.S. Bureau of Mines classified as "subbituminous A or high-volatile C bituminous coal." The ash content of the coal ranges from 5.1 to 24.2 percent and averages about 12 percent. The moisture content ranges from 9.2 to 12.3 percent and averages about 10 percent. The sulfur content ranges from 0.3 to 0.9 percent and averages about 0.6 percent. Average analyses of the coal beds of the Cedar Mountain area are given in table 10.

Coal Mining

In the Cedar Mountain area coal was first mined in about 1880. Between that date and 1944, the last year of recorded production, about 4 million tons of coal had been produced in the area. The peak production was reached in 1930, when 394 thousand tons of coal was mined.

Summary of Reserves

The total reserves of coal remaining in the ground in the Cedar Mountain area are estimated to be about 67 million short tons. Approximately 22 percent of these reserves is classified as measured and indicated and 78 percent as inferred. The reserve figures by township and bed are shown in table 14, on page 50.

TIGER MOUNTAIN AND NIBLOCK AREAS

Geographic and Geologic Setting

The Tiger Mountain area is about 4 miles southeast of Issaquah; and the Niblock area, here named for the Niblock mine, is about 9 miles east of Issaquah (fig. 21). The Niblock area is sometimes referred to as the Snoqualmie area by other workers. Little is known about the geology of these two areas; the coal beds of both occur in the Puget Group, but their stratigraphic relations to the other coal beds in King County are unknown. In the Tiger Mountain area the rocks strike north to northeast and dip about 45° west beneath glacial sands and gravels. To the east the coal-bearing sedimentary rocks are intruded by a large body of andesite (Warren and others, 1945). The coal-bearing strata at Niblock strike north to northwest and dip steeply to the southwest.

Coal Beds

Three coal beds have been worked in the Tiger Mountain area. Data were sufficient to estimate coal reserves for two of these beds. Reserves were estimated for three beds in the Niblock area. Other coal beds have been reported in both places, but data on their thickness and extent are not available. The stratigraphic position of the coal beds is shown on figure 19, and the location and classification of reserves by individual beds are shown on figures 20 through 23.

Physical and chemical properties.—The coals at Tiger Mountain are of subbituminous B rank, and those at Niblock are of high-volatile A bituminous rank. The one analysis of the coal at Tiger Mountain showed it to have both a relatively high ash and moisture content, of 19.2 and 12.4 percent, respectively. The sulfur content is 0.2 percent. The coal in the Niblock area has an ash content ranging from 10.7 to 24.3 percent and averaging about 16 percent, a moisture content ranging from 4.9 to 8.2 percent and averaging about 6 percent, and a sulfur content ranging from 0.5 to 1.5 percent and averaging 1 percent. Analyses for the Tiger Mountain and the Niblock areas are given in table 10.

Coal Mining

Only a small amount of coal has been produced from these two areas. About 50,000 tons of coal has been produced from the Tiger Mountain area and about half that amount from the Niblock area.

Summary of Reserves

The reserves for the Tiger Mountain area are estimated to be

about 9 million tons, of which about 9 percent is classified as measured and indicated and 91 percent is classified as inferred. The reserves for the Niblock area are estimated to be about 14 million tons, of which about 46 percent is classified as measured and indicated and 54 percent is classified as inferred. The reserve figures for these two areas are shown by township and bed in tables 13 and 15, on pages 49 and 51 respectively.

TAYLOR AREA

Geographic and Geologic Setting

The Taylor area is about 8 miles southeast of the Cedar Mountain area. The coal-bearing rocks in the Taylor area overlie Eocene volcanic rocks (Warren and others, 1945) and are cut by several igneous dikes and sills. These coal-bearing rocks occur in a southeast-plunging syncline with steeply dipping limbs. Throughout most of the area the coal beds dip about 70°. To the southeast these rocks are covered by glacial drift.

Coal Beds

At least ten coal beds occur in the Taylor area (fig. 19). Data were sufficient so that reserves could be estimated for five of these beds.

Physical and chemical properties.—The coals of the Taylor area range in rank from high-volatile B bituminous to high-volatile A bituminous. The ash content of the coal in the Taylor area ranges from 10.1 to 24.9 percent and averages about 16 percent. The moisture content ranges from 4.3 to 6.4 percent and averages about 5 percent. The sulfur content ranges from 0.4 to to 1.9 percent and averages 1 percent. Analyses of these coals are shown in table 10.

Coal Mining

The mines in the Taylor area were first opened in 1891 (Evans, 1912, p. 134). Production figures are not available for the period prior to 1905, but from that date to 1940, the last year of recorded production, about 640 thousand tons of coal was mined.

Summary of Reserves

The reserves of coal remaining in the ground in the Taylor area are estimated to total about 19 million tons. Approximately 15 percent of this total is classified as measured and indicated, and 85 percent is classified as inferred. Reserve figures by township and bed are shown in table 16, on page 51.

GREEN RIVER DISTRICT

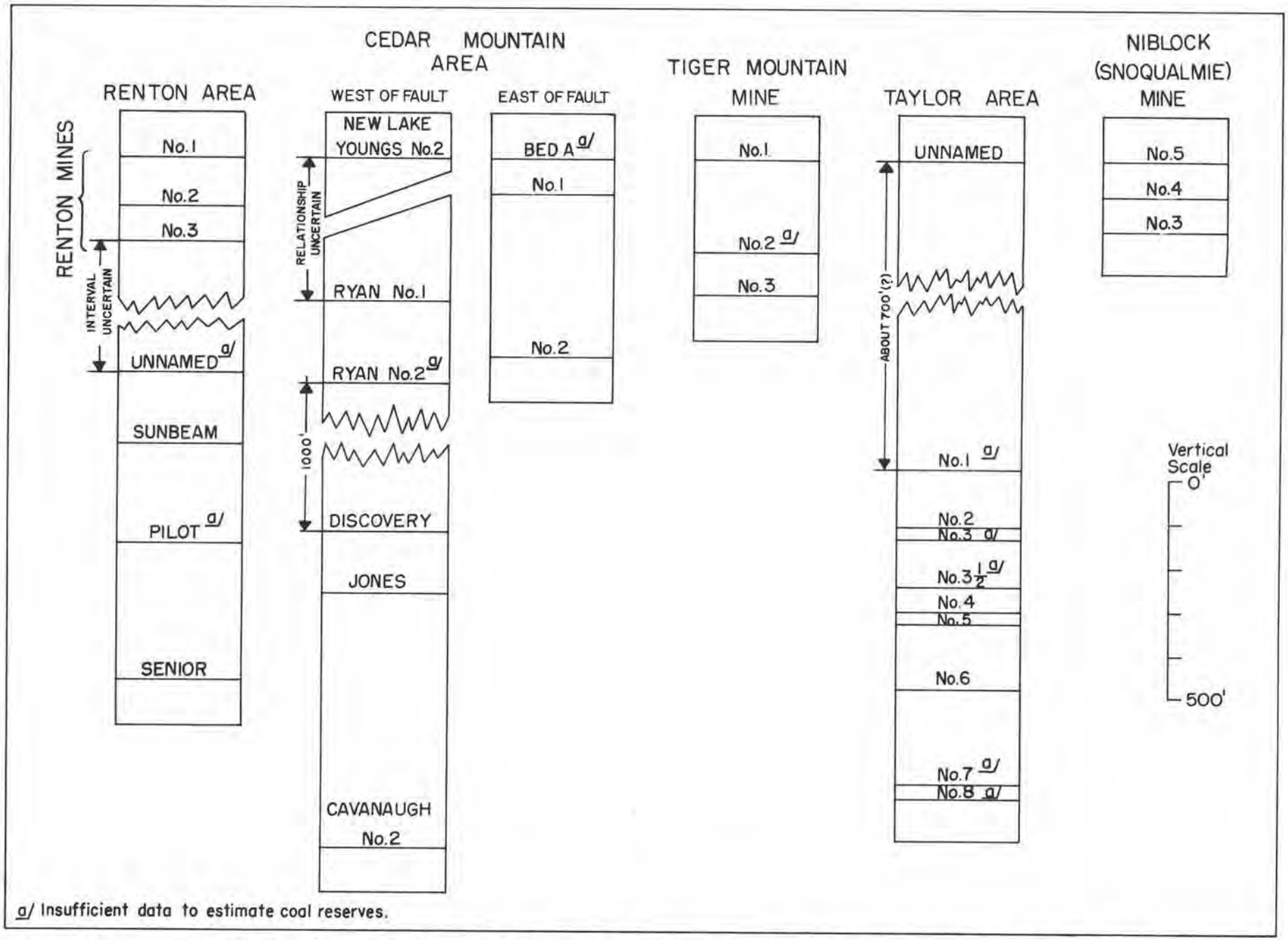
Geographic and Geologic Setting

The Green River district is about 20 miles southeast of Seattle in the south-central part of King County (fig. 2). The coal-bearing

Table 10.—Averages of analyses (as-received basis) of coal samples from the Renton, Cedar Mountain, Tiger Mountain, Taylor, and Niblock areas, King County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Area	Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
		M	VM	FC	Ash			
Renton	No. 1	16.6	32.2	39.9	11.2	0.5	9,546	3
	No. 2	15.0	32.6	38.6	13.8	.6	9,470	2
	No. 3	15.4	34.6	41.5	8.4	.5	10,277	8
	Springbrook	14.1	33.5	46.9	5.6	.4	11,060	1
	Sunbeam	14.9	36.0	42.3	6.8	1.0	10,823	3
	Newenham	13.2	37.4	43.1	6.3	1.6	11,130	1
Cedar Mountain	Discovery	10.1	34.4	37.1	18.3	.5	9,755	2
	Jones	10.7	36.1	42.2	10.9	.4	10,700	13
	Cavanaugh No. 2	9.7	40.1	43.7	6.5	.9	11,800	1
Tiger Mountain	No. 1	19.2	32.5	35.9	12.4	.2	8,810	1
Taylor	No. 2	6.4	36.7	41.4	15.5	1.3	11,140	1
	No. 3	4.9	36.1	34.1	24.9	1.9	10,000	1
	No. 4	4.8	36.5	48.6	10.1	.8	12,410	1
	No. 5	4.3	35.6	45.2	14.9	.7	11,870	1
	No. 6	5.6	36.0	44.0	14.4	.9	11,550	1
	Unnamed	6.0	34.2	42.9	16.9	.4	11,000	1
Niblock	No. 5	4.9	27.3	43.5	24.3	1.5	10,580	1
	No. 4	6.1	22.7	58.8	12.4	.9	10,710	1
	No. 3	8.2	27.2	53.9	10.7	.5	12,440	1



a/ Insufficient data to estimate coal reserves.

Figure 19. Generalized columnar sections of the Renton, Cedar Mountain, Tiger Mountain, Taylor, and Niblock areas

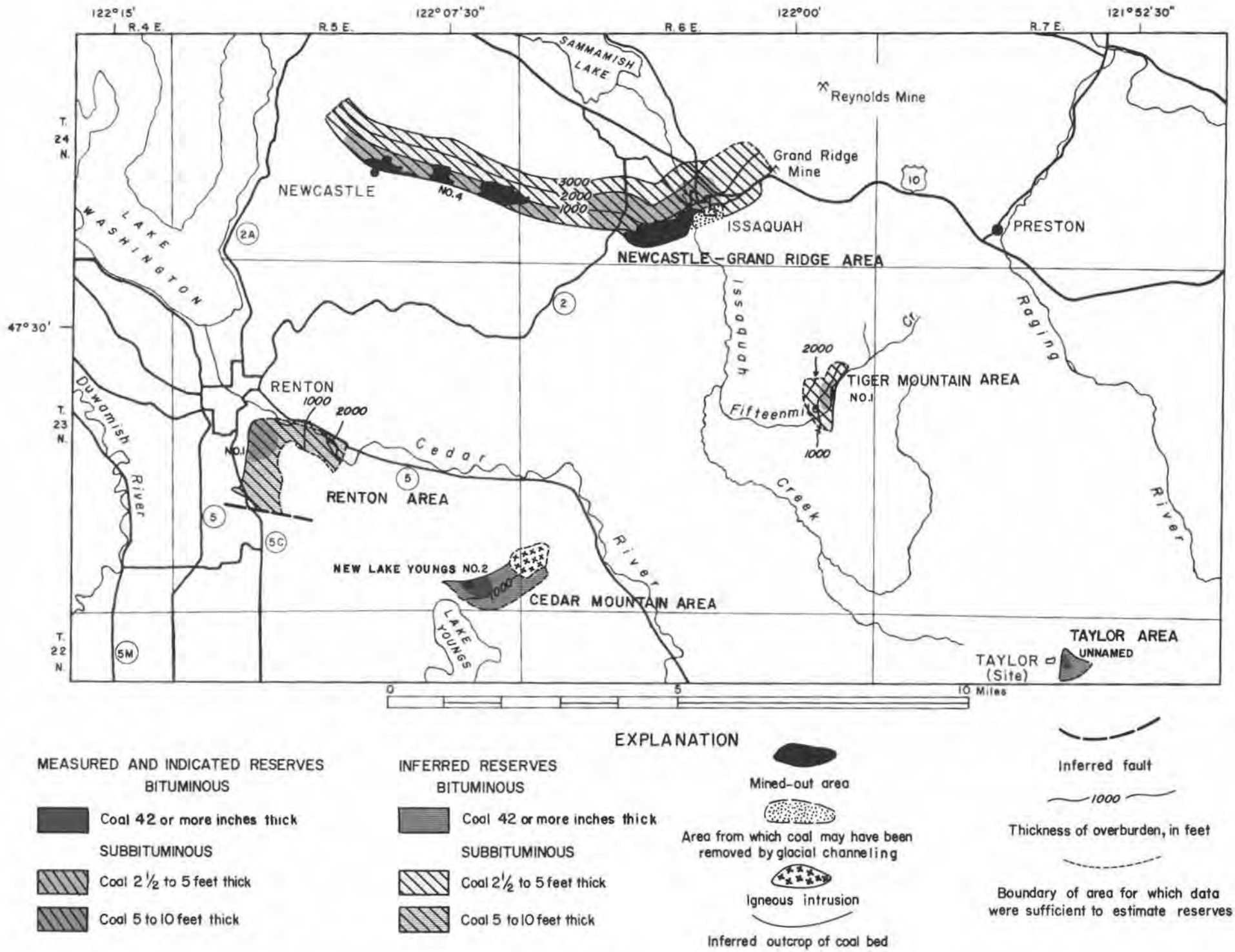


FIGURE 20. GENERALIZED MAP OF THE RENTON NO.1, NEWCASTLE NO. 4, NEW LAKE YOUNGS NO.2, TIGER MOUNTAIN NO.1, AND TAYLOR UNNAMED COAL BEDS

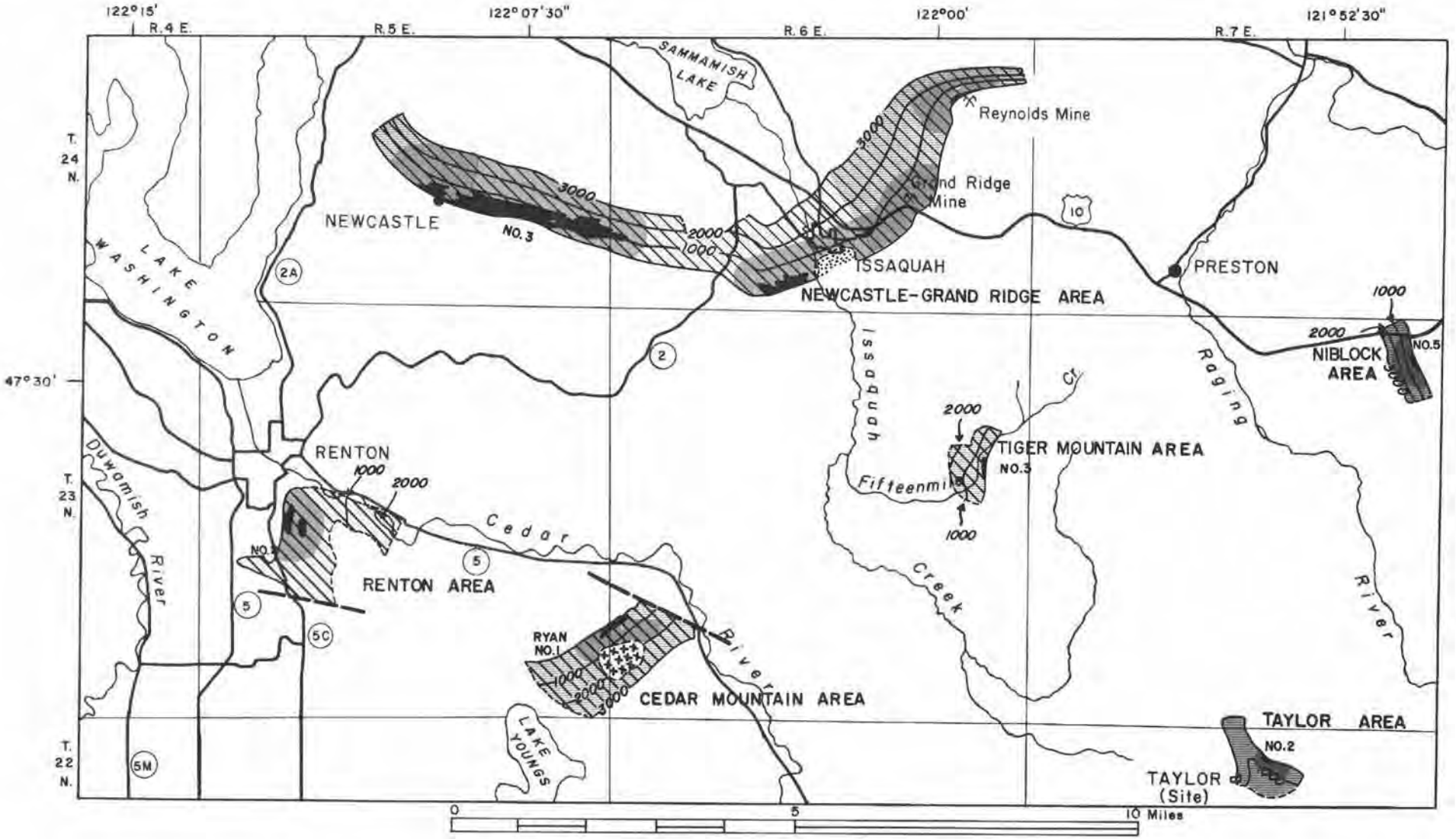
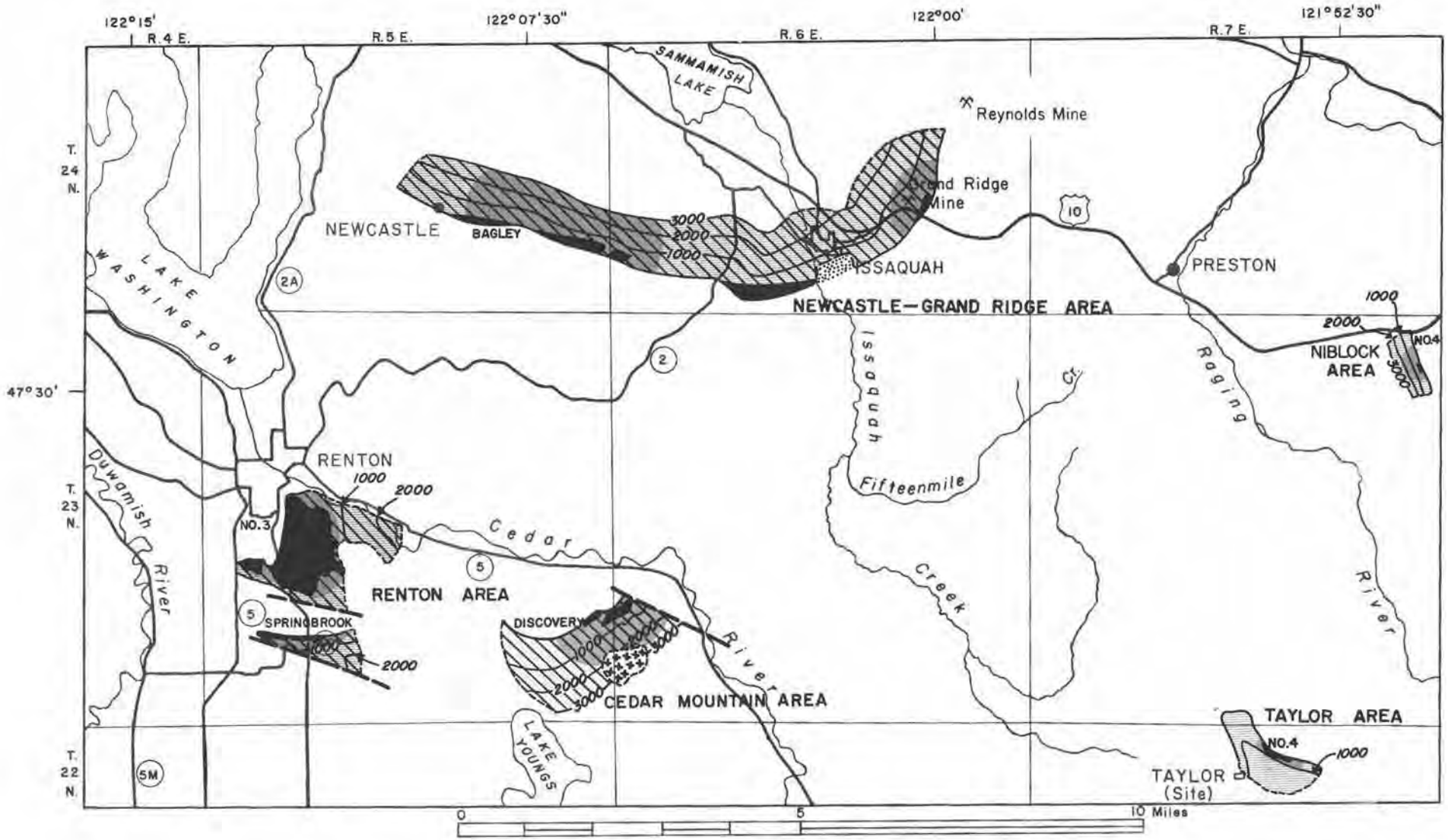


FIGURE 21. GENERALIZED MAP OF THE RENTON NO.2, NEWCASTLE NO.3, RYAN NO.1, NIBLOCK NO.5, TIGER MOUNTAIN NO.3, AND TAYLOR NO.2 COAL BEDS



EXPLANATION

MEASURED AND INDICATED RESERVES
BITUMINOUS

- Coal 28 to 42 inches thick

SUBBITUMINOUS

- Coal 2½ to 5 feet thick
- Coal 5 to 10 feet thick

INFERRED RESERVES
BITUMINOUS

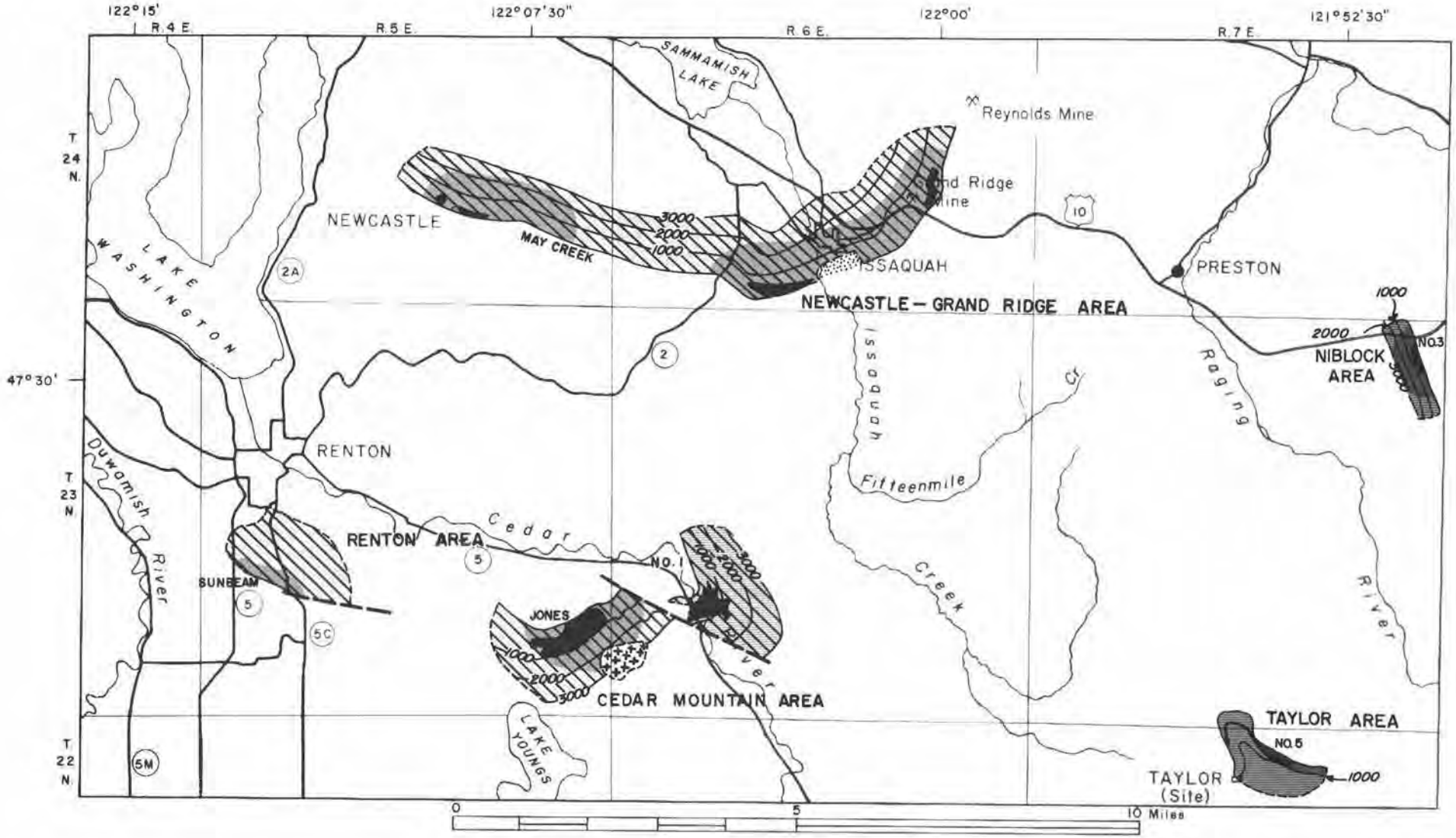
- Coal 28 to 42 inches thick

SUBBITUMINOUS

- Coal 2½ to 5 feet thick
- Coal 5 to 10 feet thick

- Mined-out area
- Area from which coal may have been removed by glacial channeling
- Igneous intrusion
- Inferred outcrop of coal bed
- Inferred fault
- 1000 — Thickness of overburden, in feet
- Boundary of area for which data were sufficient to estimate reserves

FIGURE 22. GENERALIZED MAP OF THE RENTON NO.3, SPRINGBROOK, BAGLEY, NIBLOCK NO.4, DISCOVERY, AND TAYLOR NO.4 COAL BEDS



EXPLANATION

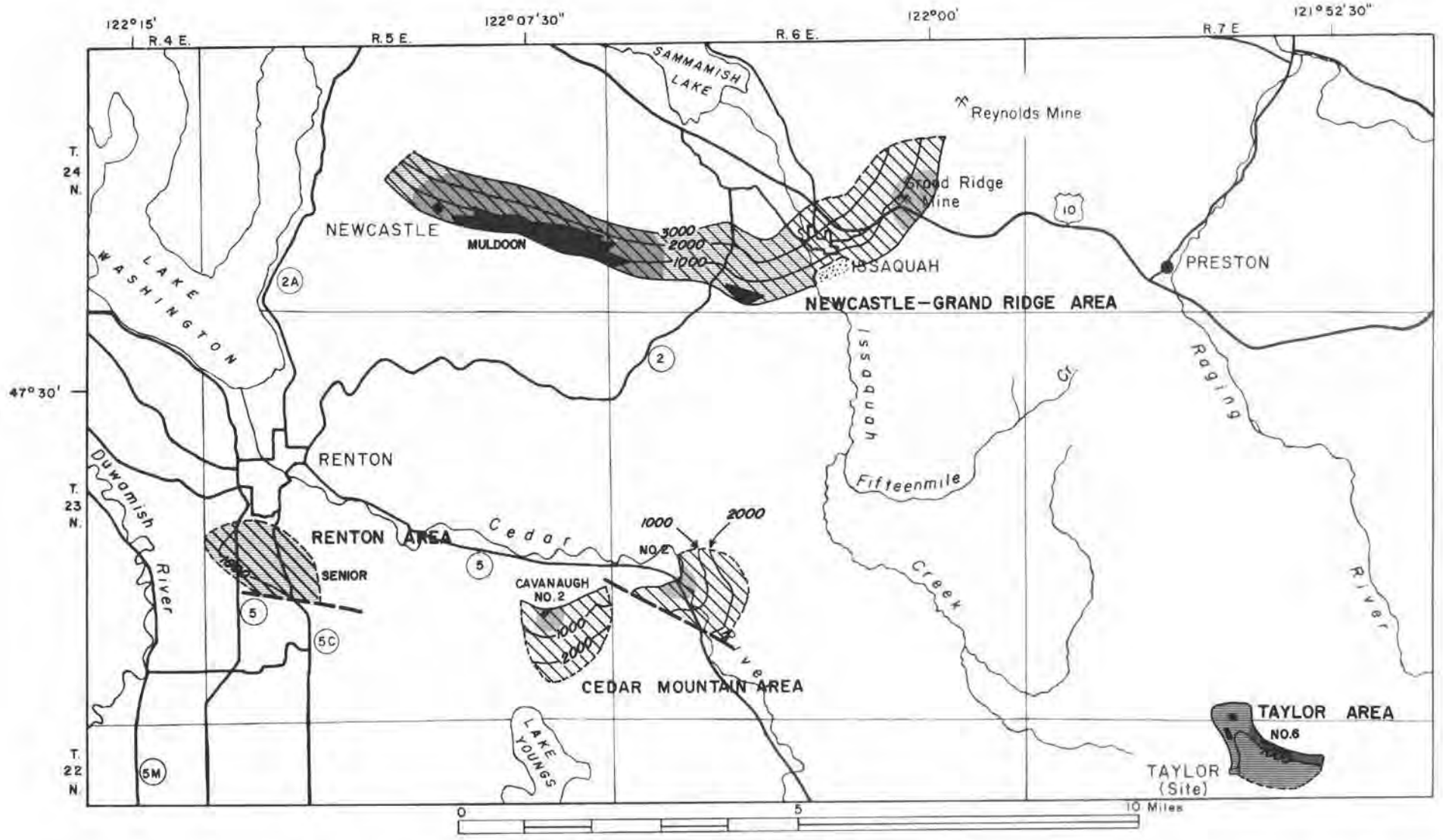
MEASURED AND INDICATED RESERVES
BITUMINOUS
Coal 42 or more inches thick
SUBBITUMINOUS
Coal 2½ to 5 feet thick

INFERRED RESERVES
BITUMINOUS
Coal 42 or more inches thick
SUBBITUMINOUS
Coal 2½ to 5 feet thick
Coal 5 to 10 feet thick

Mined-out area
Area from which coal may have been removed by glacial channeling
Igneous intrusion
Inferred outcrop of coal bed

Inferred fault
1000
Thickness of overburden, in feet
Boundary of area for which data were sufficient to estimate reserves

FIGURE 23. GENERALIZED MAP OF THE MAY CREEK, SUNBEAM, JONES, CEDAR MOUNTAIN NO.1, NIBLOCK NO.3, AND TAYLOR NO.5 COAL BEDS



EXPLANATION

MEASURED AND INDICATED RESERVES
BITUMINOUS
Coal 42 or more inches thick
SUBBITUMINOUS
Coal 2½ to 5 feet thick
Coal 5 to 10 feet thick

INFERRED RESERVES
BITUMINOUS
Coal 42 or more inches thick
SUBBITUMINOUS
Coal 2½ to 5 feet thick
Coal 5 to 10 feet thick

Mined-out area

Area from which coal may have been removed by glacial channeling

Inferred outcrop of coal bed

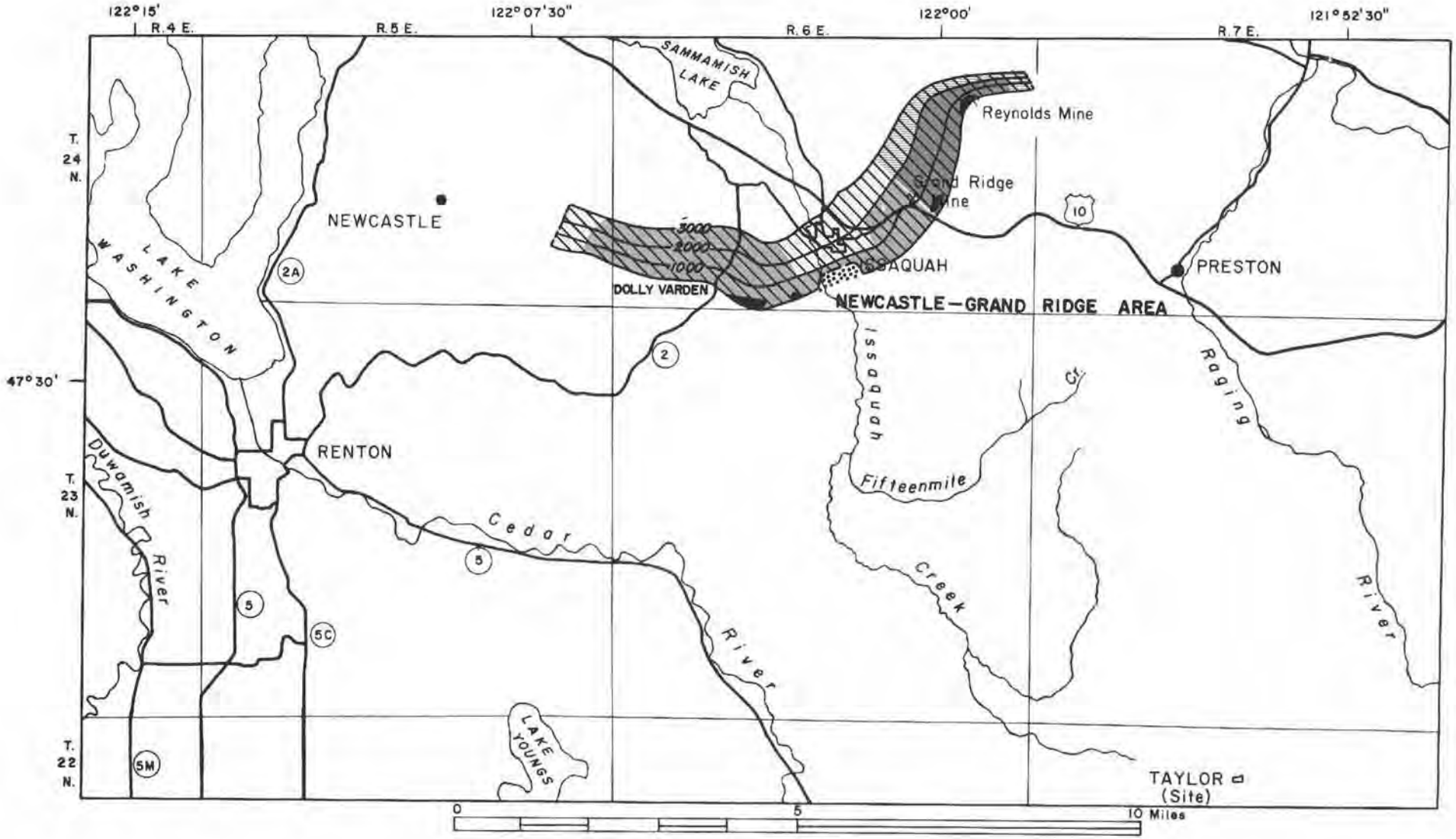
Inferred fault

1000

Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

FIGURE 24. GENERALIZED MAP OF THE MULDOON, SENIOR, TAYLOR NO. 6, CAVANAUGH NO. 2, AND CEDAR MOUNTAIN NO. 2 COAL BEDS



EXPLANATION

MEASURED AND INDICATED RESERVES

SUBBITUMINOUS

Coal 2½ to 5 feet thick

Coal 5 to 10 feet thick

INFERRED RESERVES

SUBBITUMINOUS

Coal 2½ to 5 feet thick

Coal 5 to 10 feet thick

Mined-out area

Area from which coal may have been removed by glacial channeling

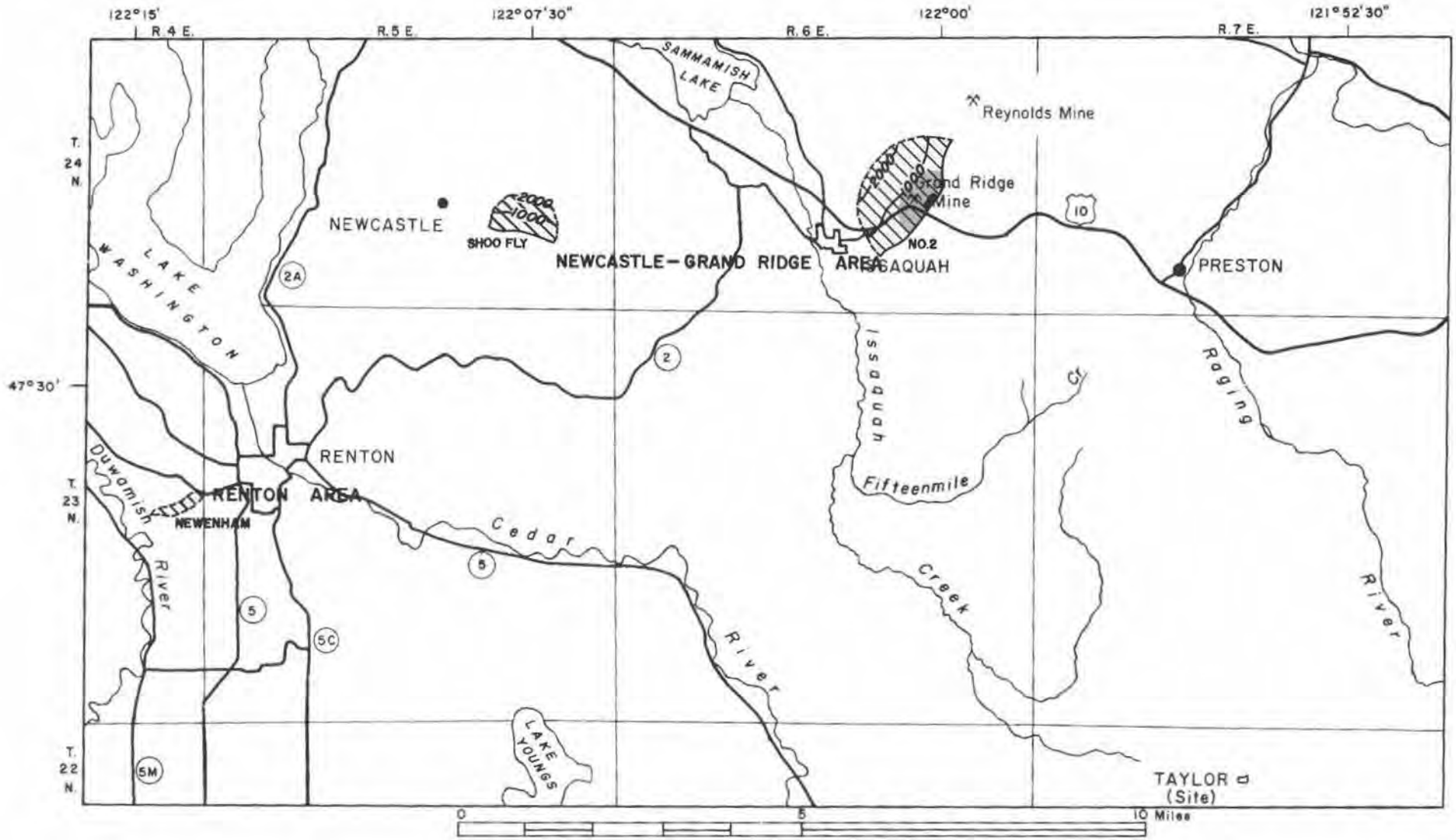
Inferred outcrop of coal bed

1000

Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

FIGURE 25. GENERALIZED MAP OF THE DOLLY VARDEN COAL BED



EXPLANATION

COAL RESERVES

SUBBITUMINOUS

Measured and indicated

Coal 2 1/2 to 5 feet thick

Inferred

Coal 2 1/2 to 5 feet thick

Mined-out area

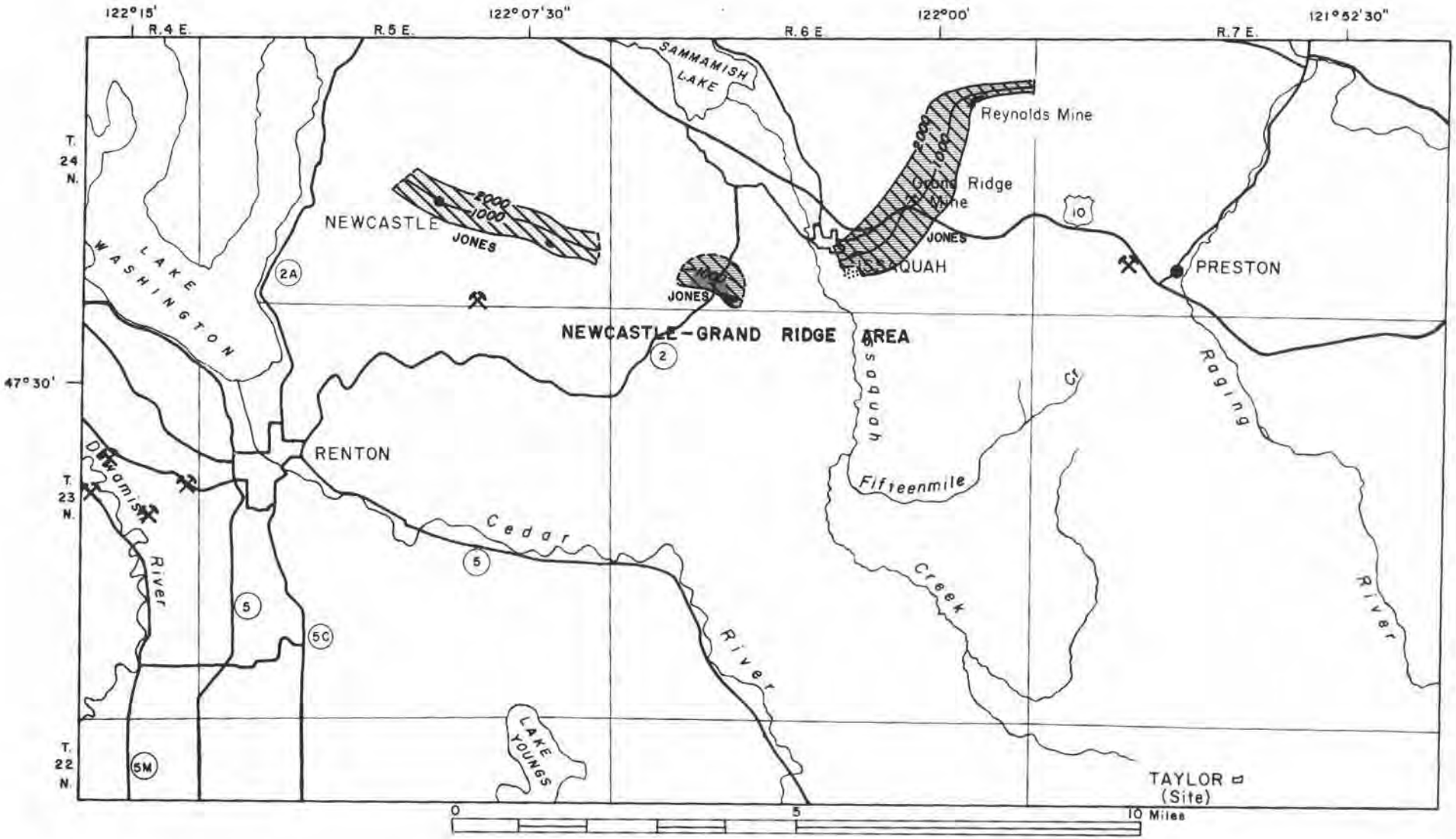
Inferred outcrop of coal bed

1000

Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

FIGURE 26 . GENERALIZED MAP OF THE NEWENHAM, SHOO FLY, AND GRAND RIDGE NO. 2 COAL BEDS



EXPLANATION

MEASURED AND INDICATED RESERVES

SUBBITUMINOUS

Coal 5 to 10 feet thick

INFERRED RESERVES

SUBBITUMINOUS

Coal 2½ to 5 feet thick

Coal 5 to 10 feet thick

Mined-out area

Area from which coal may have been removed by glacial channeling

Inferred outcrop of coal bed

1000

Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

Mine or prospect

FIGURE 27. GENERALIZED MAP OF THE JONES COAL BED

Table 11.— Estimated remaining reserves of coal in the Newcastle-Grand Ridge area, King County, Washington as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 24 N., R. 5 E.													
No. 4	0-1,000	3.59	-----	-----	3.59	0.60	-----	-----	0.60	4.19	-----	-----	4.19
	1,000-2,000	4.03	-----	-----	4.03	.40	-----	-----	.40	4.43	-----	-----	4.43
	2,000-3,000	-----	-----	-----	-----	4.31	-----	-----	4.31	4.31	-----	-----	4.31
Bed total		7.62	-----	-----	7.62	5.31	-----	-----	5.31	12.93	-----	-----	12.93
Muldoon	0-1,000	-----	1.49	-----	1.49	-----	0.80	-----	0.80	-----	2.29	-----	2.29
	1,000-2,000	-----	4.37	-----	4.37	-----	.82	-----	.82	-----	5.19	-----	5.19
	2,000-3,000	-----	3.77	-----	3.77	-----	1.12	-----	1.12	-----	4.89	-----	4.89
Bed total		-----	9.63	-----	9.63	-----	2.74	-----	2.74	-----	12.37	-----	12.37
No. 3	0-1,000	1.17	2.31	-----	3.48	-----	0.77	-----	0.77	1.17	3.08	-----	4.25
	1,000-2,000	2.32	2.54	-----	4.86	-----	.60	-----	.60	2.32	3.14	-----	5.46
	2,000-3,000	2.24	1.40	-----	3.64	-----	.70	-----	.70	2.24	2.10	-----	4.34
Bed total		5.73	6.25	-----	11.98	-----	2.07	-----	2.07	5.73	8.32	-----	14.05
Bagley	0-1,000	-----	4.52	-----	4.52	-----	1.32	-----	1.32	-----	5.84	-----	5.84
	1,000-2,000	-----	6.04	-----	6.04	-----	1.72	-----	1.72	-----	7.76	-----	7.76
	2,000-3,000	-----	4.84	-----	4.84	-----	1.25	-----	1.25	-----	6.09	-----	6.09
Bed total		-----	15.40	-----	15.40	-----	4.29	-----	4.29	-----	19.69	-----	19.69
Maycreek	0-1,000	3.76	-----	-----	3.76	1.59	-----	-----	1.59	5.35	-----	-----	5.35
	1,000-2,000	2.61	-----	-----	2.61	1.61	-----	-----	1.61	4.22	-----	-----	4.22
	2,000-3,000	.19	-----	-----	.19	3.28	-----	-----	3.28	3.47	-----	-----	3.47
Bed total		6.56	-----	-----	6.56	6.48	-----	-----	6.48	13.04	-----	-----	13.04
Shoo Fly	0-1,000	-----	-----	-----	-----	1.19	-----	-----	1.19	1.19	-----	-----	1.19
	1,000-2,000	-----	-----	-----	-----	.77	-----	-----	.77	.77	-----	-----	.77
Bed total		-----	-----	-----	-----	1.96	-----	-----	1.96	1.96	-----	-----	1.96
Dolly Varden	0-1,000	0.32	-----	-----	0.32	0.38	-----	-----	0.38	0.70	-----	-----	0.70
	1,000-2,000	.28	-----	-----	.28	.47	-----	-----	.47	.75	-----	-----	.75
	2,000-3,000	.10	-----	-----	.10	.50	-----	-----	.50	.60	-----	-----	.60
Bed total		0.70	-----	-----	0.70	1.35	-----	-----	1.35	2.05	-----	-----	2.05
Jones	0-1,000	-----	-----	-----	-----	4.40	-----	-----	4.40	4.40	-----	-----	4.40
	1,000-2,000	-----	-----	-----	-----	4.02	-----	-----	4.02	4.02	-----	-----	4.02
Bed total		-----	-----	-----	-----	8.42	-----	-----	8.42	8.42	-----	-----	8.42
Township total		20.61	31.28	-----	51.89	23.52	9.10	-----	32.62	44.13	40.38	-----	84.51
T. 24 N., R. 6 E.													
No. 4	0-1,000	3.13	-----	-----	3.13	3.21	-----	-----	3.21	6.34	-----	-----	6.34
	1,000-2,000	6.14	-----	-----	6.14	3.09	-----	-----	3.09	9.23	-----	-----	9.23
	2,000-3,000	-----	-----	-----	-----	5.41	-----	-----	5.41	5.41	-----	-----	5.41
Bed total		9.27	-----	-----	9.27	11.71	-----	-----	11.71	20.98	-----	-----	20.98
No. 3	0-1,000	2.06	8.19	-----	10.25	2.20	1.92	-----	4.12	4.26	10.11	-----	14.37
	1,000-2,000	2.12	3.98	-----	6.10	3.85	5.73	-----	9.58	5.97	9.71	-----	15.68
	2,000-3,000	.37	-----	-----	.37	3.86	8.38	-----	12.24	4.23	8.38	-----	12.61
Bed total		4.55	12.17	-----	16.72	9.91	16.03	-----	25.94	14.46	28.20	-----	42.66
Bagley	0-1,000	-----	4.83	-----	4.83	-----	6.47	-----	6.47	-----	11.30	-----	11.30
	1,000-2,000	-----	2.74	-----	2.74	-----	17.56	-----	17.56	-----	20.30	-----	20.30
	2,000-3,000	-----	1.49	-----	1.49	-----	7.99	-----	7.99	-----	9.48	-----	9.48
Bed total		-----	9.06	-----	9.06	-----	32.02	-----	32.02	-----	41.08	-----	41.08
No. 2	0-1,000	1.61	-----	-----	1.61	1.89	-----	-----	1.89	3.50	-----	-----	3.50
	1,000-2,000	-----	-----	-----	-----	3.09	-----	-----	3.09	3.09	-----	-----	3.09
	2,000-3,000	-----	-----	-----	-----	.34	-----	-----	.34	.34	-----	-----	.34
Bed total		1.61	-----	-----	1.61	5.32	-----	-----	5.32	6.93	-----	-----	6.93
May Creek	0-1,000	5.48	-----	-----	5.48	2.63	-----	-----	2.63	8.11	-----	-----	8.11
	1,000-2,000	3.38	-----	-----	3.38	6.27	-----	-----	6.27	9.65	-----	-----	9.65
	2,000-3,000	.09	-----	-----	.09	5.98	-----	-----	5.98	6.07	-----	-----	6.07
Bed total		8.95	-----	-----	8.95	14.88	-----	-----	14.88	23.83	-----	-----	23.83
Muldoon	0-1,000	1.32	1.18	-----	2.50	2.19	4.20	-----	6.39	3.51	5.38	-----	8.89
	1,000-2,000	.14	1.84	-----	1.98	4.66	4.27	-----	8.93	4.80	6.11	-----	10.91
	2,000-3,000	-----	1.17	-----	1.17	2.11	3.94	-----	6.05	2.11	5.11	-----	7.22
Bed total		1.46	4.19	-----	5.65	8.96	12.41	-----	21.37	10.42	16.60	-----	27.02
Dolly Varden	0-1,000	5.67	4.00	-----	9.67	-----	0.60	-----	0.60	5.67	4.60	-----	10.27
	1,000-2,000	5.23	5.43	-----	10.66	1.80	.64	-----	2.44	7.03	6.07	-----	13.10
	2,000-3,000	3.50	-----	-----	3.50	3.91	5.11	-----	9.02	7.41	5.11	-----	12.52
Bed total		14.40	9.43	-----	23.83	5.71	6.35	-----	12.06	20.11	15.78	-----	35.89
Jones	0-1,000	-----	0.92	-----	0.92	-----	12.99	-----	12.99	-----	13.91	-----	13.91
	1,000-2,000	-----	-----	-----	-----	-----	12.79	-----	12.79	-----	12.79	-----	12.79
Bed total		-----	0.92	-----	0.92	-----	25.78	-----	25.78	-----	26.70	-----	26.70
Township total		40.24	35.77	-----	76.01	56.49	92.59	-----	149.08	96.73	128.36	-----	225.09
Grand total		60.85	67.05	-----	127.90	80.01	101.69	-----	181.70	140.86	168.74	-----	309.60

Table 12.—Estimated remaining reserves of coal in the Renton area, King County, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 23 N., R. 4 E.													
Newenham	0-1,000	-----	-----	-----	-----	0.57	-----	-----	0.57	0.57	-----	-----	0.57
T. 23 N., R. 5 E.													
No. 1	0-1,000	-----	1.74	-----	1.74	-----	5.49	-----	5.49	-----	7.23	-----	7.23
	1,000-2,000	-----	-----	-----	-----	-----	1.74	-----	1.74	-----	1.74	-----	1.74
	2,000-3,000	-----	-----	-----	-----	-----	.53	-----	.53	-----	.53	-----	.53
Bed total		-----	1.74	-----	1.74	-----	7.76	-----	7.76	-----	9.50	-----	9.50
No. 2	0-1,000	2.69	-----	-----	2.69	4.54	-----	-----	4.54	7.23	-----	-----	7.23
	1,000-2,000	-----	-----	-----	-----	1.73	-----	-----	1.73	1.73	-----	-----	1.73
	2,000-3,000	-----	-----	-----	-----	.58	-----	-----	.58	.58	-----	-----	.58
Bed total		2.69	-----	-----	2.69	6.85	-----	-----	6.85	9.54	-----	-----	9.54
No. 3	0-1,000	-----	2.74	-----	2.74	-----	3.02	-----	3.02	-----	5.76	-----	5.76
	1,000-2,000	-----	-----	-----	-----	-----	2.58	-----	2.58	-----	2.58	-----	2.58
	2,000-3,000	-----	-----	-----	-----	-----	.95	-----	.95	-----	.95	-----	.95
Bed total		-----	2.74	-----	2.74	-----	6.55	-----	6.55	-----	9.29	-----	9.29
Springbrook	0-1,000	0.08	1.99	-----	2.07	-----	0.54	-----	0.54	0.08	2.53	-----	2.61
	1,000-2,000	-----	-----	-----	-----	-----	1.71	-----	1.71	-----	1.71	-----	1.71
	2,000-3,000	-----	-----	-----	-----	-----	.48	-----	.48	-----	.48	-----	.48
Bed total		0.08	1.99	-----	2.07	-----	2.73	-----	2.73	0.08	4.72	-----	4.80
Sunbeam	0-1,000	0.81	-----	-----	0.81	6.76	-----	-----	6.76	7.57	-----	-----	7.57
Senior	0-1,000	-----	-----	-----	-----	-----	1.74	-----	1.74	-----	1.74	-----	1.74
	1,000-2,000	-----	-----	-----	-----	-----	7.34	-----	7.34	-----	7.34	-----	7.34
Bed total		-----	-----	-----	-----	-----	9.08	-----	9.08	-----	9.08	-----	9.08
Township total		3.58	6.47	-----	10.05	13.61	26.12	-----	39.73	17.19	32.59	-----	49.78
All townships													
Grand total		3.58	6.47	-----	10.05	14.18	26.12	-----	40.30	17.76	32.59	-----	50.35

Table 13.-- Estimated remaining reserves of coal in the Tiger Mountain area, King County, Washington as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 23 N., R. 6 E.													
No. 1	0-1,000	0.60	------	------	0.60	1.01	-----	------	1.01	1.61	------	------	1.61
	1,000-2,000	.21	------	------	.21	1.20	-----	------	1.20	1.41	------	------	1.41
	2,000-3,000	------	------	------	------	.26	-----	------	.26	.26	------	------	.26
Bed total		0.81	------	------	0.81	2.47	-----	------	2.47	3.28	------	------	3.28
No. 3	0-1,000	------	------	------	------	------	2.91	------	2.91	------	2.91	------	2.91
	1,000-2,000	------	------	------	------	------	2.38	------	2.38	------	2.38	------	2.38
	2,000-3,000	------	------	------	------	------	.44	------	.44	------	.44	------	.44
Bed total		------	------	------	------	------	5.73	------	5.73	------	5.73	------	5.73
Township total		0.81	------	------	0.81	2.47	5.73	------	8.20	3.28	5.73	------	9.01

Table 14.—Estimated remaining reserves of coal in the Cedar Mountain area, King County, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 23 N., R. 5 E.													
Cavanaugh No. 2	0-1,000	0.42	-----	-----	0.42	1.43	-----	-----	1.43	1.85	-----	-----	1.85
	1,000-2,000	-----	-----	-----	-----	2.10	-----	-----	2.10	2.10	-----	-----	2.10
	2,000-3,000	-----	-----	-----	-----	1.28	-----	-----	1.28	1.28	-----	-----	1.28
Bed total		0.42	-----	-----	0.42	4.81	-----	-----	4.81	5.23	-----	-----	5.23
Jones	0-1,000	0.65	-----	-----	0.65	1.71	-----	-----	1.71	2.36	-----	-----	2.36
	1,000-2,000	1.13	-----	-----	1.13	1.26	-----	-----	1.26	2.39	-----	-----	2.39
	2,000-3,000	.28	-----	-----	.28	1.63	-----	-----	1.63	1.91	-----	-----	1.91
Bed total		2.06	-----	-----	2.06	4.60	-----	-----	4.60	6.66	-----	-----	6.66
Discovery	0-1,000	1.70	-----	-----	1.70	2.38	-----	-----	2.38	4.08	-----	-----	4.08
	1,000-2,000	.92	-----	-----	.92	2.24	-----	-----	2.24	3.16	-----	-----	3.16
	2,000-3,000	-----	-----	-----	-----	1.95	-----	-----	1.95	1.95	-----	-----	1.95
Bed total		2.62	-----	-----	2.62	6.57	-----	-----	6.57	9.19	-----	-----	9.19
Ryan No. 1	0-1,000	-----	1.65	-----	1.65	-----	2.53	-----	2.53	-----	4.18	-----	4.18
	1,000-2,000	-----	-----	-----	-----	-----	2.52	-----	2.52	-----	2.52	-----	2.52
	2,000-3,000	-----	-----	-----	-----	-----	2.01	-----	2.01	-----	2.01	-----	2.01
Bed total		-----	1.65	-----	1.65	-----	7.06	-----	7.06	-----	8.71	-----	8.71
New Lake Youngs No. 2*	0-1,000	-----	-----	0.47	0.47	-----	-----	0.97	0.97	-----	-----	1.44	1.44
	1,000-2,000	-----	-----	-----	-----	-----	-----	1.05	1.05	-----	-----	1.05	1.05
Bed total		-----	-----	0.47	0.47	-----	-----	2.02	2.02	-----	-----	2.49	2.49
Township total		5.10	1.65	0.47	7.22	15.98	7.06	2.02	25.06	21.08	8.71	2.49	32.28
T. 23 N., R. 6 E.													
Cedar Mtn. No. 2	0-1,000	0.80	-----	-----	0.80	2.01	-----	-----	2.01	2.81	-----	-----	2.81
	1,000-2,000	-----	-----	-----	-----	2.78	-----	-----	2.78	2.78	-----	-----	2.78
	2,000-3,000	-----	-----	-----	-----	1.89	-----	-----	1.89	1.89	-----	-----	1.89
Bed total		0.80	-----	-----	0.80	6.68	-----	-----	6.68	7.48	-----	-----	7.48
Jones	0-1,000	0.48	-----	-----	0.48	-----	-----	-----	-----	0.48	-----	-----	0.48
	1,000-2,000	.55	-----	-----	.55	0.22	-----	-----	0.22	.77	-----	-----	.77
	2,000-3,000	.30	-----	-----	.30	.74	-----	-----	.74	1.04	-----	-----	1.04
Bed total		1.33	-----	-----	1.33	0.96	-----	-----	0.96	2.29	-----	-----	2.29
Cedar Mtn. No. 1	0-1,000	-----	-----	-----	-----	-----	2.72	-----	2.72	-----	2.72	-----	2.72
	1,000-2,000	-----	-----	-----	-----	-----	6.20	-----	6.20	-----	6.20	-----	6.20
	2,000-3,000	-----	-----	-----	-----	-----	4.49	-----	4.49	-----	4.49	-----	4.49
Bed total		-----	-----	-----	-----	-----	13.41	-----	13.41	-----	13.41	-----	13.41
Discovery	0-1,000	0.55	-----	-----	0.55	-----	-----	-----	-----	0.55	-----	-----	0.55
	1,000-2,000	1.12	-----	-----	1.12	-----	-----	-----	-----	1.12	-----	-----	1.12
	2,000-3,000	.63	-----	-----	.63	0.51	-----	-----	0.51	1.14	-----	-----	1.14
Bed total		2.30	-----	-----	2.30	0.51	-----	-----	0.51	2.81	-----	-----	2.81
Ryan No. 1	0-1,000	-----	1.08	-----	1.08	-----	0.92	-----	0.92	-----	2.00	-----	2.00
	1,000-2,000	-----	1.70	-----	1.70	-----	.63	-----	.63	-----	2.33	-----	2.33
	2,000-3,000	-----	-----	-----	-----	-----	3.77	-----	3.77	-----	3.77	-----	3.77
Bed total		-----	2.78	-----	2.78	-----	5.32	-----	5.32	-----	8.10	-----	8.10
New Lake Youngs No. 2*	1,000-2,000	-----	-----	-----	-----	-----	-----	0.39	0.39	-----	-----	0.39	0.39
Township total		4.43	2.78	-----	7.21	8.15	18.73	0.39	27.27	12.58	21.51	0.39	34.48
Grand total		9.53	4.43	0.47	14.43	24.13	25.79	2.41	52.33	33.66	30.22	2.88	66.76

*Bituminous coal. Coal 42 or more inches thick is shown in the 10 or more feet thickness category.

Table 15.-- Estimated remaining reserves of coal in the Niblock area, King County, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 23 N., R. 7 E.													
No. 5	0-1,000	------	------	1.03	1.03	------	------	0.71	0.71	------	------	1.74	1.74
	1,000-2,000	------	------	.98	.98	------	------	.83	.83	------	------	1.81	1.81
	2,000-3,000	------	------	.34	.34	------	------	1.37	1.37	------	------	1.71	1.71
Bed total		------	------	2.35	2.35	------	------	2.91	2.91	------	------	5.26	5.26
No. 4	0-1,000	------	0.50	------	0.50	------	0.45	------	0.45	------	0.95	------	0.95
	1,000-2,000	------	.41	------	.41	------	.50	------	.50	------	.91	------	.91
	2,000-3,000	------	------	------	------	------	.83	------	.83	------	.83	------	.83
Bed total		------	0.91	------	0.91	------	1.78	------	1.78	------	2.69	------	2.69
No. 3	0-1,000	------	------	1.37	1.37	------	------	0.55	0.55	------	------	1.92	1.92
	1,000-2,000	------	------	1.50	1.50	------	------	.71	.71	------	------	2.21	2.21
	2,000-3,000	------	------	.53	.53	------	------	1.57	1.57	------	------	2.10	2.10
Bed total		------	------	3.40	3.40	------	------	2.83	2.83	------	------	6.23	6.23
Township total		------	0.91	5.75	6.66	------	1.78	5.74	7.52	------	2.69	11.49	14.18

Table 16.-- Estimated remaining reserves of coal in the Taylor area, King County, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 22 N., R. 7 E.													
Unnamed	0-1,000	------	------	0.27	0.27	------	------	1.22	1.22	------	------	1.49	1.49
No. 2	0-1,000	------	------	0.62	0.62	------	------	1.49	1.49	------	------	2.11	2.11
	1,000-2,000	------	------	------	------	------	------	1.20	1.20	------	------	1.20	1.20
Bed total		------	------	0.62	0.62	------	------	2.69	2.69	------	------	3.31	3.31
No. 4	0-1,000	------	0.45	------	0.45	------	0.94	------	0.94	------	1.39	------	1.39
	1,000-2,000	------	------	------	------	------	1.35	------	1.35	------	1.35	------	1.35
Bed total		------	0.45	------	0.45	------	2.29	------	2.29	------	2.74	------	2.74
No. 5	0-1,000	------	------	0.43	0.43	------	------	1.42	1.42	------	------	1.85	1.85
	1,000-2,000	------	------	------	------	------	------	2.45	2.45	------	------	2.45	2.45
Bed total		------	------	0.43	0.43	------	------	3.87	3.87	------	------	4.30	4.30
No. 6	0-1,000	------	------	0.88	0.88	------	------	1.64	1.64	------	------	2.52	2.52
	1,000-2,000	------	------	------	------	------	------	2.76	2.76	------	------	2.76	2.76
Bed total		------	------	0.88	0.88	------	------	4.40	4.40	------	------	5.28	5.28
Township total		------	0.45	2.20	2.65	------	2.29	12.18	14.47	------	2.74	14.38	17.12
T. 23 N., R. 7 E.													
No. 2	0-1,000	------	------	------	------	------	------	0.27	0.27	------	------	0.27	0.27
No. 4	0-1,000	------	------	------	------	------	0.30	------	0.30	------	0.30	------	0.30
No. 5	0-1,000	------	------	------	------	------	------	0.40	0.40	------	------	0.40	0.40
No. 6	0-1,000	------	------	------	------	------	------	0.70	0.70	------	------	0.70	0.70
Township total		------	------	------	------	------	0.30	1.37	1.67	------	0.30	1.37	1.67
Grand total		------	0.45	2.20	2.65	------	2.59	13.55	16.14	------	3.04	15.75	18.79

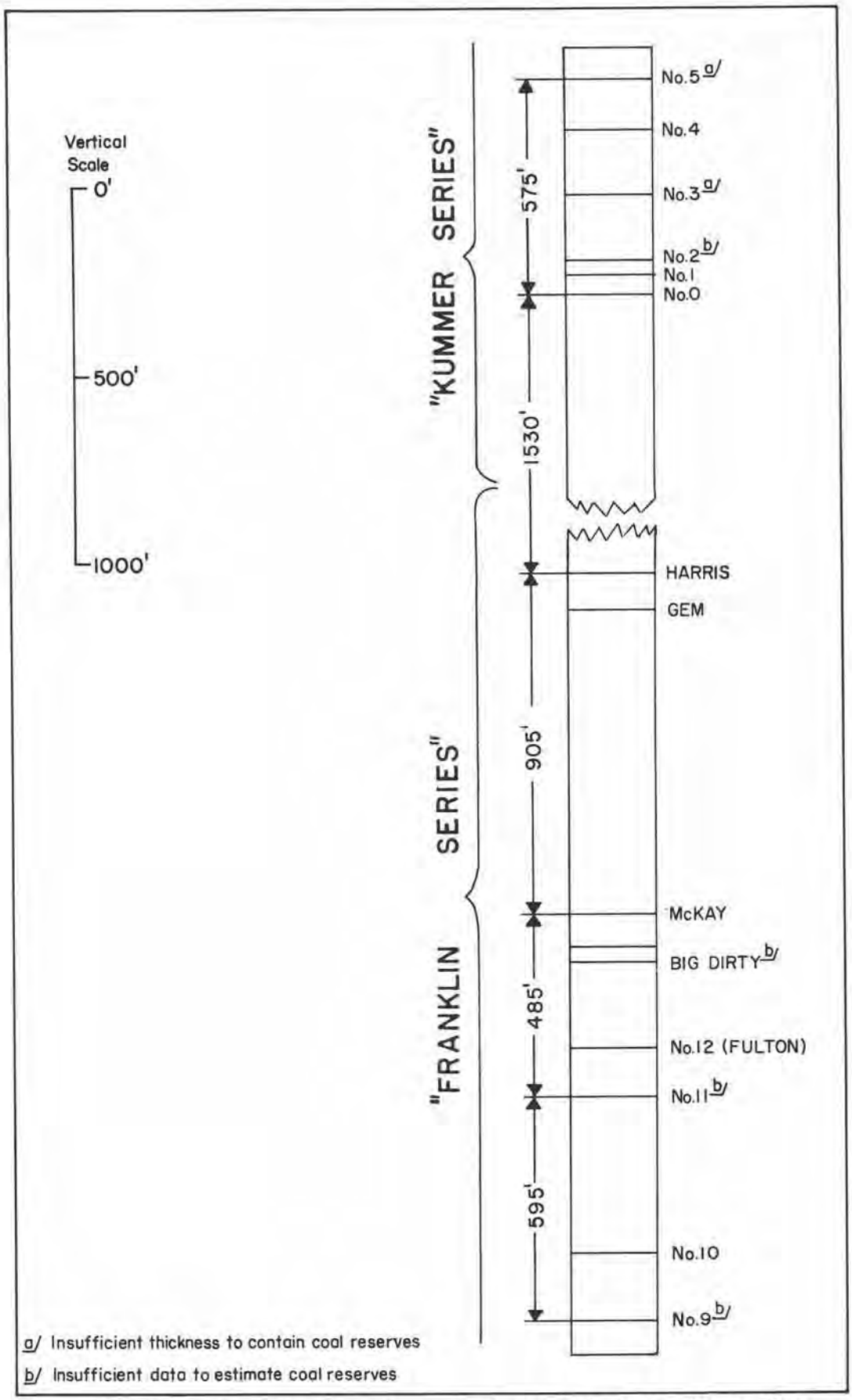


Figure 28. Generalized section of principal coal beds in the Green River district, King County, Washington
(Data from Evans, 1912, pls. 18 and 19)

Puget Group, of Eocene age, is estimated to be at least 6,500 feet thick in this district (Warren and others, 1945). The coal-bearing strata have been folded into a number of tight north- to northeast-trending anticlines and synclines and are cut by numerous west- to southeast-trending faults. As much of the district is covered by glacial drift, it is difficult to trace the faults, but some have displacements of more than 1,000 feet.

Coal Beds

Evans (1912) separated the Puget Group in the Green River district into three coal series, which, from oldest to youngest, are the Bayne, Franklin, and Kummer Series. The principal coal beds of the district are in the Kummer and the Franklin Series, as shown on figure 28. The coal beds and stratigraphic relations of the Bayne Series are not as well defined as those of the upper two coal series. In the vicinity of Black Diamond and Kummer the structure and stratigraphy are known in sufficient detail to permit correlation of coal beds, but in other parts of the district coal beds can rarely be correlated from one mine to the next, even though the distances between mines may be short.

The coal beds shown on figure 28 are recognized only in the area south of Ravensdale in the western part of the Green River district. These beds probably have correlatives in other parts of the district, but correlations are impossible because of insufficient data. The principal coal bed in the district is the McKay coal bed. It has been mined most extensively, and has been recognized over a larger area than any other coal bed in this district. The McKay coal bed has been recognized as far north as the east-trending fault that lies about half a mile south of Ravensdale (fig. 31). The other coal beds shown on figure 28 probably extend this far north, but they have not been recognized north of a point about midway between Black Diamond and Ravensdale. The Dale No. 4 and Dale No. 7 coal beds, which have been mined north of Black Diamond (figs. 29 and 30), are about 1,000 feet stratigraphically above the McKay coal bed. Their correlation with the stratigraphic section shown on figure 28 is uncertain, but they appear to overlie the Harris coal bed.

Coal reserves were estimated for four coal beds in the Ravensdale area. They are, from oldest to youngest: No. 3, No. 4, No. 5, and No. 9. There are several other beds in the Ravensdale area for which thicknesses are not available. The coal beds in the Ravensdale area are separated from the Dale and McKay coal beds to the south by a west-trending fault of apparent large displacement, and the stratigraphic relation between the Ravensdale coal beds and those to the south is unknown.

North of Ravensdale, reserves have been estimated for four coal beds in the vicinity of the Danville mine. They are, from oldest to youngest: Eight-Foot, Six-Foot, Landsburg No. 1, and Frazier. Their stratigraphic relations to coal beds in other parts of the district are unknown.

The eastern half of the Green River district includes a number of isolated mines and small areas of coal-bearing rocks separated by broader areas of glacial drift. The lack of adequate structural and stratigraphic data makes correlation of coal beds between these isolated mines and areas impossible. Therefore, reserves are estimated by individual coal bed in the vicinity of each of the mines or areas. Many additional coal beds are present in the eastern half of the Green River district, but data concerning them are insufficient to permit inclusion in the reserve estimates. More detailed information on the thickness and extent of these coal beds would greatly increase the estimated reserves. The location and classification of reserves by individual beds for the Green River district are shown on figures 29 through 33, on pages 55 to 59.

Physical and chemical properties.—Most of the coal in the Green River district is of high-volatile B bituminous rank; however, the rank ranges from subbituminous B to high-volatile A bituminous. Generally, the higher the coal bed is stratigraphically the lower it is in rank, but the rank of any one coal bed may vary along the strike. For this report the rank of the coal was determined by using the averages of all available analyses (table 17). Some of the beds were found to be on the borderline between subbituminous and bituminous; the coal of these beds was put in the bituminous category.

The ash content of the coal in the Green River district ranges from 2.2 to 31.8 percent and averages 14 percent, the moisture content ranges from 2.1 to 18.7 and averages 8 percent, and the sulfur content ranges from 0.3 to 1.4 percent and averages 0.6 percent.

Coal Mining

Coal has been mined in the Green River coal district since about 1883. Annual production reached a high of 925 thousand tons in 1903. In recent years, production has decreased to less than 100 thousand tons annually. The total production from the Green River district is about 25 million tons.

Summary of Reserves

The total reserves of coal remaining in the ground in the Green River district are estimated to be 357 million tons. Approximately 28 percent of these reserves is classified as measured and indicated and 72 percent is classified as inferred. The reserve figures by township and bed are shown in table 18, on pages 60-62.

Table 17. —Averages of analyses (as-received basis) of coal samples from the Green River district, King County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Mine or prospect	Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
		M	VM	FC	Ash			
Danville	Frazier	15.6	32.5	43.0	8.8	0.5	10,860	3
	Eight-Foot	8.9	38.1	40.3	7.6	.9	12,555	2
	Landsburg No. 1	11.1	47.5	41.3	10.0	.3	12,140	2
	Six-Foot	9.0	39.9	41.2	9.9	.5	12,610	1
Ravensdale	Ravensdale No. 9	7.3	40.3	46.6	5.8	.6	12,370	1
	Ravensdale No. 5	9.1	36.5	41.3	13.0	.6	10,856	5
	Ravensdale No. 4	7.4	37.4	44.0	11.2	.5	11,500	1
	Ravensdale No. 3	9.4	36.3	45.0	9.2	.6	11,455	2
Dale-McKay	Dale No. 4	16.0	32.6	41.8	9.4	.5	9,855	6
	Dale No. 7	14.9	32.8	42.9	9.3	.6	10,116	3
	Gem	11.6	34.7	40.8	12.7	.5	11,438	5
	McKay	9.7	38.8	46.0	5.2	.5	12,134	33
	Franklin No. 10	6.1	37.0	40.6	16.2	.6	13,567	4
Kummer	Kummer No. 4	18.7	32.7	32.9	15.7	.6	10,360	1
	Kummer No. 1	13.7	32.4	41.6	12.0	.4	10,545	3
Sunset	No. 1	12.7	31.1	43.7	12.5	.9	9,890	1
	No. 2	5.0	34.2	42.3	18.4	1.6	11,205	2
	No. 7	4.9	26.4	30.2	38.5	.4	7,990	1
Navy	No. 6	5.1	33.9	44.6	16.4	.5	11,488	1
	No. 4	4.8	33.0	45.1	17.1	.6	11,445	2
Eureka	Unnamed	5.9	31.3	43.9	18.9	.5	10,940	1
Occidental	No. 1	5.2	34.6	47.4	12.6	.7	12,075	1
	No. 2	5.4	33.0	47.1	14.5	.7	11,590	1
	No. 3	4.4	35.8	47.8	11.8	.9	12,268	6
	No. 6	5.3	33.0	45.9	20.7	.5	10,660	2
	No. 14	4.1	34.9	51.6	11.9	.5	------	2
Carbon-Bayne	Carbon	4.6	32.7	49.5	13.1	.8	12,280	3
	No. 3 and No. 5	7.5	33.8	44.0	14.5	.6	11,050	4
	No. 2 and No. 3	4.4	33.3	44.0	18.2	.6	11,362	5
	No. 1	5.5	32.0	48.9	13.1	.4	11,475	3
	Pocahontas No. 6	4.6	31.0	52.2	12.2	.7	12,730	1
Durham	No. 2	3.4	31.4	47.8	17.4	.9	14,300	1
Elk	Dutch	5.8	31.8	32.9	29.5	.6	13,620	2
	Victory	7.2	34.4	38.4	19.9	.8	13,305	2
	No. 1	7.6	33.2	43.7	15.3	.4	12,130	2
	Big Elk	5.7	35.9	42.6	15.6	.6	11,550	1
	No. 2	5.6	33.7	45.0	15.6	.6	11,285	2
Kangley-Alta	Big Seam	4.7	38.0	45.2	12.1	.9	12,420	1
McIntyre	Unnamed	10.5	35.2	42.4	11.9	.4	10,700	1

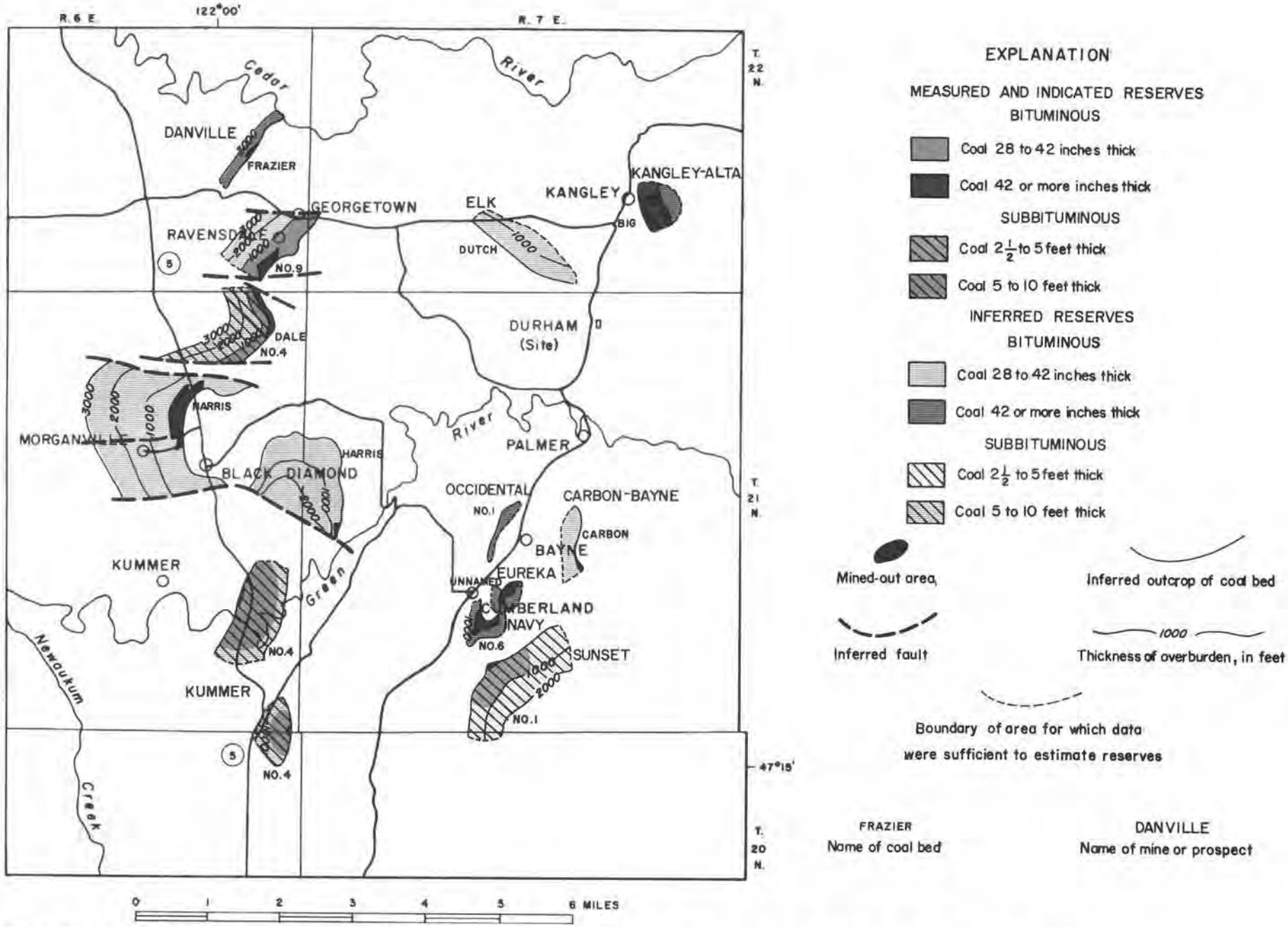


FIGURE 29. GENERALIZED MAP OF THE HARRIS AND OTHER COAL BEDS IN THE GREEN RIVER DISTRICT

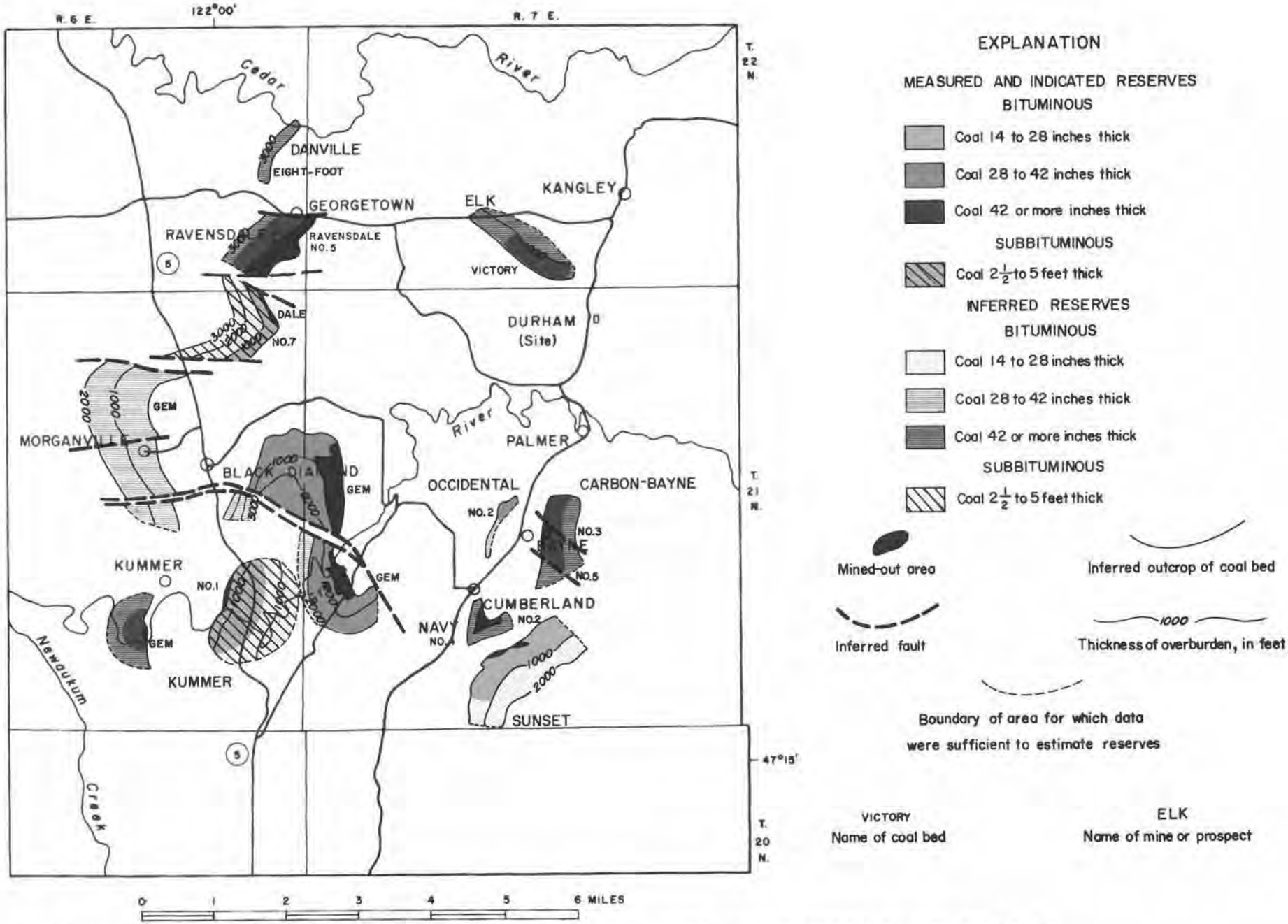


FIGURE 30 . GENERALIZED MAP OF THE GEM AND OTHER COAL BEDS IN THE GREEN RIVER DISTRICT

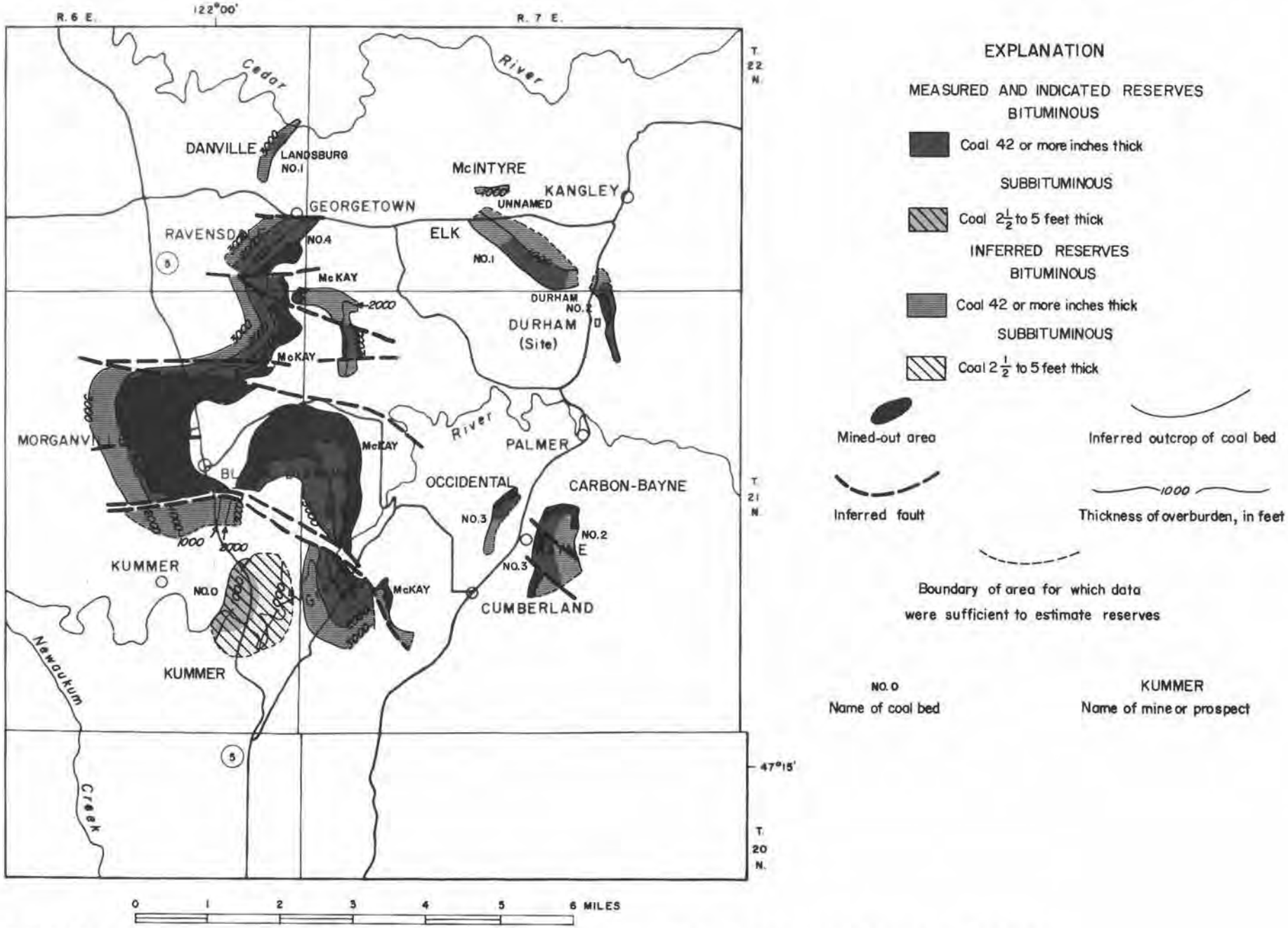
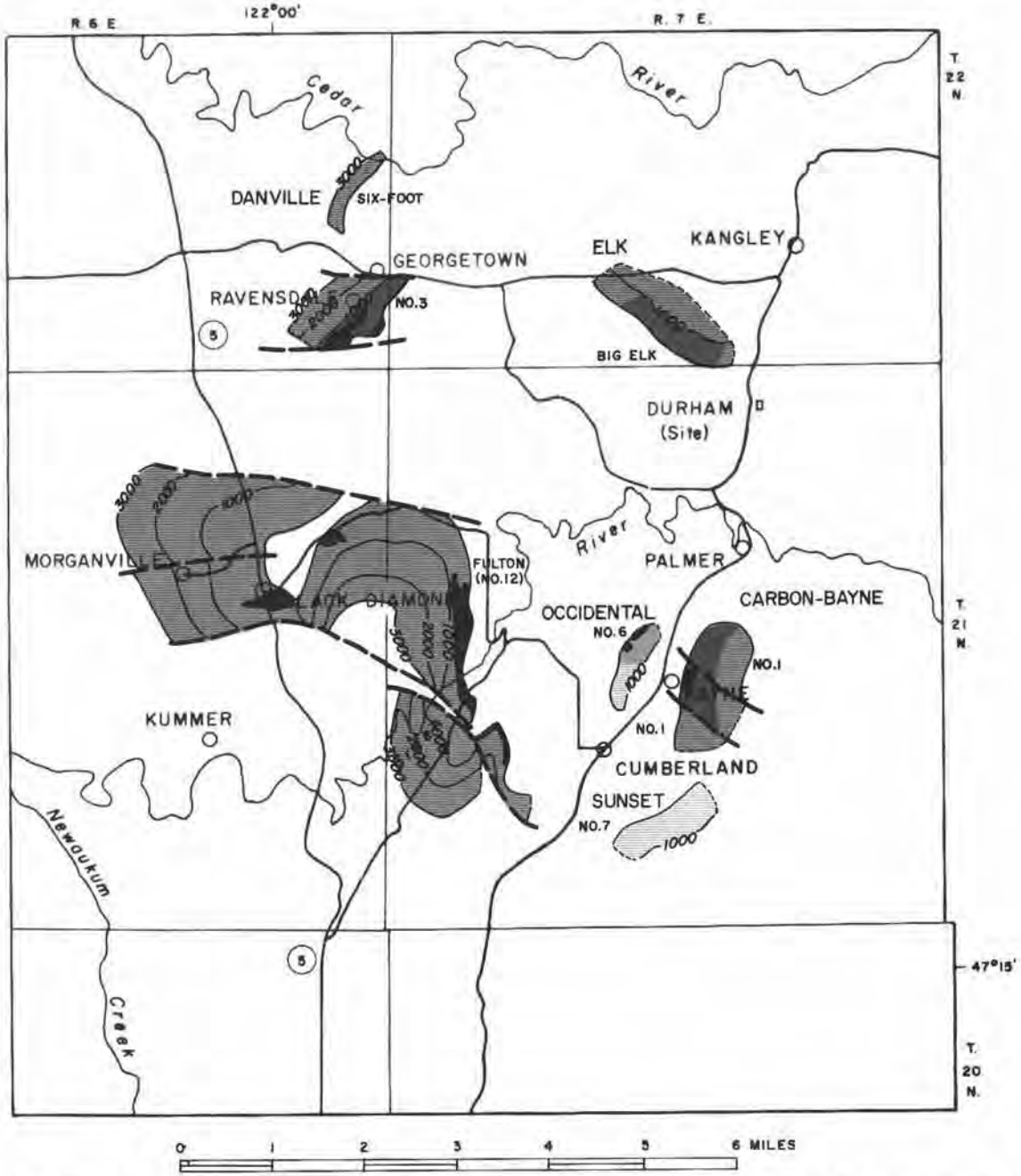


FIGURE 31. GENERALIZED MAP OF THE McKAY AND OTHER COAL BEDS IN THE GREEN RIVER DISTRICT



EXPLANATION

MEASURED AND INDICATED RESERVES
BITUMINOUS

Coal 28 to 42 inches thick

Coal 42 or more inches thick

INFERRED RESERVES
BITUMINOUS

Coal 28 to 42 inches thick

Coal 42 or more inches thick

Mined-out area

Inferred outcrop of coal bed

Inferred fault

1000 Thickness of overburden, in feet

Boundary of area for which data were sufficient to estimate reserves

NO.6
Name of coal bed

OCCIDENTAL
Name of mine or prospect

FIGURE 32 . GENERALIZED MAP OF THE FULTON (NO. 12) AND OTHER COAL BEDS IN THE GREEN RIVER DISTRICT

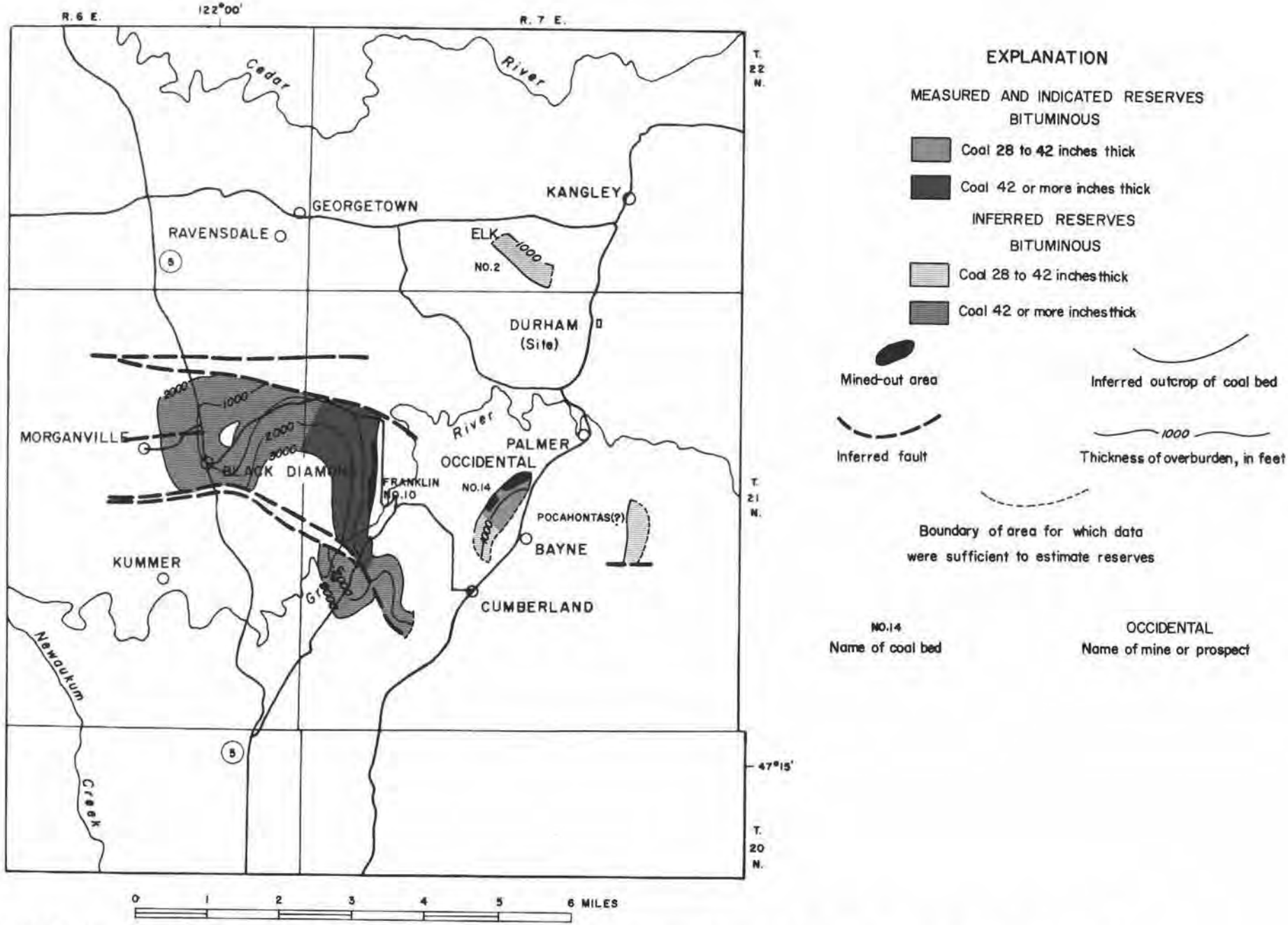


FIGURE 33 . GENERALIZED MAP OF THE FRANKLIN No. 10 AND OTHER COAL BEDS IN THE GREEN RIVER DISTRICT

Table 18.—Estimated remaining reserves of coal in the Green River district, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 20 N., R. 6 E.													
Kummer No. 4*	0-1,000	-----	0.41	-----	0.41	-----	0.41	-----	0.41	-----	0.82	-----	0.82
	1,000-2,000	-----	-----	-----	-----	-----	.28	-----	.28	-----	.28	-----	.28
Township total		-----	0.41	-----	0.41	-----	0.69	-----	0.69	-----	1.10	-----	1.10
T. 21 N., R. 6 E.													
Dale No. 4*	0-1,000	-----	1.59	-----	1.59	-----	-----	-----	-----	-----	1.59	-----	1.59
	1,000-2,000	-----	-----	-----	-----	-----	2.68	-----	2.68	-----	2.68	-----	2.68
	2,000-3,000	-----	-----	-----	-----	-----	3.12	-----	3.12	-----	3.12	-----	3.12
Bed total		-----	1.59	-----	1.59	-----	5.80	-----	5.80	-----	7.39	-----	7.39
Harris	0-1,000	-----	-----	-----	-----	-----	3.67	-----	3.67	-----	3.67	-----	3.67
	1,000-2,000	-----	-----	-----	-----	-----	3.40	-----	3.40	-----	3.40	-----	3.40
	2,000-3,000	-----	-----	-----	-----	-----	3.26	-----	3.26	-----	3.26	-----	3.26
Bed total		-----	-----	-----	-----	-----	10.33	-----	10.33	-----	10.33	-----	10.33
Kummer No. 4*	0-1,000	-----	4.60	-----	4.60	-----	2.80	-----	2.80	-----	7.40	-----	7.40
	1,000-2,000	-----	-----	-----	-----	-----	.27	-----	.27	-----	.27	-----	.27
Bed total		-----	4.60	-----	4.60	-----	3.07	-----	3.07	-----	7.67	-----	7.67
Dale No. 7*	0-1,000	0.90	-----	-----	0.90	-----	-----	-----	-----	0.90	-----	-----	0.90
	1,000-2,000	-----	-----	-----	-----	1.27	-----	-----	1.27	1.27	-----	-----	1.27
	2,000-3,000	-----	-----	-----	-----	1.56	-----	-----	1.56	1.56	-----	-----	1.56
Bed total		0.90	-----	-----	0.90	2.83	-----	-----	2.83	3.73	-----	-----	3.73
Gem	0-1,000	-----	1.12	1.00	2.12	-----	3.29	2.07	5.36	-----	4.41	3.07	7.48
	1,000-2,000	-----	.71	-----	.71	-----	2.94	.19	3.13	-----	3.65	.19	3.84
	2,000-3,000	-----	.93	-----	.93	-----	.69	-----	.69	-----	1.62	-----	1.62
Bed total		-----	2.76	1.00	3.76	-----	6.92	2.26	9.18	-----	9.68	3.26	12.94
Kummer No. 1*	0-1,000	0.98	-----	-----	0.98	1.91	-----	-----	1.91	2.89	-----	-----	2.89
	1,000-2,000	4.00	-----	-----	4.00	2.22	-----	-----	2.22	6.22	-----	-----	6.22
Bed total		4.98	-----	-----	4.98	4.13	-----	-----	4.13	9.11	-----	-----	9.11
McKay	0-1,000	-----	-----	3.24	3.24	-----	-----	4.11	4.11	-----	-----	7.35	7.35
	1,000-2,000	-----	-----	6.94	6.94	-----	-----	2.50	2.50	-----	-----	9.44	9.44
	2,000-3,000	-----	-----	5.43	5.43	-----	-----	12.51	12.51	-----	-----	17.94	17.94
Bed total		-----	-----	15.61	15.61	-----	-----	19.12	19.12	-----	-----	34.73	34.73
Kummer No. 0*	0-1,000	0.78	-----	-----	0.78	1.39	-----	-----	1.39	2.17	-----	-----	2.17
	1,000-2,000	1.42	-----	-----	1.42	2.96	-----	-----	2.96	4.38	-----	-----	4.38
Bed total		2.20	-----	-----	2.20	4.35	-----	-----	4.35	6.55	-----	-----	6.55
Fulton (No. 12)	0-1,000	-----	-----	-----	-----	-----	-----	16.42	16.42	-----	-----	16.42	16.42
	1,000-2,000	-----	-----	-----	-----	-----	-----	12.82	12.82	-----	-----	12.82	12.82
	2,000-3,000	-----	-----	-----	-----	-----	-----	10.23	10.23	-----	-----	10.23	10.23
Bed total		-----	-----	-----	-----	-----	-----	39.47	39.47	-----	-----	39.47	39.47
Franklin No. 10	0-1,000	-----	-----	-----	-----	-----	-----	7.74	7.74	-----	-----	7.74	7.74
	1,000-2,000	-----	-----	-----	-----	-----	-----	14.72	14.72	-----	-----	14.72	14.72
	2,000-3,000	-----	-----	-----	-----	-----	-----	2.90	2.90	-----	-----	2.90	2.90
Bed total		-----	-----	-----	-----	-----	-----	25.36	25.36	-----	-----	25.36	25.36
Township total		8.08	8.95	16.61	33.64	11.31	26.12	86.21	123.64	19.39	35.07	102.82	157.28
T. 21 N., R. 7 E.													
Harris	0-1,000	-----	-----	-----	-----	-----	1.54	-----	1.54	-----	1.54	-----	1.54
	1,000-2,000	-----	-----	-----	-----	-----	.94	-----	.94	-----	.94	-----	.94
	2,000-3,000	-----	-----	-----	-----	-----	1.04	-----	1.04	-----	1.04	-----	1.04
Bed total		-----	-----	-----	-----	-----	3.52	-----	3.52	-----	3.52	-----	3.52
Occidental No. 1	0-1,000	-----	-----	-----	-----	-----	-----	0.40	0.40	-----	-----	0.40	0.40
Carbon	0-1,000	-----	-----	-----	-----	-----	0.95	-----	0.95	-----	0.95	-----	0.95
Eureka-unnamed	0-1,000	-----	-----	-----	-----	-----	-----	0.87	0.87	-----	-----	0.87	0.87
Navy No. 6	0-1,000	-----	-----	-----	-----	-----	-----	1.40	1.40	-----	-----	1.40	1.40
Sunset No. 1*	0-1,000	1.54	-----	-----	1.54	2.36	-----	-----	2.36	3.90	-----	-----	3.90
	1,000-2,000	-----	-----	-----	-----	2.66	-----	-----	2.66	2.66	-----	-----	2.66
Bed total		1.54	-----	-----	1.54	5.02	-----	-----	5.02	6.56	-----	-----	6.56
Gem	0-1,000	-----	1.66	-----	1.66	-----	-----	-----	-----	-----	1.66	-----	1.66
	1,000-2,000	-----	2.92	-----	2.92	-----	-----	-----	-----	-----	2.92	-----	2.92
	2,000-3,000	-----	.12	-----	.12	-----	0.24	-----	0.24	-----	.36	-----	.36
Bed total		-----	4.70	-----	4.70	-----	0.24	-----	0.24	-----	4.94	-----	4.94

*Subbituminous coal. Coal 2.5 to 5.0 feet and 5.0 to 10.0 feet thick is shown in the 14 to 28 inches and 28 to 42 inches thickness categories.

Table 18.—Estimated remaining reserves of coal in the Green River district, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 21 N., R. 7 E.—continued													
Occidental No. 2	0-1,000	-----	0.22	-----	0.22	-----	0.21	-----	0.21	-----	0.43	-----	0.43
Carbon-Bayne No. 3	0-1,000	-----	-----	0.72	0.72	-----	-----	2.71	2.71	-----	-----	3.43	3.43
Navy No. 4	0-1,000	-----	-----	-----	-----	-----	-----	1.21	1.21	-----	-----	1.21	1.21
Sunset No. 2	0-1,000	1.44	-----	-----	1.44	0.41	-----	-----	0.41	1.85	-----	-----	1.85
	1,000-2,000	-----	-----	-----	-----	1.45	-----	-----	1.45	1.45	-----	-----	1.45
Bed total		1.44	-----	-----	1.44	1.86	-----	-----	1.86	3.30	-----	-----	3.30
Durham No. 2	0-1,000	-----	-----	0.46	0.46	-----	-----	0.08	0.08	-----	-----	0.54	0.54
McKay	0-1,000	-----	-----	3.00	3.00	-----	-----	3.37	3.37	-----	-----	6.37	6.37
	1,000-2,000	-----	-----	4.62	4.62	-----	-----	4.00	4.00	-----	-----	8.62	8.62
	2,000-3,000	-----	-----	2.79	2.79	-----	-----	5.08	5.08	-----	-----	7.87	7.87
Bed total		-----	-----	10.41	10.41	-----	-----	12.45	12.45	-----	-----	22.86	22.86
Occidental No. 3	0-1,000	-----	-----	0.47	0.47	-----	-----	0.89	0.89	-----	-----	1.36	1.36
Carbon-Bayne No. 2	0-1,000	-----	-----	0.69	0.69	-----	-----	1.88	1.88	-----	-----	2.57	2.57
Sunset No. 7	0-1,000	-----	-----	-----	-----	-----	1.38	-----	1.38	-----	1.38	-----	1.38
Fulton (No. 12)	0-1,000	-----	-----	-----	-----	-----	-----	10.82	10.82	-----	-----	10.82	10.82
	1,000-2,000	-----	-----	-----	-----	-----	-----	9.83	9.83	-----	-----	9.83	9.83
	2,000-3,000	-----	-----	-----	-----	-----	-----	9.28	9.28	-----	-----	9.28	9.28
Bed total		-----	-----	-----	-----	-----	-----	29.93	29.93	-----	-----	29.93	29.93
Occidental No. 6	0-1,000	-----	0.44	-----	0.44	-----	0.44	-----	0.44	-----	0.88	-----	0.88
Carbon-Bayne No. 1	0-1,000	-----	-----	2.68	2.68	-----	-----	1.65	1.65	-----	-----	4.33	4.33
Franklin No. 10	0-1,000	-----	-----	5.17	5.17	-----	-----	4.54	4.54	-----	-----	9.71	9.71
	1,000-2,000	-----	-----	6.76	6.76	-----	-----	4.87	4.87	-----	-----	11.63	11.63
	2,000-3,000	-----	-----	5.66	5.66	-----	-----	3.28	3.28	-----	-----	8.94	8.94
Bed total		-----	-----	17.59	17.59	-----	-----	12.69	12.69	-----	-----	30.28	30.28
Occidental No. 14	0-1,000	-----	0.44	-----	0.44	-----	0.29	-----	0.29	-----	0.73	-----	0.73
	1,000-2,000	-----	.49	-----	.49	-----	.38	-----	.38	-----	.87	-----	.87
Bed total		-----	0.93	-----	0.93	-----	0.67	-----	0.67	-----	1.60	-----	1.60
Pocahontas (?)	0-1,000	-----	-----	-----	-----	-----	0.75	-----	0.75	-----	0.75	-----	0.75
Township total		2.98	6.29	33.02	42.29	6.88	8.16	66.16	81.20	9.86	14.45	99.18	123.49
T. 22 N., R. 6 E.													
Frazier	0-1,000	-----	-----	-----	-----	-----	-----	1.68	1.68	-----	-----	1.68	1.68
	1,000-2,000	-----	-----	-----	-----	-----	-----	2.01	2.01	-----	-----	2.01	2.01
	2,000-3,000	-----	-----	-----	-----	-----	-----	2.02	2.02	-----	-----	2.02	2.02
Bed total		-----	-----	-----	-----	-----	-----	5.71	5.71	-----	-----	5.71	5.71
Ravensdale No. 9	0-1,000	-----	0.89	-----	0.89	-----	-----	-----	-----	-----	0.89	-----	0.89
	1,000-2,000	-----	-----	-----	-----	-----	0.71	-----	0.71	-----	0.71	-----	0.71
	2,000-3,000	-----	-----	-----	-----	-----	.52	-----	.52	-----	.52	-----	.52
Bed total		-----	0.89	-----	0.89	-----	1.23	-----	1.23	-----	2.12	-----	2.12
Dale No. 4*	0-1,000	-----	0.04	-----	0.04	-----	-----	-----	-----	-----	0.04	-----	0.04
	1,000-2,000	-----	-----	-----	-----	-----	0.10	-----	0.10	-----	.10	-----	.10
	2,000-3,000	-----	-----	-----	-----	-----	.12	-----	.12	-----	.12	-----	.12
Bed total		-----	0.04	-----	0.04	-----	0.22	-----	0.22	-----	0.26	-----	0.26
Eight-Foot	0-1,000	-----	-----	-----	-----	-----	-----	1.27	1.27	-----	-----	1.27	1.27
	1,000-2,000	-----	-----	-----	-----	-----	-----	1.58	1.58	-----	-----	1.58	1.58
	2,000-3,000	-----	-----	-----	-----	-----	-----	2.67	2.67	-----	-----	2.67	2.67
Bed total		-----	-----	-----	-----	-----	-----	5.52	5.52	-----	-----	5.52	5.52
Ravensdale No. 5	0-1,000	-----	-----	0.56	0.56	-----	-----	-----	-----	-----	-----	0.56	0.56
	1,000-2,000	-----	-----	2.21	2.21	-----	-----	-----	-----	-----	-----	2.21	2.21
	2,000-3,000	-----	-----	-----	-----	-----	-----	1.63	1.63	-----	-----	1.63	1.63
Bed total		-----	-----	2.77	2.77	-----	-----	1.63	1.63	-----	-----	4.40	4.40
Dale No. 7*	0-1,000	0.05	-----	-----	0.05	-----	-----	-----	-----	0.05	-----	-----	0.05
	1,000-2,000	-----	-----	-----	-----	0.08	-----	-----	0.08	.08	-----	-----	.08
	2,000-3,000	-----	-----	-----	-----	.18	-----	-----	.18	.18	-----	-----	.18
Bed total		0.05	-----	-----	0.05	0.26	-----	-----	0.26	0.31	-----	-----	0.31
Landsburg No. 1	0-1,000	-----	-----	1.58	1.58	-----	-----	2.70	2.70	-----	-----	4.28	4.28
	1,000-2,000	-----	-----	-----	-----	-----	-----	5.12	5.12	-----	-----	5.12	5.12
	2,000-3,000	-----	-----	-----	-----	-----	-----	5.39	5.39	-----	-----	5.39	5.39
Bed total		-----	-----	1.58	1.58	-----	-----	13.21	13.21	-----	-----	14.79	14.79
Ravensdale No. 4	0-1,000	-----	-----	1.17	1.17	-----	-----	-----	-----	-----	-----	1.17	1.17
	1,000-2,000	-----	-----	1.84	1.84	-----	-----	-----	-----	-----	-----	1.84	1.84
	2,000-3,000	-----	-----	-----	-----	-----	-----	1.42	1.42	-----	-----	1.42	1.42
Bed total		-----	-----	3.01	3.01	-----	-----	1.42	1.42	-----	-----	4.43	4.43

*Subbituminous coal. Coal 2.5 to 5.0 feet and 5.0 to 10.0 feet thick is shown in the 14 to 28 inches and 28 to 42 inches thickness categories.

Table 18.—Estimated remaining reserves of coal in the Green River district, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 22 N., R. 6 E.—continued													
McKay	0-1,000	-----	-----	0.73	0.73	-----	-----	-----	-----	-----	-----	0.73	0.73
	1,000-2,000	-----	-----	.43	.43	-----	-----	-----	-----	-----	-----	.43	.43
	2,000-3,000	-----	-----	-----	-----	-----	-----	0.14	0.14	-----	-----	.14	.14
Bed total		-----	-----	1.16	1.16	-----	-----	0.14	0.14	-----	-----	1.30	1.30
Six-foot	0-1,000	-----	-----	-----	-----	-----	-----	1.08	1.08	-----	-----	1.08	1.08
	1,000-2,000	-----	-----	-----	-----	-----	-----	1.39	1.39	-----	-----	1.39	1.39
	2,000-3,000	-----	-----	-----	-----	-----	-----	1.51	1.51	-----	-----	1.51	1.51
Bed total		-----	-----	-----	-----	-----	-----	3.98	3.98	-----	-----	3.98	3.98
Ravensdale No. 3	0-1,000	-----	-----	1.43	1.43	-----	-----	-----	-----	-----	-----	1.43	1.43
	1,000-2,000	-----	-----	.71	.71	-----	-----	0.91	0.91	-----	-----	1.62	1.62
	2,000-3,000	-----	-----	-----	-----	-----	-----	1.23	1.23	-----	-----	1.23	1.23
Bed total		-----	-----	2.14	2.14	-----	-----	2.14	2.14	-----	-----	4.28	4.28
Township total		0.05	0.93	10.66	11.64	0.26	1.45	33.75	35.46	0.31	2.38	44.41	47.10
T. 22 N., R. 7 E.													
Ravensdale No. 9	0-1,000	-----	0.04	-----	0.04	-----	-----	-----	-----	-----	0.04	-----	0.04
Dutch	0-1,000	-----	-----	-----	-----	-----	1.63	-----	1.63	-----	1.63	-----	1.63
	1,000-2,000	-----	-----	-----	-----	-----	.66	-----	.66	-----	.66	-----	.66
Bed total		-----	-----	-----	-----	-----	2.29	-----	2.29	-----	2.29	-----	2.29
Big	0-1,000	-----	-----	1.06	1.06	-----	-----	-----	-----	-----	-----	1.06	1.06
	1,000-2,000	-----	-----	-----	-----	-----	-----	0.92	0.92	-----	-----	.92	.92
Bed total		-----	-----	1.06	1.06	-----	-----	0.92	0.92	-----	-----	1.98	1.98
Victory	0-1,000	-----	-----	2.68	2.68	-----	-----	2.02	2.02	-----	-----	4.70	4.70
	1,000-2,000	-----	-----	-----	-----	-----	-----	2.53	2.53	-----	-----	2.53	2.53
Bed total		-----	-----	2.68	2.68	-----	-----	4.55	4.55	-----	-----	7.23	7.23
Unnamed	0-1,000	-----	-----	-----	-----	-----	-----	0.32	0.32	-----	-----	0.32	0.32
Ravensdale No. 4	0-1,000	-----	-----	0.23	0.23	-----	-----	-----	-----	-----	-----	0.23	0.23
Elk No. 1	0-1,000	-----	-----	1.57	1.57	-----	-----	0.46	0.46	-----	-----	2.03	2.03
	1,000-2,000	-----	-----	-----	-----	-----	-----	1.83	1.83	-----	-----	1.83	1.83
Bed total		-----	-----	1.57	1.57	-----	-----	2.29	2.29	-----	-----	3.86	3.86
Durham No. 2	0-1,000	-----	-----	1.36	1.36	-----	-----	0.32	0.32	-----	-----	1.68	1.68
Ravensdale No. 3	0-1,000	-----	-----	0.21	0.21	-----	-----	-----	-----	-----	-----	0.21	0.21
Big Elk	0-1,000	-----	-----	3.50	3.50	-----	-----	2.28	2.28	-----	-----	5.78	5.78
	1,000-2,000	-----	-----	-----	-----	-----	-----	4.06	4.06	-----	-----	4.06	4.06
Bed total		-----	-----	3.50	3.50	-----	-----	6.34	6.34	-----	-----	9.84	9.84
Elk No. 2	0-1,000	-----	-----	-----	-----	0.66	-----	-----	0.66	0.66	-----	-----	0.66
Township total		-----	0.04	10.61	10.65	0.66	2.29	14.74	17.69	0.66	2.33	25.35	28.34
Grand total		11.11	16.62	70.90	98.63	19.11	38.71	200.86	258.68	30.22	55.33	271.76	357.31

PIERCE COUNTY COAL DEPOSITS

Geographic and Geologic Setting

The coal deposits of Pierce County occur in the Puget Group of Eocene age (Daniels, 1914, p. 22-27) and are confined to a narrow north-south belt 3 to 6 miles wide near the center of the county (fig. 2), extending northward from the Nisqually River nearly to the White River. On both east and west sides of the belt these coal-bearing rocks dip beneath volcanic rocks of Tertiary age. In the northern part of the county much of the coal-bearing sequence is concealed by a mantle of glacial drift, and in places, in the vicinity of the Puyallup River, flat-lying Quaternary (?) lava flows that originated from Mount Rainier cover the coal-bearing rocks. The coal-bearing strata have been intensely folded and faulted, and most of the folds are narrow, north-trending structures with steeply dipping limbs. Dips of 60° or more are common throughout the county. The faults are normal and high-angle reverse, with displacements ranging from a few feet to more than 1,500 feet.

Knowledge of the coal deposits of Pierce County is confined largely to the areas of extensive mining, and very little is known about the intervening areas or about the relation of one area to another. For this reason, the detailed descriptions of the coal deposits in this report are given by separate geographic areas: the Wilkeson-Carbonado coal field, the Spiketon area, the Melmont area, and the Fairfax-Montezuma and Ashford areas.

Washington Geological Survey Bulletin No. 10 (Daniels, 1914) is the most comprehensive report on Pierce County coals, and it supplied much of the information presented in the current report.

Coal Beds

The coal beds of Pierce County range in rank from high-volatile A bituminous to low-volatile bituminous. They have the highest rank of any of the major coal-bearing areas of the State.

Coking Coal

The most important known coking coal deposits in Washington are in the Wilkeson-Carbonado coal field and in the Fairfax-Montezuma and Ashford areas to the south. The coking properties of the coal in these areas are due to physical and chemical changes resulting from folding and faulting of the rocks that contain the coal beds. The coking properties of these coal beds vary within a few miles, reflecting differences in the degree of metamorphism. According to Green (1947, p. 6), these deposits are the most important coking coal reserve on the Pacific Coast. Most of the coke that has been manufactured in Washington has been made from coal mines in these areas.

As a result of a study made of coking coals in Washington, Daniels (1941, p. 62) concluded that ". . . coals from Pierce County can be coked successfully in byproduct ovens to produce domestic, smelter, foundry, and metallurgical coke suitable for ferrous smelting in blast furnaces. The coke is suitable also for manufacture of producer gas and water gas. Selection of coals and proper blending are necessary, as in other localities."

Estimates of reserves of coking coal in the Wilkeson-Carbonado and Fairfax areas range from 60 million tons to 125 million tons (Daniels, 1941, p. 16). The 60-million-ton estimate was of washed coal that could be recovered from a depth of 500 feet below present mine workings and from unmined tracts adjacent to the older mines. The 125-million-ton estimate was defined as including recoverable coal within economic limits of depth.

Coal Mining

In Pierce County, coal was first discovered about 1862 in the canyon of the Carbon River. The first recorded mining of coal in the county was in 1874 along Gale Creek (Daniels, 1914, p. 60). Production figures are not available for the period prior to 1892, but in that year 353,757 tons of coal was produced. Annual production increased to a high of 832,272 tons in 1913, declining thereafter. By 1959 the total annual production had dwindled to less than 1,000 tons.

The intense deformation that the coal-bearing strata have undergone has made coal prospecting and mining difficult. All the Pierce County coal is mined by underground methods because the beds dip too steeply and the structures are too complex to permit strip mining.

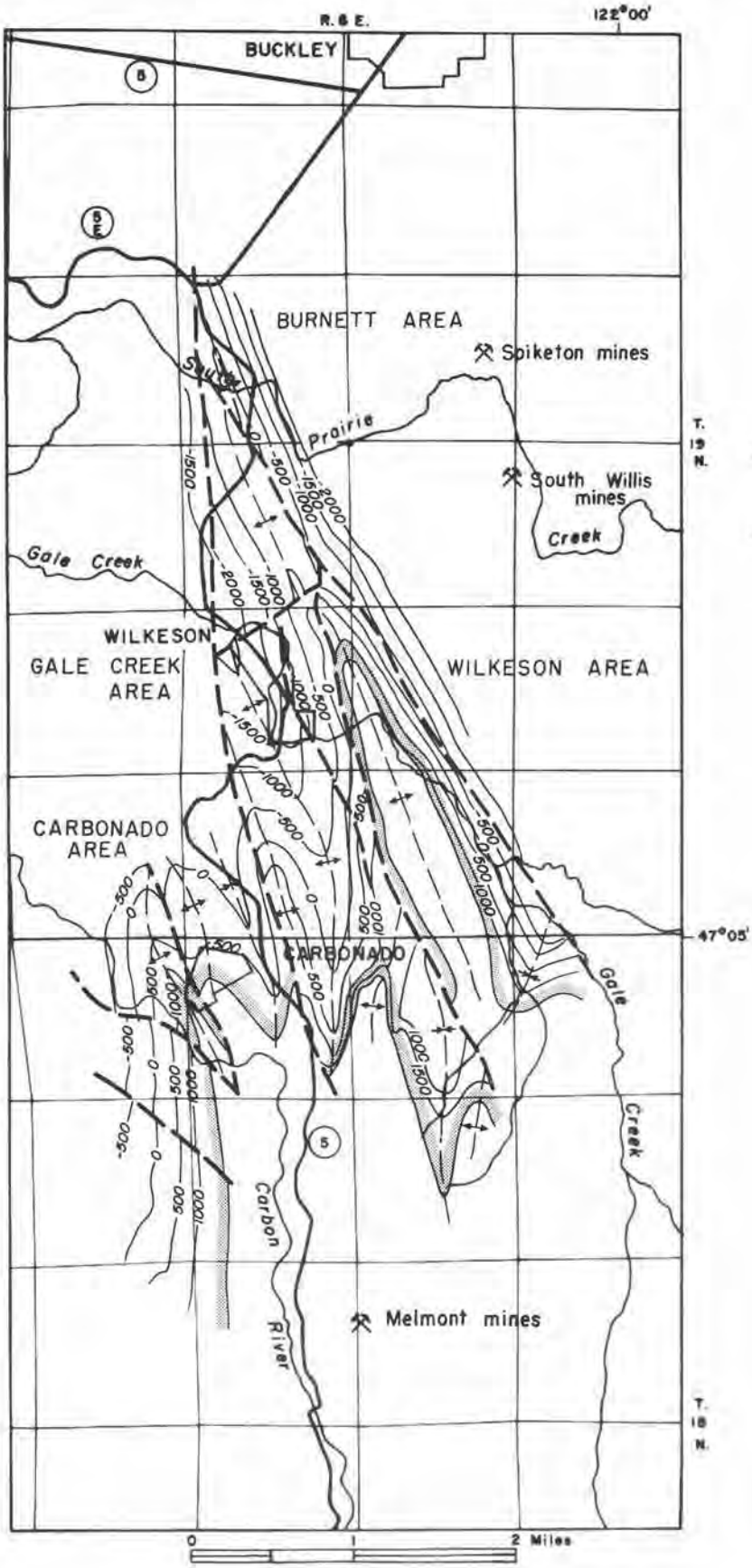
Summary of Reserves

The total reserves of coal remaining in the ground in Pierce County as of January 1, 1960, are estimated to be 362 million tons. Approximately 37 percent of these reserves is classified as measured and indicated and 63 percent as inferred. The reserve figures by township are shown in table 36, on page 112. These reserve figures would no doubt be greatly increased if the structural and stratigraphic relations of the areas between the widely spaced mines were better known. A detailed geologic study of the entire coal-bearing part of Pierce County is necessary before the true potential of the coal reserves of the county can be estimated.

WILKESON-CARBONADO COAL FIELD

Geographic and Geologic Setting

The Wilkeson-Carbonado coal field is in the north-central part of Pierce County. It includes the Burnett, Wilkeson, Gale Creek,



EXPLANATION

Inferred outcrop of the Wilkeson No. 3 coal bed

1000

Structure contour drawn on top of Wilkeson No. 3 coal bed, datum is mean sea level

Inferred fault

Axis of anticline, approximately located

Axis of syncline, approximately located

FIGURE 34. GENERALIZED STRUCTURE CONTOUR MAP OF THE WILKESON–CARBONADO COAL FIELD

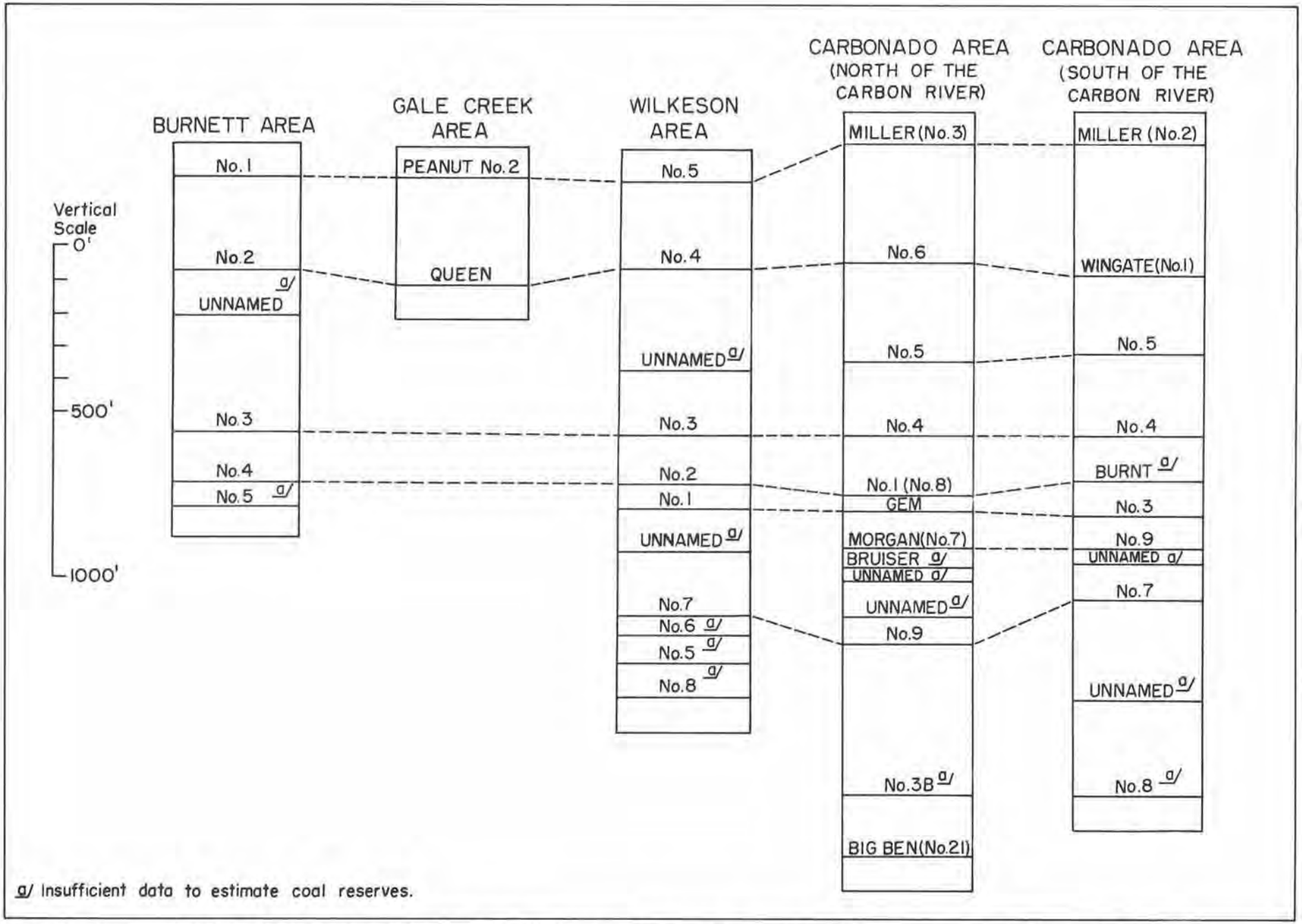


Figure 35. Generalized columnar sections in the Wilkeson-Carbonado coal field showing coal beds and correlations used in estimating coal reserves

and Carbonado areas (fig. 34). The field has been intensively mined, and the structure and stratigraphy are fairly well known (Willis, 1898; Willis and Smith, 1899; and Daniels, 1914).

The principal structure of the field is a northwest-trending anticline extending from the Burnett area south through the Wilkeson area. This fold is flanked on the west by a series of smaller plunging anticlines and synclines. The strata have been cut by both normal and high-angle reverse faults. Fault displacements range from a few feet to more than 1,500 feet. Most of the major faults are parallel or subparallel to the fold axes.

Coal Beds

Reserves were estimated for nine coal beds in the Wilkeson-Carbonado coal field. Several additional coal beds are present in the field, but because their thickness is unknown they could not be included in the reserve estimates. No doubt some of these beds are thicker locally than the minimum used in estimating reserves in the better known beds. The coal beds for which reserves were estimated range from 2 to 8 feet in thickness. The coal beds are steeply dipping throughout most of the field, with an average dip of about 55°. The correlations used in this report are shown on figure 35, and for the most part are similar to the correlations made by Daniels (1914, p. 46). The location and classification of coal reserves by individual beds are shown on figures 38 through 46, on pages 70 to 78.

Physical and chemical properties.—The coals of the Wilkeson-Carbonado coal field range in rank from high-volatile A bituminous to medium-volatile bituminous, and many of them have good coking qualities. The coal in this field has relatively low ash and moisture content as compared to coal in other areas of Pierce County. The ash content has a range of 6.0 to 25.7 percent and averages about 12 percent. The moisture content ranges from 1.1 to 7.4 percent and averages about 3 percent. The sulfur content ranges from 0.3 to 3.2 percent and averages 0.7 percent. The average chemical analyses of the various coal beds of the field are given in table 19.

Coal Mining

About 18.6 million tons of coal has been produced from this field since 1892, the first year for which production figures are available. This is nearly 90 percent of the total coal production of Pierce County.

Summary of Reserves

The reserves of coal remaining in the ground in the Wilkeson-Carbonado coal field are estimated to total 222 million tons. Approximately 32 percent of these reserves is classified as measured and indicated and 68 percent as inferred. The reserve figures by township and bed are shown in table 23, on page 81.

SPIKETON AREA

Geographic and Geologic Setting

The Spiketon area, as described in this report, is northeast of the Wilkeson-Carbonado coal field and includes the coal beds that were mined at the Spiketon and South Willis mines (fig. 34). The coal-bearing strata of the Spiketon area are on the east flank of the major northwest-trending anticline of the Burnett and Wilkeson areas. The coal beds are in the upper part of the Puget Group of Eocene age and are stratigraphically above the coal beds of the Wilkeson-Carbonado coal field. All coal beds of the Spiketon area dip about 60° to the east.

Coal Beds

More than 10 coal beds are present in the Spiketon area. These beds range from a few inches to as much as 5 feet in thickness, and the average thickness of the Nos. 6, 7, 8, and 10 beds, which have

Table 19.—Averages of analyses (as-received basis) of coal samples from the Wilkeson-Carbonado coal field, Pierce County, Washington

(Coal bed names used are those at Wilkeson and at Carbonado north of the Carbon River. M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
	M	VM	FC	Ash			
Wilkeson No. 5 --	3.9	33.3	54.5	8.4	0.8	13,475	6
Wilkeson No. 4 --	3.3	34.2	52.1	10.3	1.1	13,468	26
Carbonado No. 5 -	3.8	34.9	50.6	10.6	.6	12,910	4
Wilkeson No. 3 --	2.8	31.4	51.4	14.2	.4	12,637	18
Wilkeson No. 2 --	3.7	28.8	52.4	14.9	.6	12,302	16
Wilkeson No. 1 --	2.7	28.7	52.7	15.7	1.1	12,483	6
Morgan (No. 7) --	2.6	29.9	48.7	18.7	.5	12,398	6
Wilkeson No. 7 --	2.8	24.3	61.9	10.8	.5	13,410	5
Big Ben ---------	3.7	29.9	53.3	13.0	.5	12,843	3

been mined to the greatest extent, is about 4 feet. The correlation of the coal beds at Spiketon with those at South Willis, as shown on figure 36, was made by Daniels (1914, p. 49). The coal beds designated by numbers are at Spiketon and those designated by names are at South Willis. The location and classification of coal reserves by individual beds are shown on figures 38 through 46, on pages 70 to 78.

Physical and chemical properties.—The coal in the Spiketon area is of high-volatile A bituminous rank. Although only five analyses are available, it seems that the coal in this area has a relatively higher ash content than the older coal in the Wilkeson-Carbonado field. The ash content ranges from 17.5 to 22.9 percent and averages 20 percent. The moisture content ranges from 3.2 to 6.7 percent and averages 5 percent. The sulfur content ranges from 0.4 to 0.8 percent and averages 0.6 percent. Analyses of the coal beds in the Spiketon area are given in table 20.

Coal Mining

About a million tons of coal was produced in the Spiketon area from the early 1890's to 1930. This is about 4 percent of the total Pierce County coal production.

Summary of Reserves

The reserves of coal remaining in the ground in the Spiketon area are estimated to total 88.8 million tons. Approximately 54 percent of these reserves is classified as measured and indicated and 46 percent as inferred. The reserve figures by township and bed are shown in table 24, on page 82.

MELMONT AREA

Geographic and Geologic Setting

The Melmont area is south of the Wilkeson-Carbonado coal field. Some of the mine workings at Melmont are within three-fourths of a mile of the southern part of the Carbonado area (fig. 34). The rocks of the Melmont area are broken by a number of north- to northwest-trending faults, and they have been folded into several small north-trending anticlines and synclines. Although the Melmont area is only a short distance from parts of the Wilkeson-Carbonado coal field, the stratigraphic relations between these two areas cannot be determined with certainty. However, as has been pointed out by Daniels (1914, p. 41), the coal beds of the Melmont area seem to underlie the coal beds of the Carbonado area and are probably in the lower part of the Puget Group of Eocene age.

Coal Beds

Coal reserves have been estimated for seven coal beds in the Melmont area. These beds range from 3 to 13 feet in thickness, and they have an average dip of 55°. The stratigraphic positions of the various coal beds of the Melmont area are shown on figure 37. The location and classification of coal reserves by individual beds are shown on figures 38 through 44, on pages 70 through 76.

Physical and chemical properties.—Only six analyses of the coal beds of the Melmont area are available. On the basis of these analyses, the coals range in rank from medium-volatile to low-volatile bituminous. This is the highest rank of coal found in Pierce County. The ash content of the coal ranges from 14.9 to 18.6 percent and averages about 17 percent. The moisture content ranges from 3.1 to 9.2 percent and averages about 6 percent. The sulfur content ranges from 0.3 to 0.7 percent and averages 0.5 percent. Average analyses of the Melmont coals are given in table 21, on page 79.

Coal Mining

The first recorded production of coal in the Melmont area was in 1902, and the latest coal production was in 1918. About 900,000 tons was produced during this period. This represents about 4 percent of the total Pierce County coal production.

Table 20.—Averages of analyses (as-received basis) of coal samples from the Spiketon area, Pierce County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Source of analyses is Fieldner and others, 1931.)

Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
	M	VM	FC	Ash			
No. 10 or Winsor	4.91	31.46	43.80	19.82	0.41	10,938	2
No. 8 or Pittsburg	4.69	32.71	42.22	20.38	.55	10,856	1
Snell	6.70	25.71	50.10	17.50	.78	11,560	1
Black Carbon	5.08	32.82	39.14	22.96	.54	10,442	1

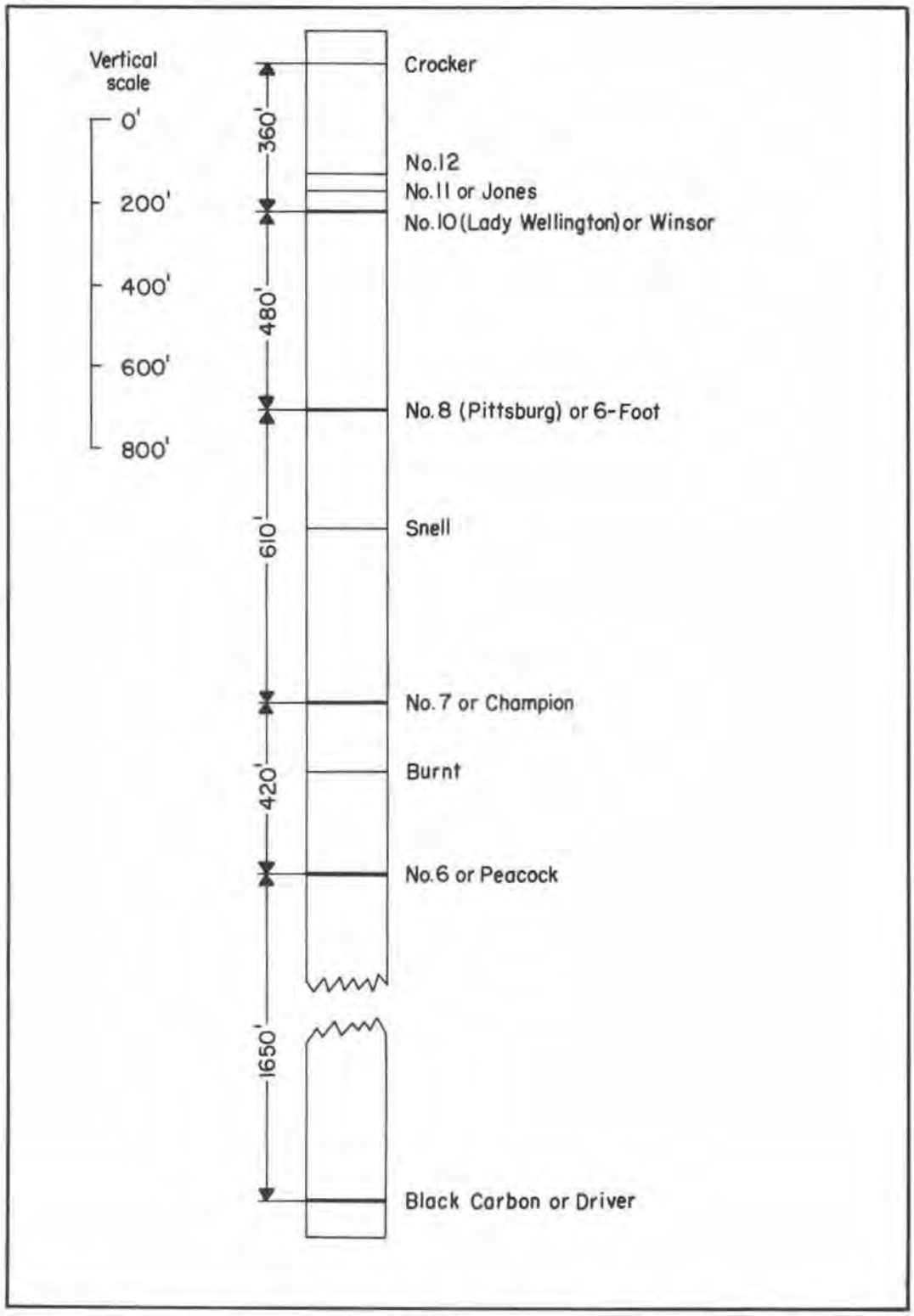


Figure 36. Generalized section of principal coal beds in the Spiketon area, Pierce County, Washington

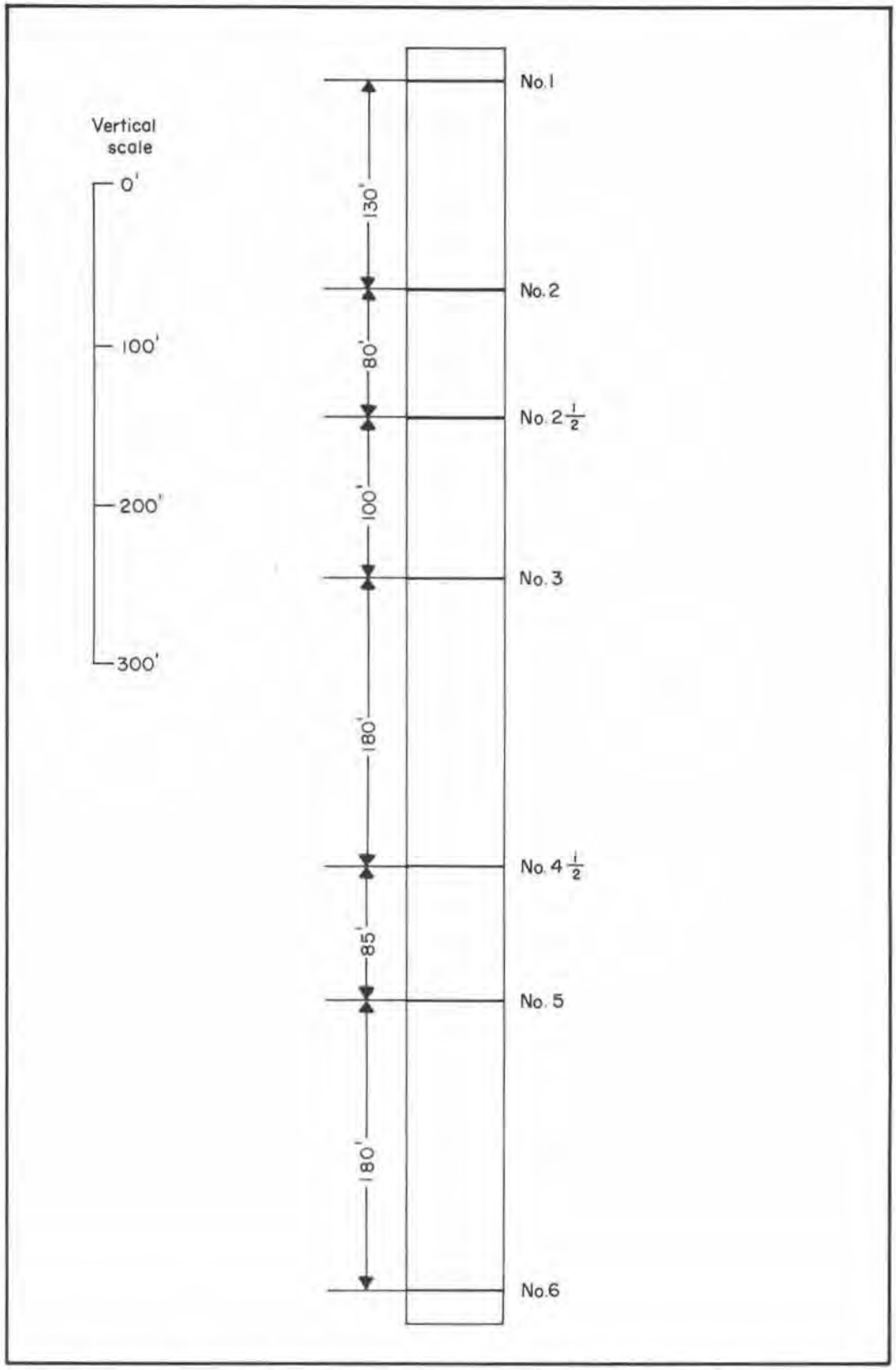


Figure 37. Generalized section of principal coal beds in the Melmont area, Pierce County, Washington

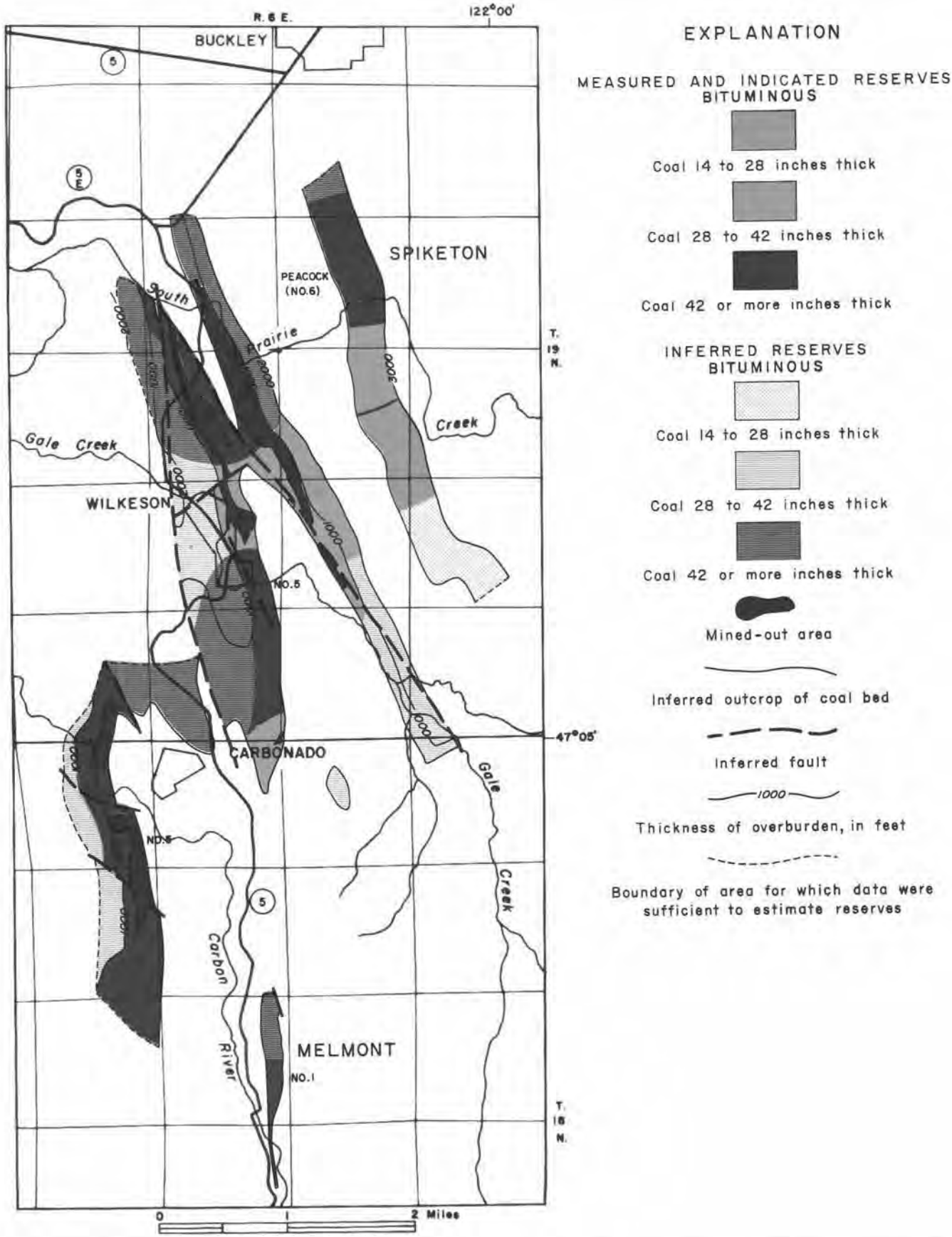


FIGURE 38. GENERALIZED MAP OF THE NO. 1 BED OF MELMONT, NO. 5 BED OF WILKESON, AND PEACOCK (NO. 6) BED OF SPIKETON

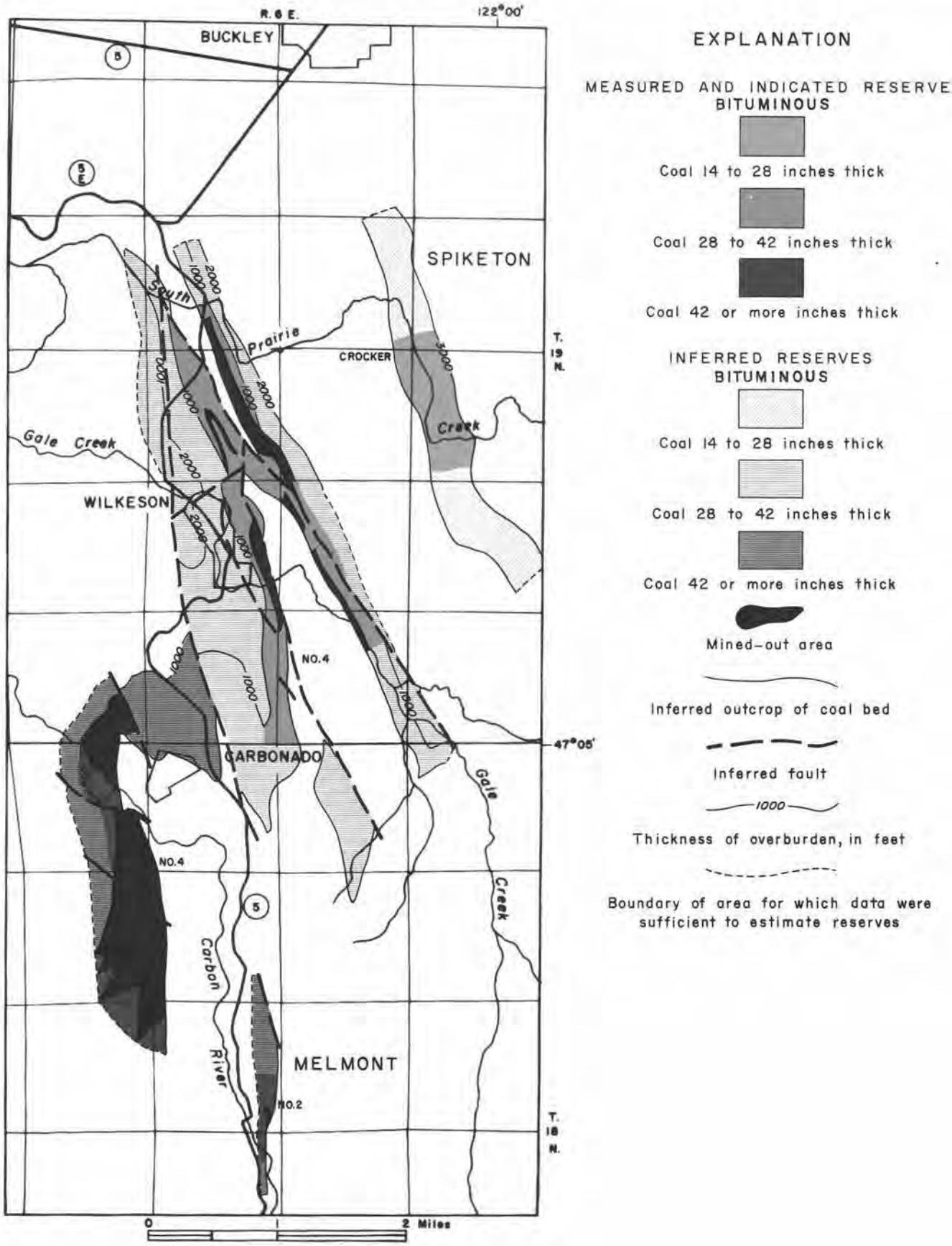


FIGURE 39. GENERALIZED MAP OF THE NO. 2 BED OF MELMONT, NO. 4 BED OF WILKESON, AND CROCKER BED OF SPIKETON

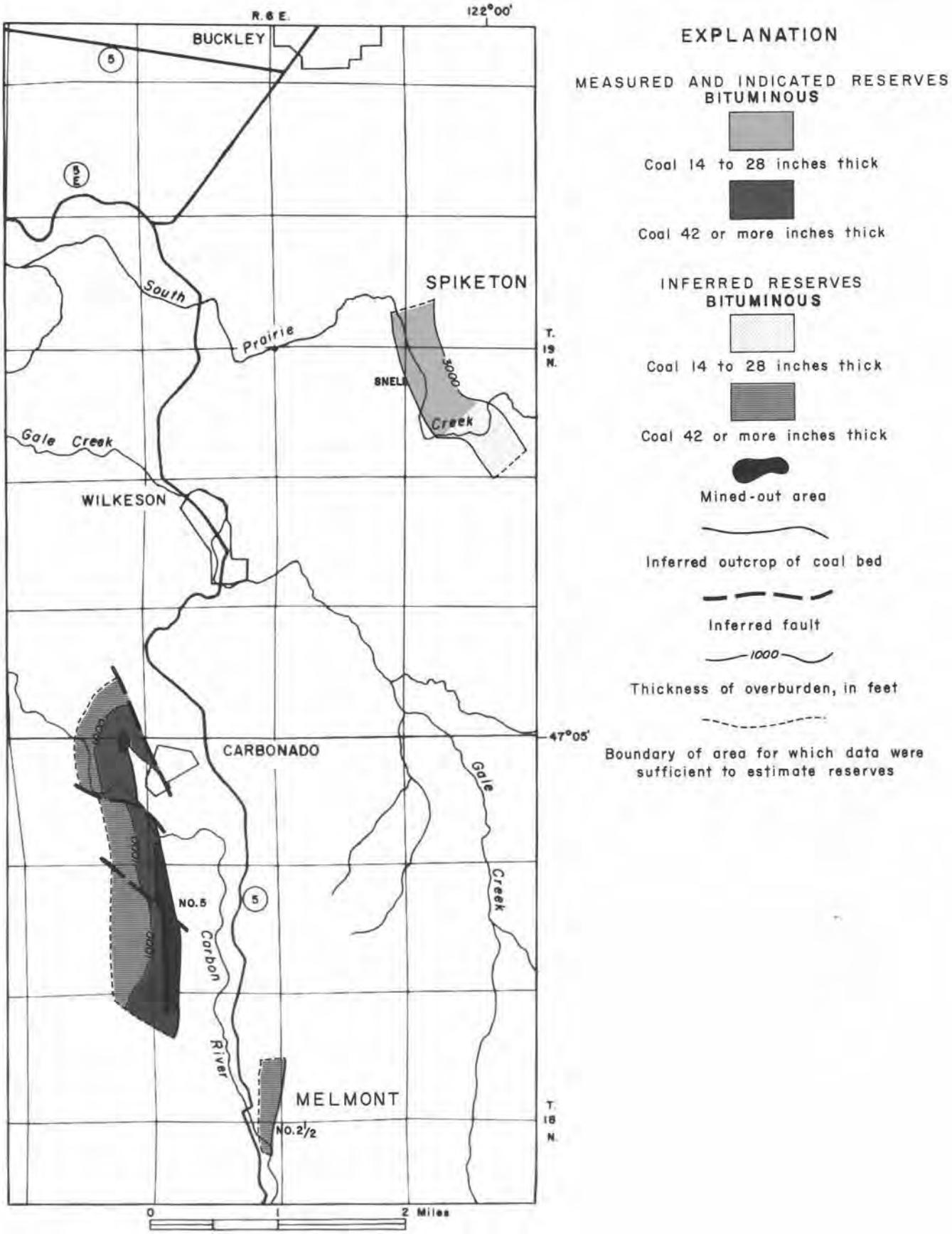


FIGURE 40. GENERALIZED MAP OF THE NO. 2½ BED OF MELMONT, NO. 5 BED OF CARBONADO, AND SNELL BED OF SPIKETON

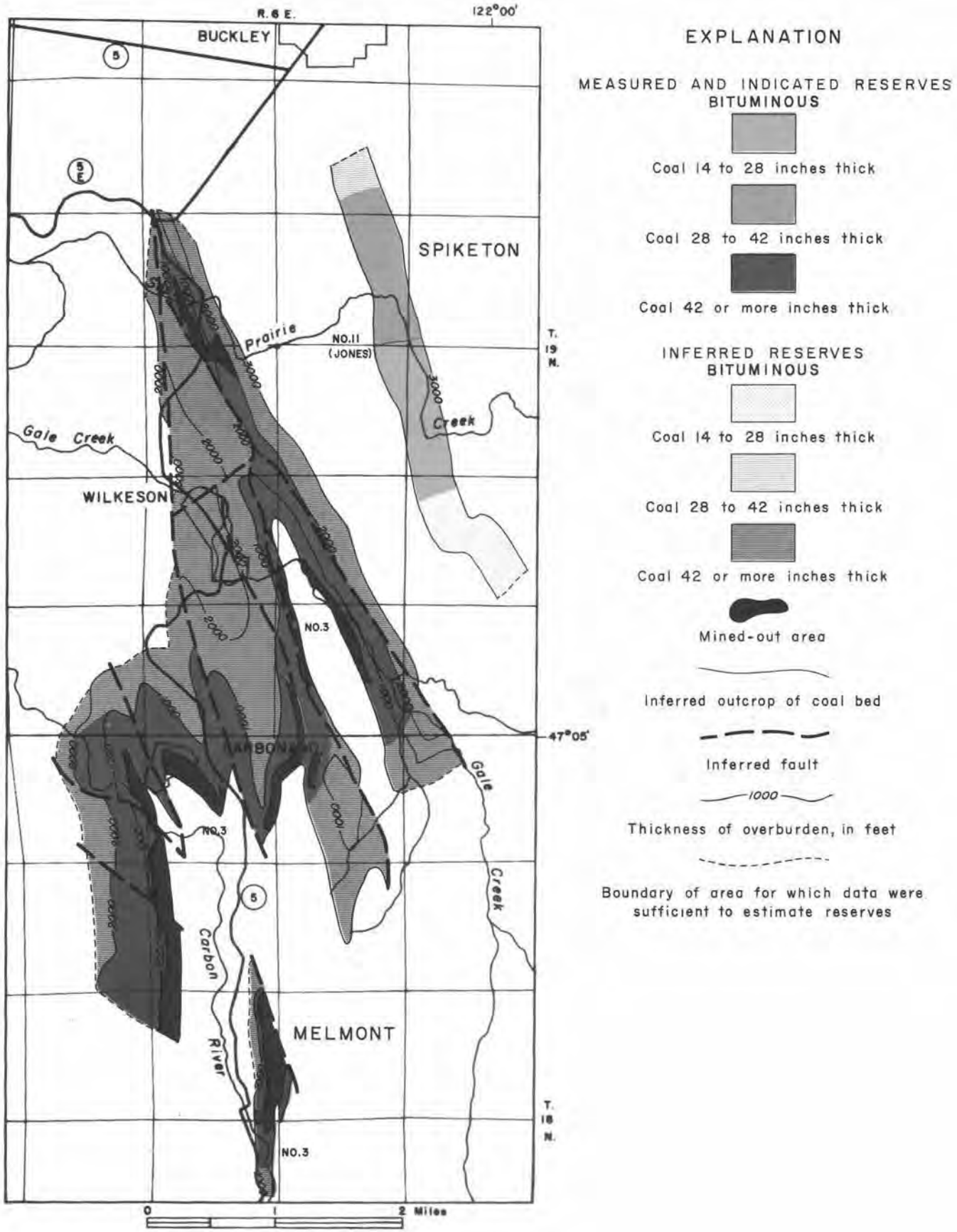


FIGURE 41. GENERALIZED MAP OF THE NO. 3 BED OF MELMONT, NO. 3 BED OF WILKESON, AND NO. 11 (JONES) BED OF SPIKETON

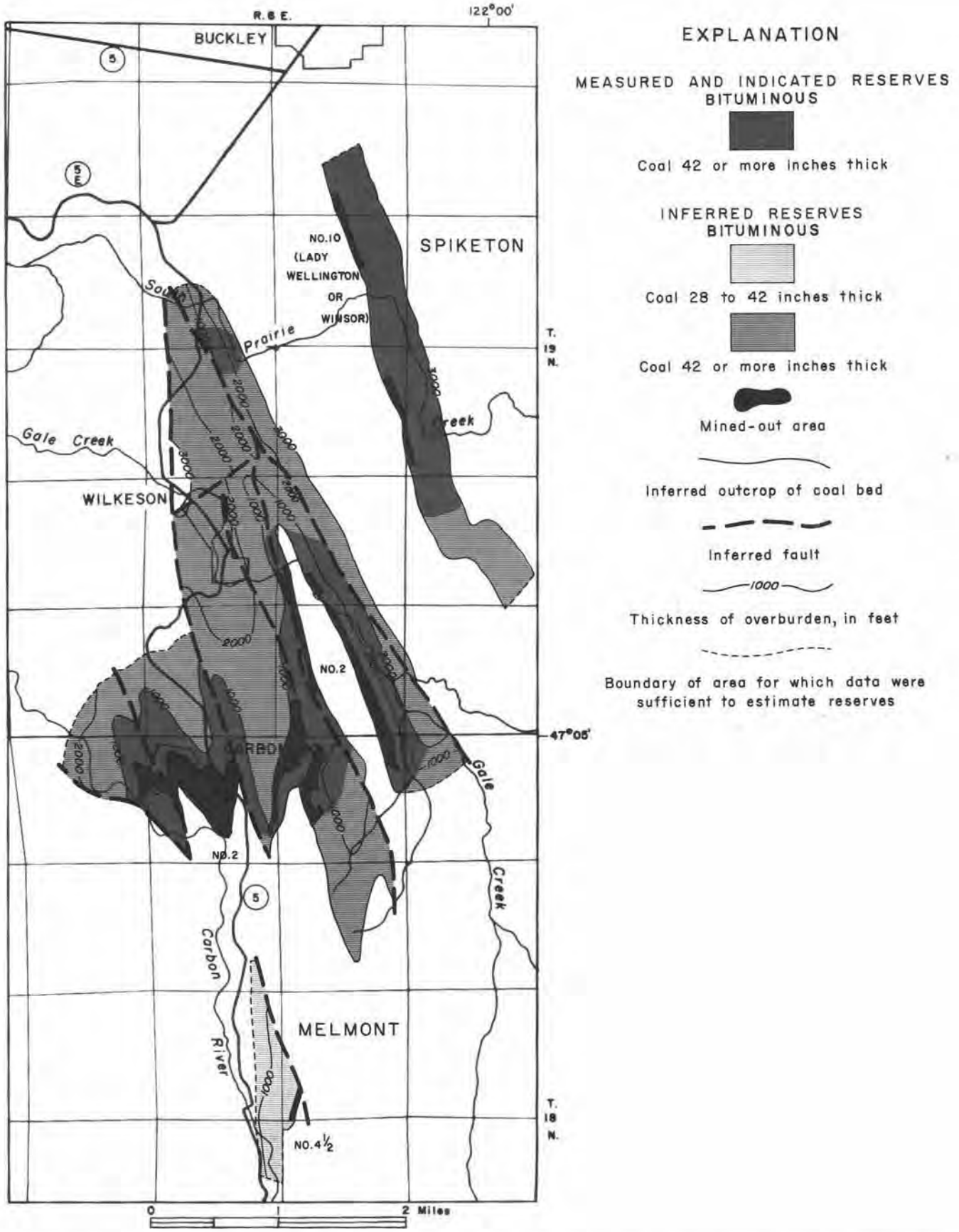


FIGURE 42. GENERALIZED MAP OF THE NO. 4½ BED OF MELMONT, NO. 2 BED OF WILKESON, AND NO. 10 (LADY WELLINGTON OR WINSOR) BED OF SPIKETON

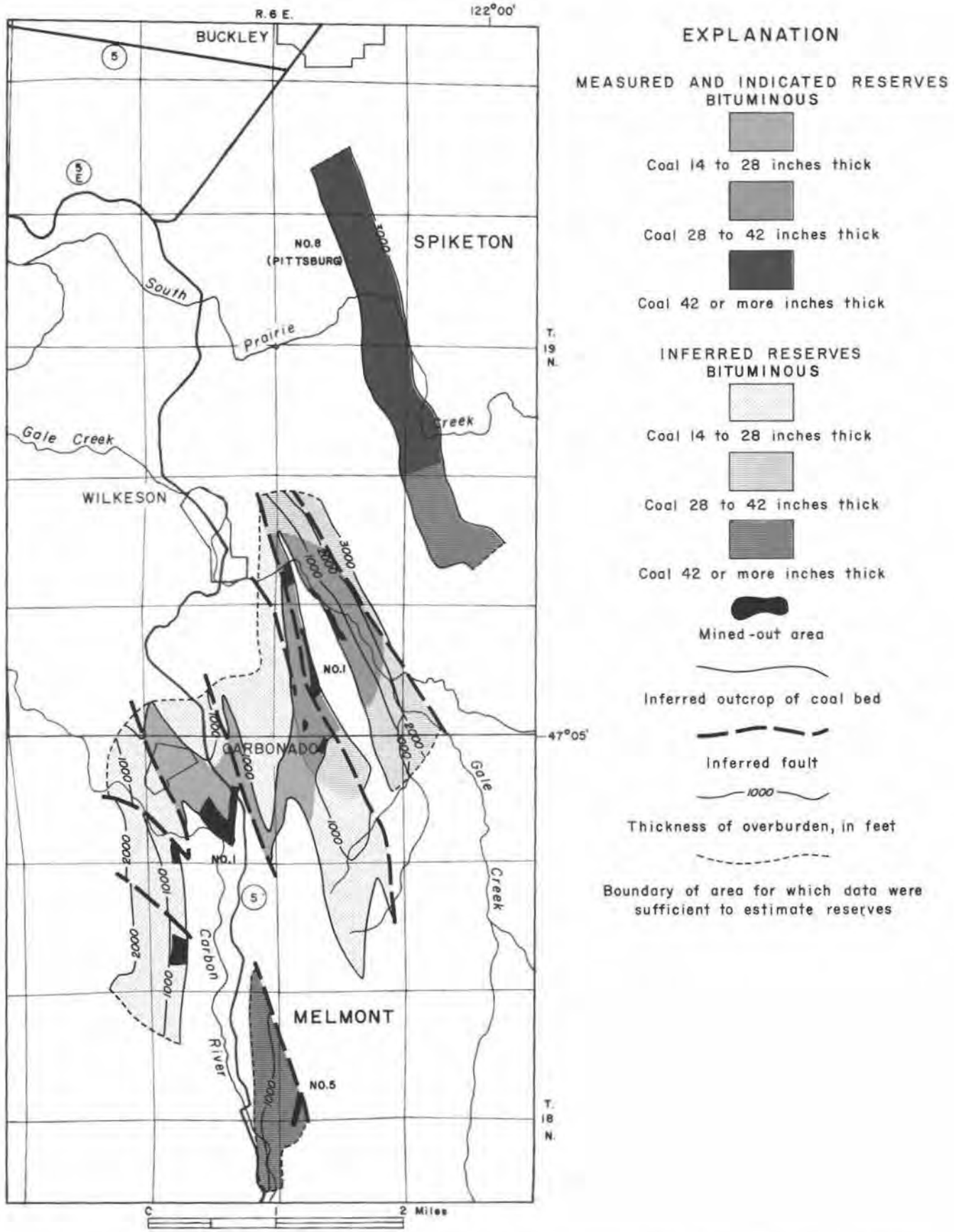


FIGURE 43. GENERALIZED MAP OF THE NO. 5 BED OF MELMONT, NO. 1 BED OF WILKESON, AND NO. 8 (PITTSBURG) BED OF SPIKETON

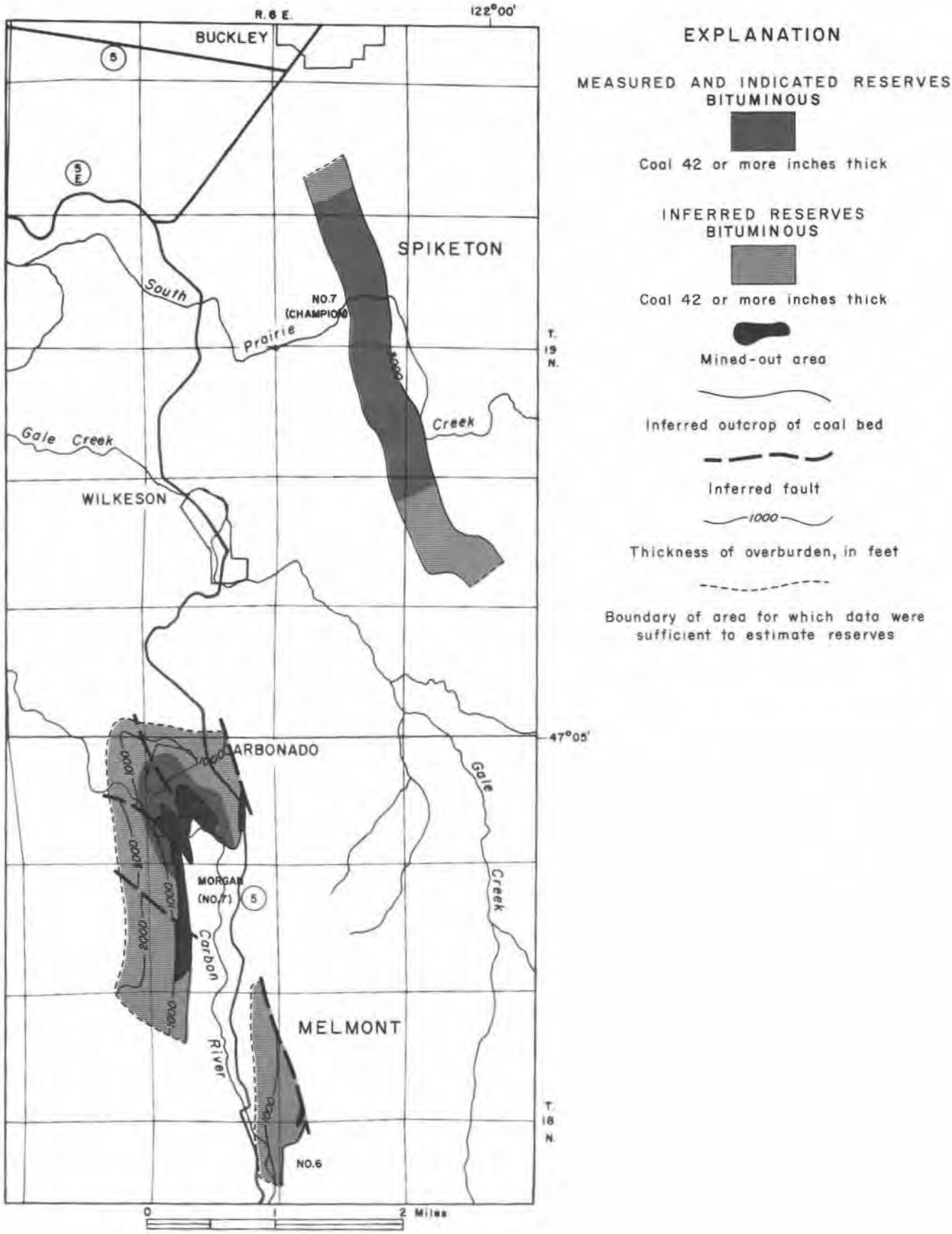


FIGURE 44. GENERALIZED MAP OF THE NO. 6 BED OF MELMONT, MORGAN (NO. 7) BED OF CARBONADO, AND NO. 7 (CHAMPION) BED OF SPIKETON

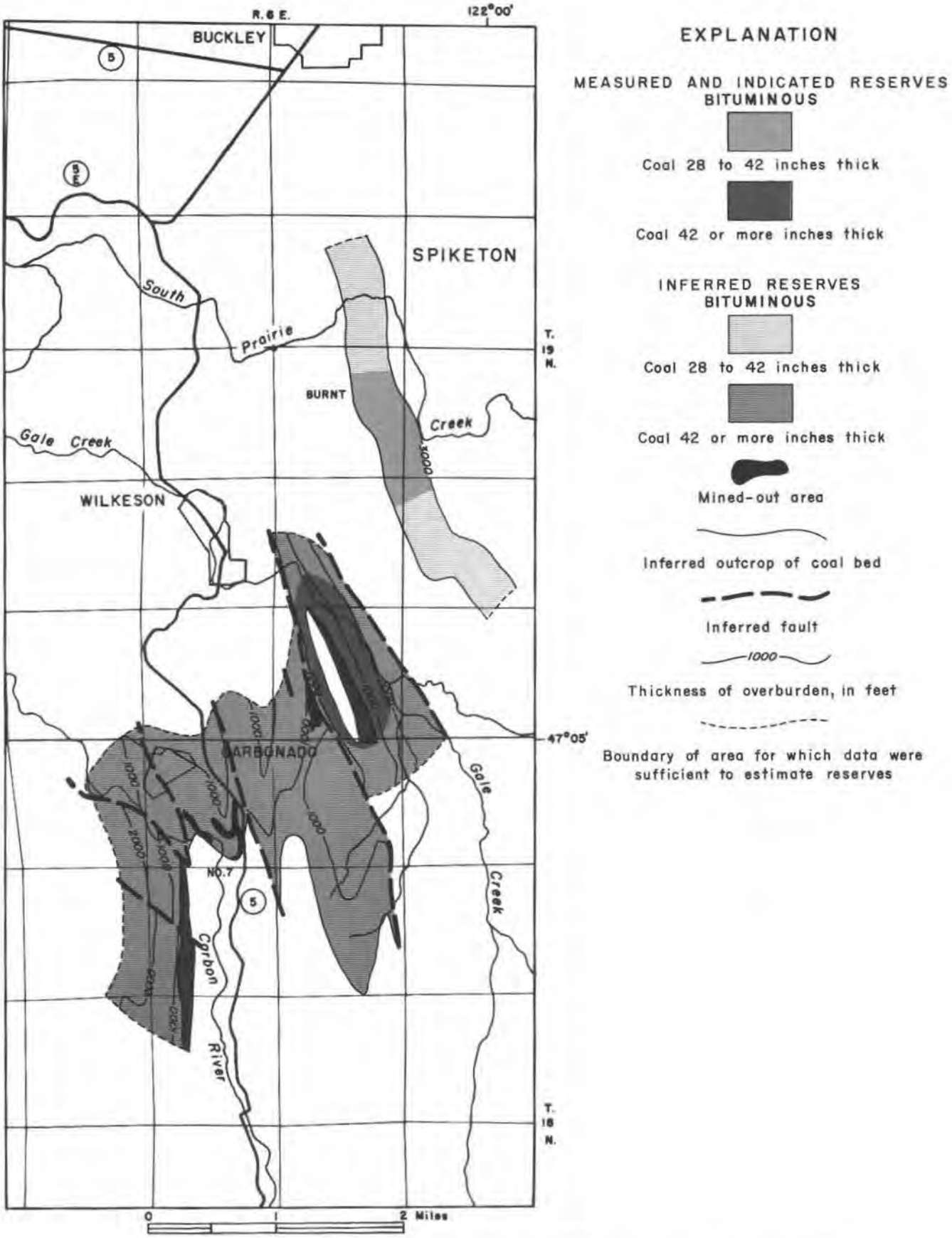


FIGURE 45. GENERALIZED MAP OF THE NO. 7 BED OF WILKESON AND BURNT BED OF SPIKETON

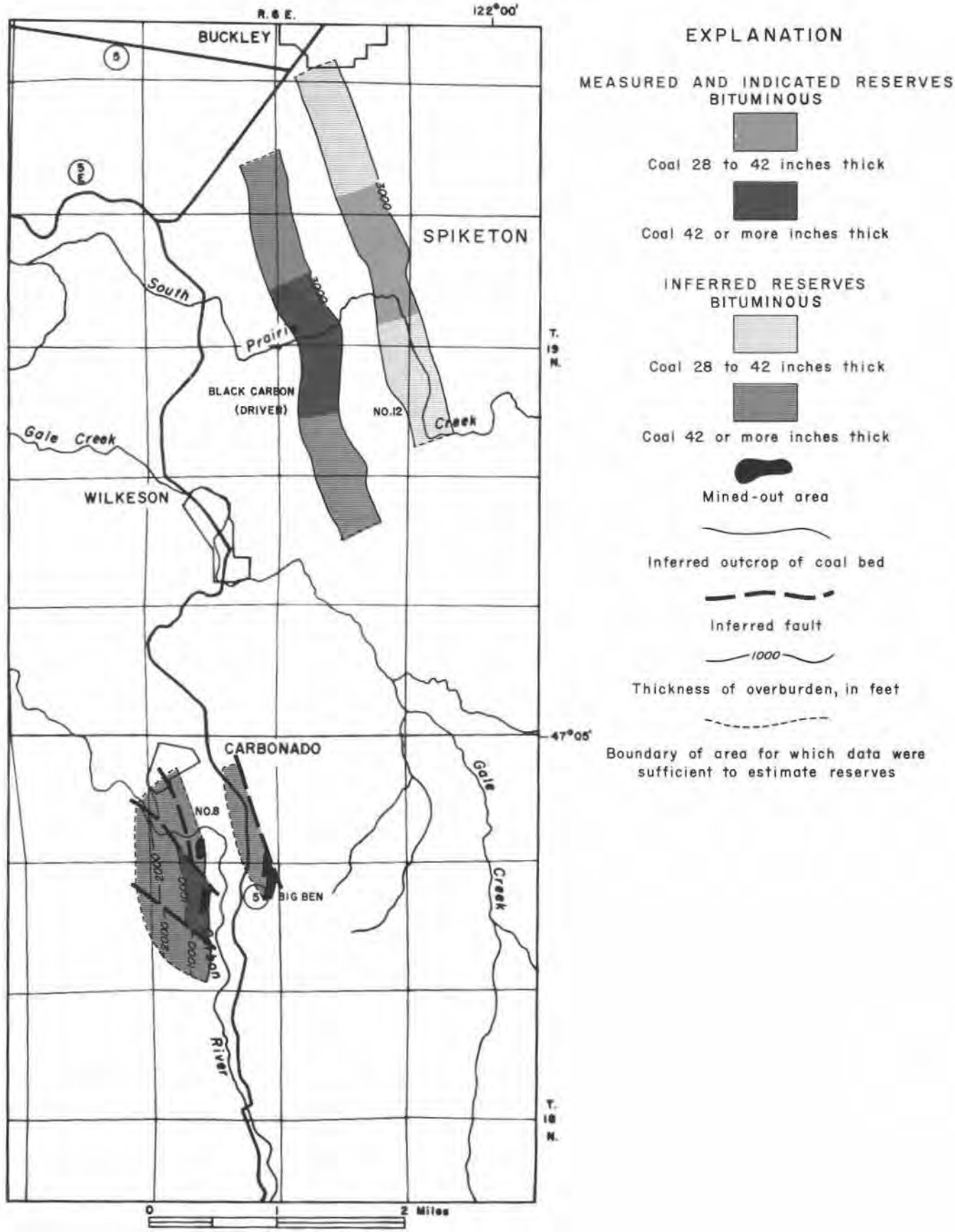


FIGURE 46. GENERALIZED MAP OF THE NO. 8 AND BIG BEN BEDS OF CARBONADO AND THE BLACK CARBON (DRIVER) AND NO. 12 BEDS OF SPIKETON

Table 21.—Averages of analyses (as-received basis) of coal samples from the Melmont area, Pierce County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Source of analyses is Fieldner and others, 1931.)

Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
	M	VM	FC	Ash			
No. 1 --------	9.2	9.4	63.7	17.7	0.7	11,130	1
No. 2 --------	5.8	12.1	64.9	17.2	.4	11,770	3
No. 3 --------	3.4	22.5	59.9	15.2	.4	12,580	2

Summary of Reserves

The total reserves of coal remaining in the ground in the Melmont area are estimated to be about 16 million tons. Approximately 10 percent of these reserves is classified as measured and indicated and 90 percent as inferred. The reserve figures by township and bed are shown in table 25, on page 83.

FAIRFAX-MONTEZUMA AND ASHFORD AREAS

Geographic and Geologic Setting

The Fairfax-Montezuma and Ashford areas (fig. 47) are in central and south-central Pierce County, south of the Wilkeson-Carbonado coal field. The coal beds in these two areas occur in the Puget Group of Eocene age, but the stratigraphic relations between them have not been positively determined.

In the Fairfax-Montezuma area, data obtained in mine workings and scattered prospects indicate that numerous small north-trending anticlines and synclines are present and that the strata are cut by many faults. At Ashford the strata have also been greatly faulted and are intruded by igneous rocks. The sedimentary rocks between the Fairfax-Montezuma and Ashford areas are known to contain coal beds, but data concerning their extent and thickness are not available.

Coal Beds

More than six coal beds have been opened or mined to varying extents in mines at Fairfax and Montezuma, but the total number of beds present is unknown. Although the mine workings are close together, the complexities of the structure and the lack of data make correlation of coal beds between the various mines impossible. The dip of the coal beds is usually more than 60°. For the purpose of estimating reserves, those coal beds on which thickness data were available were extended for limited distances along the anticlinal or synclinal structures that were apparent from the mine workings. The mine workings at Fairfax penetrated gravel on both the north and south sides of the Carbon River, indicating that the coal beds have been eroded to an undetermined depth along the present river channel. On figure 47 the maximum area for which reserves have been estimated

Table 22.—Averages of analyses (as-received basis) of coal samples from the Fairfax-Montezuma and Ashford areas, Pierce County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Fieldner and others, 1931; and Cooper and Abernethy, 1941.)

Location			Mine or prospect	Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
Sec.	T.	R.			M	VM	FC	Ash			
26	18 N.	6 E.	Fairfax -------	No. 3 (McNeill) --	1.9	23.3	64.5	10.3	0.5	13,720	1
				Blacksmith --------	3.3	21.0	63.0	12.7	.7	13,050	1
34	18 N.	6 E.	-----do------	No. 1 ----------	2.9	21.3	63.8	12.0	.7	13,240	1
				No. 2 ----------	3.0	20.6	63.4	16.3	.4	13,050	3
				No. 3 ----------	3.3	22.5	65.5	8.2	.5	13,787	3
				No. 4 ----------	2.0	21.9	64.7	11.4	.6	13,490	1
				No. 5 ----------	3.1	20.9	65.0	10.9	.4	13,390	2
			Prospect ------	No. 1 ----------	4.8	26.4	60.7	8.1	1.1	13,630	1
				No. 2 ----------	2.6	24.8	52.8	19.8	.7	11,860	1
2	17 N.	6 E.	Montezuma ---	No. 1 ----------	5.7	19.2	62.4	12.7	1.0	12,640	1
				No. 2 ----------	3.0	18.1	56.2	22.7	.7	11,250	1
				No. 3 ----------	4.0	18.1	58.5	19.4	.5	11,820	1
				No. 4 ----------	2.6	21.0	65.6	10.8	.6	13,420	1
15	15 N.	6 E.	Ashford -------	Nisqually ---------	5.8	15.3	64.7	24.2	.4	10,410	1

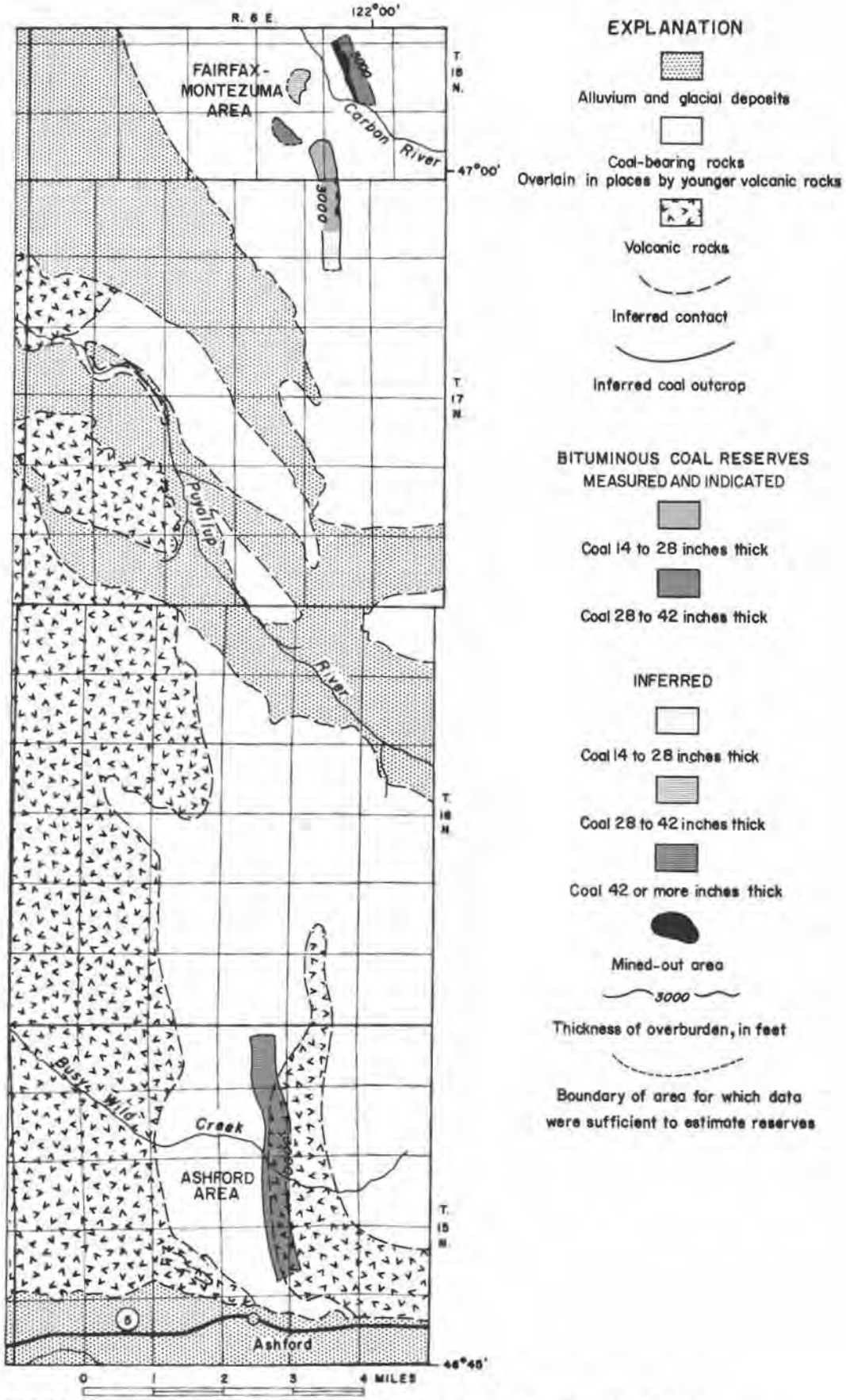


FIGURE 47. MAP OF THE FAIRFAX-MONTEZUMA AND ASHFORD COAL AREAS

Table 23.—Estimated remaining reserves of coal in the Wilkeson–Carbonado coal field, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 18 N., R. 6 E.													
Wilkeson No. 5	0–1,000	-----	0.27	2.27	2.54	-----	0.25	0.07	0.32	-----	0.52	2.34	2.86
	1,000–2,000	-----	-----	.31	.31	-----	.01	1.19	1.20	-----	.01	1.50	1.51
Bed total		-----	0.27	2.58	2.85	-----	0.26	1.26	1.52	-----	0.53	2.84	4.37
Wilkeson No. 4	0–1,000	-----	-----	1.24	1.24	-----	2.21	0.34	2.55	-----	2.21	1.58	3.79
	1,000–2,000	-----	-----	.81	.81	-----	.07	1.23	1.30	-----	.07	2.04	2.11
Bed total		-----	-----	2.05	2.05	-----	2.28	1.57	3.85	-----	2.28	3.62	5.90
Carbonado No. 5	0–1,000	-----	-----	2.71	2.71	-----	-----	-----	-----	-----	-----	2.71	2.71
	1,000–2,000	-----	-----	-----	-----	-----	-----	2.58	2.58	-----	-----	2.58	2.58
Bed total		-----	-----	2.71	2.71	-----	-----	2.58	2.58	-----	-----	5.29	5.29
Wilkeson No. 3	0–1,000	-----	-----	3.52	3.52	-----	-----	5.05	5.05	-----	-----	8.57	8.57
	1,000–2,000	-----	-----	4.06	4.06	-----	-----	2.24	2.24	-----	-----	6.30	6.30
	2,000–3,000	-----	-----	.20	.20	-----	-----	1.97	1.97	-----	-----	2.17	2.17
Bed total		-----	-----	7.78	7.78	-----	-----	9.26	9.26	-----	-----	17.04	17.04
Wilkeson No. 2	0–1,000	-----	-----	5.22	5.22	-----	-----	3.44	3.44	-----	-----	8.66	8.66
	1,000–2,000	-----	-----	.34	.34	-----	-----	3.44	3.44	-----	-----	3.78	3.78
	2,000–3,000	-----	-----	-----	-----	-----	-----	.40	.40	-----	-----	.40	.40
Bed total		-----	-----	5.56	5.56	-----	-----	7.28	7.28	-----	-----	12.84	12.84
Wilkeson No. 1	0–1,000	1.58	0.05	-----	1.63	2.69	1.03	-----	3.72	4.27	1.08	-----	5.35
	1,000–2,000	-----	-----	-----	-----	2.47	.29	-----	2.76	2.47	.29	-----	2.76
	2,000–3,000	-----	-----	-----	-----	-----	.01	-----	.01	-----	.01	-----	.01
Bed total		1.58	0.05	-----	1.63	5.16	1.33	-----	6.49	6.74	1.38	-----	8.12
Morgan (No. 7)	0–1,000	-----	-----	1.98	1.98	-----	-----	2.22	2.22	-----	-----	4.20	4.20
	1,000–2,000	-----	-----	.22	.22	-----	-----	4.41	4.41	-----	-----	4.63	4.63
	2,000–3,000	-----	-----	-----	-----	-----	-----	2.29	2.29	-----	-----	2.29	2.29
Bed total		-----	-----	2.20	2.20	-----	-----	8.92	8.92	-----	-----	11.12	11.12
Wilkeson No. 7	0–1,000	-----	-----	0.07	0.07	-----	-----	14.05	14.05	-----	-----	14.12	14.12
	1,000–2,000	-----	-----	-----	-----	-----	-----	11.18	11.18	-----	-----	11.18	11.18
	2,000–3,000	-----	-----	-----	-----	-----	-----	.30	.30	-----	-----	.30	.30
Bed total		-----	-----	0.07	0.07	-----	-----	25.53	25.53	-----	-----	25.60	25.60
Carbonado No. 8	0–1,000	-----	-----	1.08	1.08	-----	-----	2.40	2.40	-----	-----	3.48	3.48
	1,000–2,000	-----	-----	-----	-----	-----	-----	2.99	2.99	-----	-----	2.99	2.99
	2,000–3,000	-----	-----	-----	-----	-----	-----	1.59	1.59	-----	-----	1.59	1.59
Bed total		-----	-----	1.08	1.08	-----	-----	6.98	6.98	-----	-----	8.06	8.06
Big Ben	0–1,000	-----	-----	-----	-----	-----	-----	1.92	1.92	-----	-----	1.92	1.92
Township total		1.58	0.32	24.03	25.93	5.16	3.87	65.30	74.33	6.74	4.19	89.33	100.26
T. 19 N., R 6 E.													
Wilkeson No. 5	0–1,000	-----	1.73	3.60	5.33	-----	0.73	4.15	4.88	-----	2.46	7.75	10.21
	1,000–2,000	-----	.95	-----	.95	-----	1.93	3.07	5.00	-----	2.88	3.07	5.95
	2,000–3,000	-----	-----	-----	-----	-----	.15	-----	.15	-----	.15	-----	.15
Bed total		-----	2.68	3.60	6.28	-----	2.81	7.22	10.03	-----	5.49	10.82	16.31
Wilkeson No. 4	0–1,000	-----	4.61	0.03	4.64	-----	2.29	1.86	4.15	-----	6.90	1.89	8.79
	1,000–2,000	-----	-----	-----	-----	-----	7.68	.61	8.29	-----	7.68	.61	8.29
	2,000–3,000	-----	-----	-----	-----	-----	.72	-----	.72	-----	.72	-----	.72
Bed total		-----	4.61	0.03	4.64	-----	10.69	2.47	13.16	-----	15.30	2.50	17.80
Carbonado No. 5	0–1,000	-----	-----	0.35	0.35	-----	-----	-----	-----	-----	-----	0.35	0.35
	1,000–2,000	-----	-----	-----	-----	-----	-----	0.58	0.58	-----	-----	.58	.58
Bed total		-----	-----	0.35	0.35	-----	-----	0.58	0.58	-----	-----	0.93	0.93
Wilkeson No. 3	0–1,000	-----	-----	8.99	8.99	-----	-----	0.46	0.46	-----	-----	9.45	9.45
	1,000–2,000	-----	-----	7.88	7.88	-----	-----	9.75	9.75	-----	-----	17.63	17.63
	2,000–3,000	-----	-----	-----	-----	-----	-----	10.81	10.81	-----	-----	10.81	10.81
Bed total		-----	-----	16.87	16.87	-----	-----	21.02	21.02	-----	-----	37.89	37.89
Wilkeson No. 2	0–1,000	-----	-----	5.41	5.41	-----	-----	0.80	0.80	-----	-----	6.21	6.21
	1,000–2,000	-----	-----	2.44	2.44	-----	-----	11.35	11.35	-----	-----	13.79	13.79
	2,000–3,000	-----	-----	.14	.14	-----	-----	8.19	8.19	-----	-----	8.33	8.33
Bed total		-----	-----	7.99	7.99	-----	-----	20.34	20.34	-----	-----	28.33	28.33
Wilkeson No. 1	0–1,000	0.15	1.79	-----	1.94	0.19	0.64	-----	0.83	0.34	2.43	-----	2.77
	1,000–2,000	-----	.98	-----	.98	1.72	.34	-----	2.06	1.72	1.32	-----	3.04
	2,000–3,000	-----	.16	-----	.16	-----	.90	-----	.90	-----	1.06	-----	1.06
Bed total		0.15	2.93	-----	3.08	1.91	1.88	-----	3.79	2.06	4.81	-----	6.87
Morgan (No. 7)	0–1,000	-----	-----	-----	-----	-----	-----	0.01	0.01	-----	-----	0.01	0.01
	1,000–2,000	-----	-----	-----	-----	-----	-----	.64	.64	-----	-----	.64	.64
Bed total		-----	-----	-----	-----	-----	-----	0.65	0.65	-----	-----	0.65	0.65

Table 23.—Estimated remaining reserves of coal in the Wilkeson-Carbonado coal field, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 19 N., R. 6 E.—continued													
Wilkeson No. 7	0-1,000	-----	-----	3.03	3.03	-----	-----	1.31	1.31	-----	-----	4.34	4.34
	1,000-2,000	-----	-----	2.14	2.14	-----	-----	3.90	3.90	-----	-----	6.04	6.04
	2,000-3,000	-----	-----	-----	-----	-----	-----	2.65	2.65	-----	-----	2.65	2.65
Bed total		-----	-----	5.17	5.17	-----	-----	7.86	7.86	-----	-----	13.03	13.03
Township total		0.15	10.22	34.01	44.38	1.91	15.38	60.14	77.43	2.06	25.60	94.15	121.81
Grand total		1.73	10.54	58.04	70.31	7.07	19.25	125.44	151.76	8.80	29.79	183.48	222.07

Table 24.-- Estimated remaining reserves of coal in the Spiketon area, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 19 N., R. 6 E.													
Crocker	0-1,000	0.58	------	------	0.58	1.12	------	------	1.12	1.70	------	------	1.70
	1,000-2,000	.58	------	------	.58	1.12	------	------	1.12	1.70	------	------	1.70
	2,000-3,000	.58	------	------	.58	1.12	------	------	1.12	1.70	------	------	1.70
Bed total		1.74	------	------	1.74	3.36	------	------	3.36	5.10	------	------	5.10
No. 12	0-1,000	------	0.93	------	0.93	------	1.74	------	1.74	------	2.67	------	2.67
	1,000-2,000	------	.93	------	.93	------	1.74	------	1.74	------	2.67	------	2.67
	2,000-3,000	------	.93	------	.93	------	1.74	------	1.74	------	2.67	------	2.67
Bed total		------	2.79	------	2.79	------	5.22	------	5.22	------	8.01	------	8.01
No. 11	0-1,000	0.59	0.88	------	1.47	0.39	0.26	------	0.65	0.98	1.14	------	2.12
	1,000-2,000	.59	.88	------	1.47	.39	.79	------	1.18	.98	1.67	------	2.65
	2,000-3,000	.59	.88	------	1.47	.39	.79	------	1.18	.98	1.67	------	2.65
Bed total		1.77	2.64	------	4.41	1.17	1.84	------	3.01	2.94	4.48	------	7.42
No. 10	0-1,000	------	------	2.77	2.77	------	------	0.74	0.74	------	------	3.51	3.51
	1,000-2,000	------	------	3.02	3.02	------	------	1.87	1.87	------	------	4.89	4.89
	2,000-3,000	------	------	3.02	3.02	------	------	1.87	1.87	------	------	4.89	4.89
Bed total		------	------	8.81	8.81	------	------	4.48	4.48	------	------	13.29	13.29
No. 8	0-1,000	------	------	2.88	2.88	------	------	1.00	1.00	------	------	3.88	3.88
	1,000-2,000	------	------	3.07	3.07	------	------	2.12	2.12	------	------	5.19	5.19
	2,000-3,000	------	------	3.07	3.07	------	------	2.12	2.12	------	------	5.19	5.19
Bed total		------	------	9.02	9.02	------	------	5.24	5.24	------	------	14.26	14.26
Snell	0-1,000	0.37	------	------	0.37	0.24	------	------	0.24	0.61	------	------	0.61
	1,000-2,000	.37	------	------	.37	.24	------	------	.24	.61	------	------	.61
	2,000-3,000	.37	------	------	.37	.24	------	------	.24	.61	------	------	.61
Bed total		1.11	------	------	1.11	0.72	------	------	0.72	1.83	------	------	1.83
No. 7	0-1,000	------	------	2.67	2.67	------	------	1.22	1.22	------	------	3.89	3.89
	1,000-2,000	------	------	2.67	2.67	------	------	2.03	2.03	------	------	4.70	4.70
	2,000-3,000	------	------	2.67	2.67	------	------	2.03	2.03	------	------	4.70	4.70
Bed total		------	------	8.01	8.01	------	------	5.28	5.28	------	------	13.29	13.29
Burnt	0-1,000	------	0.76	------	0.76	------	1.60	------	1.60	------	2.36	------	2.36
	1,000-2,000	------	.76	------	.76	------	1.60	------	1.60	------	2.36	------	2.36
	2,000-3,000	------	.76	------	.76	------	1.60	------	1.60	------	2.36	------	2.36
Bed total		------	2.28	------	2.28	------	4.80	------	4.80	------	7.08	------	7.08
No. 6	0-1,000	0.36	0.47	1.17	2.00	0.42	------	0.23	0.65	0.78	0.47	1.40	2.65
	1,000-2,000	.36	.47	1.17	2.00	.42	------	1.09	1.51	.78	.47	2.26	3.51
	2,000-3,000	.36	.47	1.17	2.00	.42	------	1.09	1.51	.78	.47	2.26	3.51
Bed total		1.08	1.41	3.51	6.00	1.26	------	2.41	3.67	2.34	1.41	5.92	9.67
Black Carbon	0-1,000	------	------	1.18	1.18	------	------	1.49	1.49	------	------	2.67	2.67
	1,000-2,000	------	------	1.18	1.18	------	------	1.93	1.93	------	------	3.11	3.11
	2,000-3,000	------	------	1.18	1.18	------	------	1.93	1.93	------	------	3.11	3.11
Bed total		------	------	3.54	3.54	------	------	5.35	5.35	------	------	8.89	8.89
Grand total		5.70	9.12	32.89	47.71	6.51	11.86	22.76	41.13	12.21	20.98	55.65	88.84

Table 25.—Estimated remaining reserves of coal in the Melmont area, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 18 N., R. 6 E.													
No. 1	0-1,000	------	------	0.29	0.29	------	------	0.47	0.47	------	------	0.76	0.76
No. 2	0-1,000	------	------	1.25	1.25	------	------	2.37	2.37	------	------	3.62	3.62
	1,000-2,000	------	------	------	------	------	------	.25	.25	------	------	.25	.25
Bed total		------	------	1.25	1.25	------	------	2.62	2.62	------	------	3.87	3.87
No. 2½	0-1,000	------	------	------	------	------	------	1.28	1.28	------	------	1.28	1.28
No. 3	0-1,000	------	------	0.04	0.04	------	------	0.29	0.29	------	------	0.33	0.33
	1,000-2,000	------	------	------	------	------	------	.69	.69	------	------	.69	.69
Bed total		------	------	0.04	0.04	------	------	0.98	0.98	------	------	1.02	1.02
No. 4½	0-1,000	------	------	------	------	------	0.99	------	0.99	------	0.99	------	0.99
	1,000-2,000	------	------	------	------	------	.65	------	.65	------	.65	------	.65
Bed total		------	------	------	------	------	1.64	------	1.64	------	1.64	------	1.64
No. 5	0-1,000	------	------	------	------	------	------	2.32	2.32	------	------	2.32	2.32
	1,000-2,000	------	------	------	------	------	------	1.69	1.69	------	------	1.69	1.69
Bed total		------	------	------	------	------	------	4.01	4.01	------	------	4.01	4.01
No. 6	0-1,000	------	------	------	------	------	------	1.73	1.73	------	------	1.73	1.73
	1,000-2,000	------	------	------	------	------	------	2.18	2.18	------	------	2.18	2.18
Bed total		------	------	------	------	------	------	3.91	3.91	------	------	3.91	3.91
Grand total		------	------	1.58	1.58	------	1.64	13.27	14.91	------	1.64	14.85	16.49

for any one coal bed is shown, and the reserves by individual bed are given in table 26; however, due to the lack of correlation between coal beds and the restricted area of reserves, individual maps of the various coal beds are not presented.

Numerous coal beds are believed to occur near Ashford, but, according to Daniels (1914, p. 42), "they are not commercially minable because of the structural difficulties involved." Accordingly, reserves have been estimated for only the one coal bed that has been mined. The strike of this bed is north-northwest and the dip is about 55° to the east. The bed is very much disrupted by faulting. It consists of two benches and is reported to be more than 10 feet thick in places. Coal reserves are shown in table 27, on page 85.

Physical and chemical properties.—The coal in the Fairfax-Montezuma area is of medium-volatile bituminous rank, and the coal at Ashford is of high-volatile A bituminous rank. The coal at both localities is reported to have coking qualities. The ash content of the coal in the Fairfax-Montezuma area ranges from 7.9 to 22.7 percent and averages 14 percent; the moisture content ranges from 1.9 to 5.7 percent and averages about 3 percent; and the sulfur content ranges from 0.4 to 1.1 percent and averages 0.6 percent. According to the one analysis of the coal at Ashford, the ash content is 24.2 percent, the moisture content is 5.8 percent, and the sulfur content is 0.4 percent. Analyses are given in table 22, on page 79.

Coal Mining

Four mines have been in operation in the Fairfax-Montezuma area, and numerous prospects have been opened. At Ashford, several prospects have been opened, and one mine was worked to a very limited extent. About 700,000 tons of coal has been mined in the Fairfax-Montezuma area. This is less than 3 percent of the total Pierce County production. Only about 1,000 tons was mined at Ashford.

Summary of Reserves

The reserves of coal in the Fairfax-Montezuma area are estimated to total 21 million tons, of which about 60 percent is classed as measured and indicated. For the Ashford area, 13 million tons of coal reserves have been estimated, all classed as inferred. Additional data regarding the thickness and distribution of coal beds in these and surrounding areas, obtained through detailed geologic mapping, would greatly increase these reserve estimates.

Table 26.—Estimated remaining reserves of coal in the Fairfax-Montezuma area, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 17 N., R. 6 E.													
No. 1	0-1,000	0.08	-----	-----	0.08	0.19	-----	-----	0.19	0.27	-----	-----	0.27
	1,000-2,000	.08	-----	-----	.08	.19	-----	-----	.19	.27	-----	-----	.27
	2,000-3,000	.08	-----	-----	.08	.19	-----	-----	.19	.27	-----	-----	.27
Bed total		0.24	-----	-----	0.24	0.57	-----	-----	0.57	0.81	-----	-----	0.81
No. 2	0-1,000	0.15	-----	-----	0.15	0.25	-----	-----	0.25	0.40	-----	-----	0.40
	1,000-2,000	.15	-----	-----	.15	.25	-----	-----	.25	.40	-----	-----	.40
	2,000-3,000	.15	-----	-----	.15	.25	-----	-----	.25	.40	-----	-----	.40
Bed total		0.45	-----	-----	0.45	0.75	-----	-----	0.75	1.20	-----	-----	1.20
No. 3	0-1,000	0.10	0.36	-----	0.46	-----	0.34	-----	0.34	0.10	0.70	-----	0.80
	1,000-2,000	.10	.36	-----	.46	-----	.34	-----	.34	.10	.70	-----	.80
	2,000-3,000	.10	.36	-----	.46	-----	.34	-----	.34	.10	.70	-----	.80
Bed total		0.30	1.08	-----	1.38	-----	1.02	-----	1.02	0.30	2.10	-----	2.40
No. 4	0-1,000	-----	0.40	-----	0.40	-----	0.17	-----	0.17	-----	0.57	-----	0.57
	1,000-2,000	-----	.40	-----	.40	-----	.17	-----	.17	-----	.57	-----	.57
	2,000-3,000	-----	.40	-----	.40	-----	.17	-----	.17	-----	.57	-----	.57
Bed total		-----	1.20	-----	1.20	-----	0.51	-----	0.51	-----	1.71	-----	1.71
No. 5	0-1,000	0.05	0.38	-----	0.43	-----	0.29	-----	0.29	0.05	0.67	-----	0.72
	1,000-2,000	.05	.38	-----	.43	-----	.29	-----	.29	.05	.67	-----	.72
	2,000-3,000	.05	.38	-----	.43	-----	.29	-----	.29	.05	.67	-----	.72
Bed total		0.15	1.14	-----	1.29	-----	0.87	-----	0.87	0.15	2.01	-----	2.16
No. 6	0-1,000	0.44	-----	-----	0.44	0.27	-----	-----	0.27	0.71	-----	-----	0.71
	1,000-2,000	.44	-----	-----	.44	.27	-----	-----	.27	.71	-----	-----	.71
	2,000-3,000	.44	-----	-----	.44	.27	-----	-----	.27	.71	-----	-----	.71
Bed total		1.32	-----	-----	1.32	0.81	-----	-----	0.81	2.13	-----	-----	2.13
Township total		2.46	3.42	-----	5.88	2.13	2.40	-----	4.53	4.59	5.82	-----	10.41
T. 18 N., R. 6 E. (North of Carbon River)													
Blacksmith	0-1,000	0.37	-----	-----	0.37	-----	-----	-----	-----	0.37	-----	-----	0.37
	1,000-2,000	.37	-----	-----	.37	-----	-----	-----	-----	.37	-----	-----	.37
	2,000-3,000	.37	-----	-----	.37	-----	-----	-----	-----	.37	-----	-----	.37
Bed total		1.11	-----	-----	1.11	-----	-----	-----	-----	1.11	-----	-----	1.11
No. 2	0-1,000	0.20	-----	-----	0.20	-----	-----	-----	-----	0.20	-----	-----	0.20
	1,000-2,000	.20	-----	-----	.20	-----	-----	-----	-----	.20	-----	-----	.20
	2,000-3,000	.20	-----	-----	.20	-----	-----	-----	-----	.20	-----	-----	.20
Bed total		0.60	-----	-----	0.60	-----	-----	-----	-----	0.60	-----	-----	0.60
McNeill	0-1,000	-----	0.63	-----	0.63	-----	-----	-----	-----	-----	0.63	-----	0.63
	1,000-2,000	-----	.82	-----	.82	-----	-----	-----	-----	-----	.82	-----	.82
	2,000-3,000	-----	.82	-----	.82	-----	-----	-----	-----	-----	.82	-----	.82
Bed total		-----	2.27	-----	2.27	-----	-----	-----	-----	-----	2.27	-----	2.27
(South of Carbon River)													
No. 1	0-1,000	0.15	-----	-----	0.15	-----	-----	-----	-----	0.15	-----	-----	0.15
	1,000-2,000	.15	-----	-----	.15	-----	-----	-----	-----	.15	-----	-----	.15
	2,000-3,000	.15	-----	-----	.15	-----	-----	-----	-----	.15	-----	-----	.15
Bed total		0.45	-----	-----	0.45	-----	-----	-----	-----	0.45	-----	-----	0.45
No. 2	0-1,000	0.21	-----	-----	0.21	-----	-----	-----	-----	0.21	-----	-----	0.21
	1,000-2,000	.21	-----	-----	.21	-----	-----	-----	-----	.21	-----	-----	.21
	2,000-3,000	.21	-----	-----	.21	-----	-----	-----	-----	.21	-----	-----	.21
Bed total		0.63	-----	-----	0.63	-----	-----	-----	-----	0.63	-----	-----	0.63
No. 3	0-1,000	0.21	-----	-----	0.21	0.07	-----	-----	0.07	0.28	-----	-----	0.28
	1,000-2,000	.21	-----	-----	.21	.07	-----	-----	.07	.28	-----	-----	.28
	2,000-3,000	.21	-----	-----	.21	.07	-----	-----	.07	.28	-----	-----	.28
Bed total		0.63	-----	-----	0.63	0.21	-----	-----	0.21	0.84	-----	-----	0.84
No. 4	0-1,000	0.09	0.05	-----	0.14	0.04	-----	-----	0.04	0.13	0.05	-----	0.18
	1,000-2,000	.09	.05	-----	.14	.04	-----	-----	.04	.13	.05	-----	.18
	2,000-3,000	.09	.05	-----	.14	.04	-----	-----	.04	.13	.05	-----	.18
Bed total		0.27	0.15	-----	0.42	0.12	-----	-----	0.12	0.39	0.15	-----	0.54
No. 5	0-1,000	0.13	-----	-----	0.13	0.08	-----	-----	0.08	0.21	-----	-----	0.21
	1,000-2,000	.13	-----	-----	.13	.08	-----	-----	.08	.21	-----	-----	.21
	2,000-3,000	.13	-----	-----	.13	.08	-----	-----	.08	.21	-----	-----	.21
Bed total		0.39	-----	-----	0.39	0.24	-----	-----	0.24	0.63	-----	-----	0.63

Table 26.—Estimated remaining reserves of coal in the Fairfax-Montezuma area, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 18 N., R. 6 E. (South of Carbon River)—continued													
No. 6	0-1,000	0.23	-----	-----	0.23	0.11	-----	-----	0.11	0.34	-----	-----	0.34
	1,000-2,000	.23	-----	-----	.23	.11	-----	-----	.11	.34	-----	-----	.34
	2,000-3,000	.23	-----	-----	.23	.11	-----	-----	.11	.34	-----	-----	.34
Bed total		0.69	-----	-----	0.69	0.33	-----	-----	0.33	1.02	-----	-----	1.02
Unnamed	0-1,000	-----	-----	-----	-----	-----	0.31	-----	0.31	-----	0.31	-----	0.31
	1,000-2,000	-----	-----	-----	-----	-----	.31	-----	.31	-----	.31	-----	.31
	2,000-3,000	-----	-----	-----	-----	-----	.31	-----	.31	-----	.31	-----	.31
Bed total		-----	-----	-----	-----	-----	0.93	-----	0.93	-----	0.93	-----	0.93
Unnamed	0-1,000	-----	-----	-----	-----	-----	0.24	-----	0.24	-----	0.24	-----	0.24
	1,000-2,000	-----	-----	-----	-----	-----	.24	-----	.24	-----	.24	-----	.24
	2,000-3,000	-----	-----	-----	-----	-----	.24	-----	.24	-----	.24	-----	.24
Bed total		-----	-----	-----	-----	-----	0.72	-----	0.72	-----	0.72	-----	0.72
Unnamed	0-1,000	-----	-----	-----	-----	-----	-----	0.33	0.33	-----	-----	0.33	0.33
	1,000-2,000	-----	-----	-----	-----	-----	-----	.33	.33	-----	-----	.33	.33
	2,000-3,000	-----	-----	-----	-----	-----	-----	.33	.33	-----	-----	.33	.33
Bed total		-----	-----	-----	-----	-----	-----	0.99	0.99	-----	-----	0.99	0.99
Township total		4.77	2.42	-----	7.19	0.90	1.65	0.99	3.54	5.67	4.07	0.99	10.73
Grand total		7.23	5.84	-----	13.07	3.03	4.05	0.99	8.07	10.26	9.89	0.99	21.14

Table 27.—Estimated remaining reserves of coal in the Ashford area, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 15 N., R. 6 E.													
Nisqually	0-1,000	-----	-----	-----	-----	-----	-----	4.47	4.47	-----	-----	4.47	4.47
	1,000-2,000	-----	-----	-----	-----	-----	-----	4.47	4.47	-----	-----	4.47	4.47
	2,000-3,000	-----	-----	-----	-----	-----	-----	4.47	4.47	-----	-----	4.47	4.47
Bed total		-----	-----	-----	-----	-----	-----	13.41	13.41	-----	-----	13.41	13.41
Township total		-----	-----	-----	-----	-----	-----	13.41	13.41	-----	-----	13.41	13.41

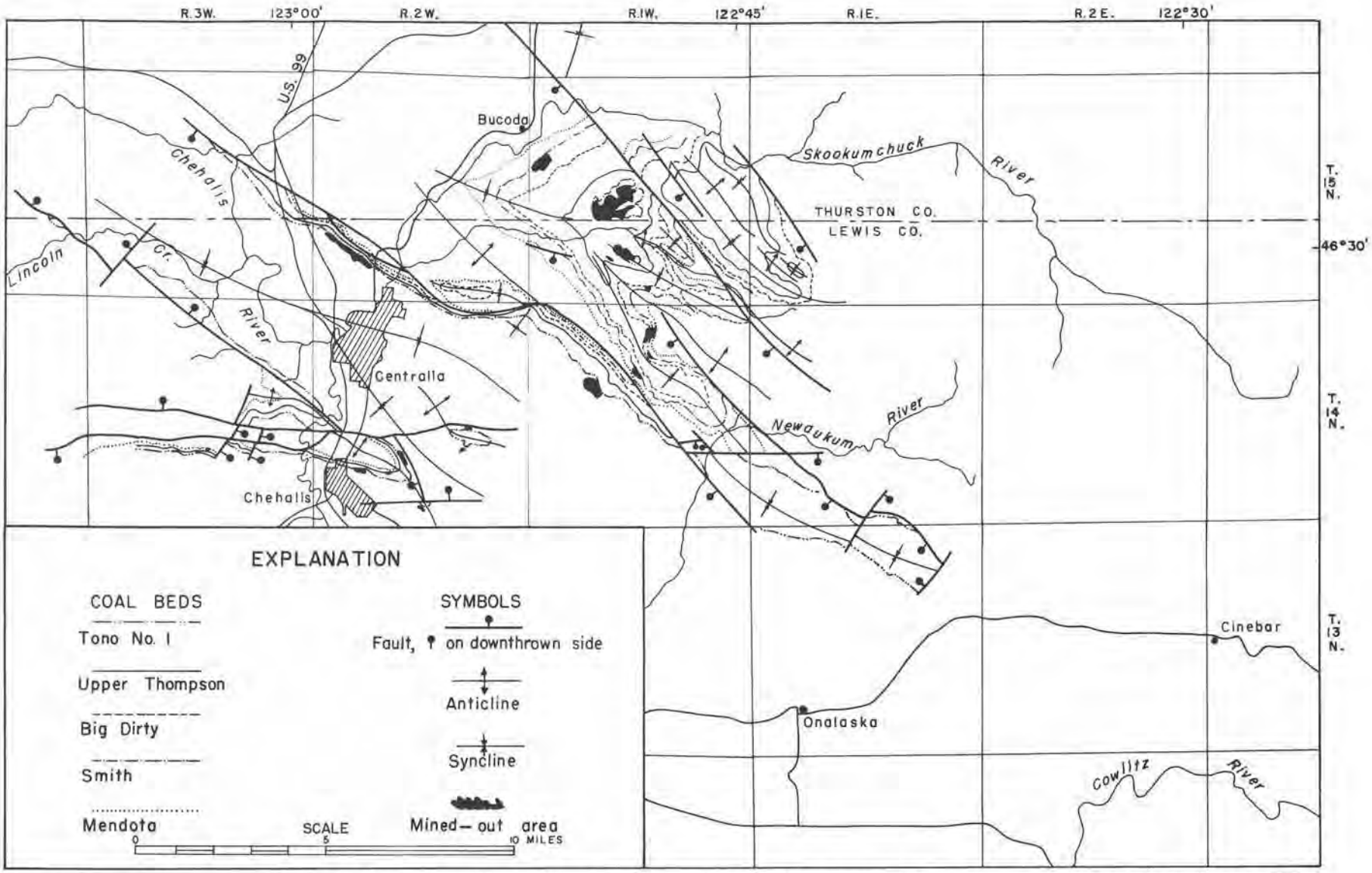


Figure 48. Index map of the Centralia – Chehalis district showing principal coal beds and structural features
(After Snavely and others, 1958)

CENTRALIA-CHEHALIS COAL DISTRICT, LEWIS AND THURSTON COUNTIES

Geographic and Geologic Setting

The Centralia-Chehalis coal district is in southwestern Thurston and northwestern Lewis Counties (fig. 1) and lies midway between Seattle, Washington, and Portland, Oregon. The information presented here is summarized from a report by Snavely and others (1958), which was based on surface mapping of coal beds supplemented by a small amount of test drilling.

The Centralia-Chehalis district extends over an area of more than 200 square miles and is the largest of the subbituminous coal fields in Washington. The coal beds in the district are in the upper and lower parts of the Skookumchuck Formation of late Eocene age. Non-coal-bearing rocks in a sequence about 1,000 feet thick separate the lower coal bed from the coal beds in the upper part of the formation. Generally, the coal beds are thickest and most persistent in the Tono basin, which is in T. 15 N., R. 1 W.

The rocks in this district have been folded and faulted, and most of the major structural elements trend northwest (fig. 48). The faults, most of which are downthrown to the south or southwest, are high angle, and they displace beds in the coal sequence as much as 1,500 feet; however, displacements are commonly less than 200 feet. The strata in the western half of the area are folded into broad open structures, and the strata in the eastern half are generally more closely folded. Most of the anticlines are long and narrow and are commonly faulted along their axes, whereas most of the synclines are broad and open.

Coal Beds

At least 14 different coal beds, whose stratigraphic positions are shown diagrammatically on figure 49, crop out in the Centralia-Chehalis district. The dip of these beds ranges from horizontal to vertical, and in areas where the beds are steeply dipping, the coal is commonly brecciated and generally shows evidence of bedding-plane slippage. Individual coal beds in the district range in thickness from a few inches to more than 40 feet; the average thickness of most beds is between 6 and 8 feet. The outcrop lines of the principal coal beds are shown on figure 48; however, the positions of these lines are largely inferred, because the coal is generally obscured by landslide debris, soil, and vegetation.

The location and classification of reserves by individual beds are shown on figures 50 through 58 on pages 89 to 97. As less than 30 inches of coal was measured in the Bear Creek bed, it has been omitted from the reserve estimate.

Physical and chemical properties.—The coal beds in the Centralia-Chehalis district range in rank from lignite to subbituminous B; most of the coal is subbituminous C. Partings of bone, carbonaceous shale, tuffaceous siltstone, and tuff are interbedded with the coal. The ash content of the coal ranges from 4.6 to 24.9 percent and averages about 10 percent. The moisture content ranges from 4 to 35 percent. In some of the coal beds fine grains of disseminated pyrite contribute to the sulfur content, which ranges from 0.3 to 4.5 percent. Averages of analyses of the coal are given in table 28.

Table 28.—Averages of analyses (as-received basis) of coal samples from the Centralia-Chehalis district, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Sources of analyses are Smith, 1911; Culver, 1919; Fieldner and others, 1931; Cooper and Abernethy, 1941; and Daniels and others, 1958.)

Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
	M	VM	FC	Ash			
Golden Glow	29.0	34.8	28.6	7.6	1.4	8,053	3
D & F	16.8	33.9	32.0	17.3	4.0	8,700	3
Tono No. 1	26.9	32.6	32.5	7.9	.9	8,218	46
Tono No. 2	24.4	32.4	33.9	9.3	1.9	8,270	1
Upper Thompson	26.4	32.1	30.6	10.8	1.1	7,756	9
Lower Thompson	26.1	31.0	30.9	12.0	1.5	7,810	1
Big Dirty	24.9	31.7	33.2	10.1	.7	8,350	2
Little Dirty	24.4	33.1	31.6	11.1	1.4	8,235	2
Smith	22.8	29.7	29.5	10.1	.6	8,763	8
Penitentiary	25.5	30.6	31.2	12.7	4.4	7,530	1
Mendota	22.0	32.0	33.1	12.9	1.7	8,343	8
Black Bear	18.8	31.1	30.4	19.7	2.2	7,877	3

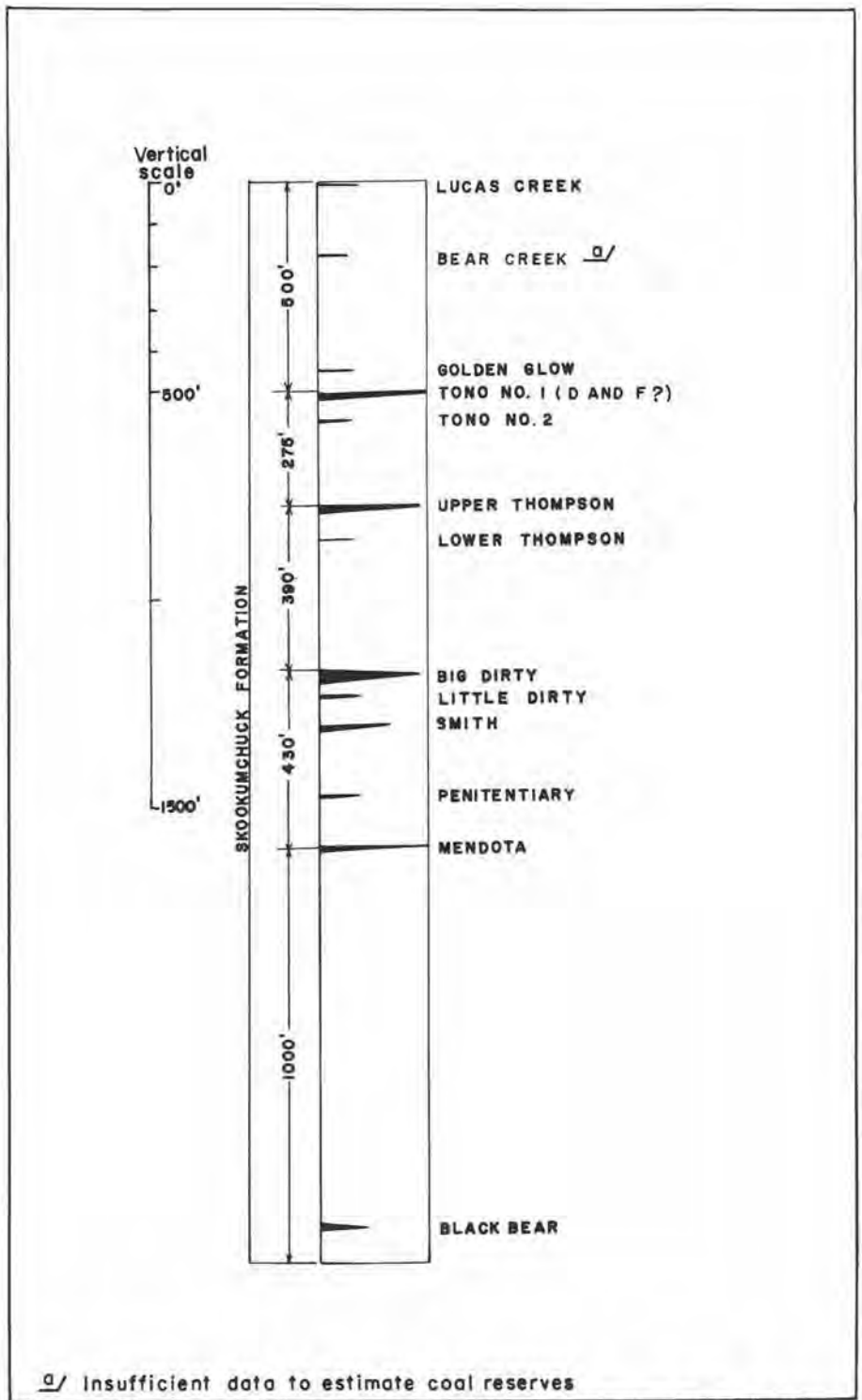


Figure 49. Generalized section showing principal coal beds in the Centralia-Chehalis district (Modified from figure 25 of Snavely and others, 1958)

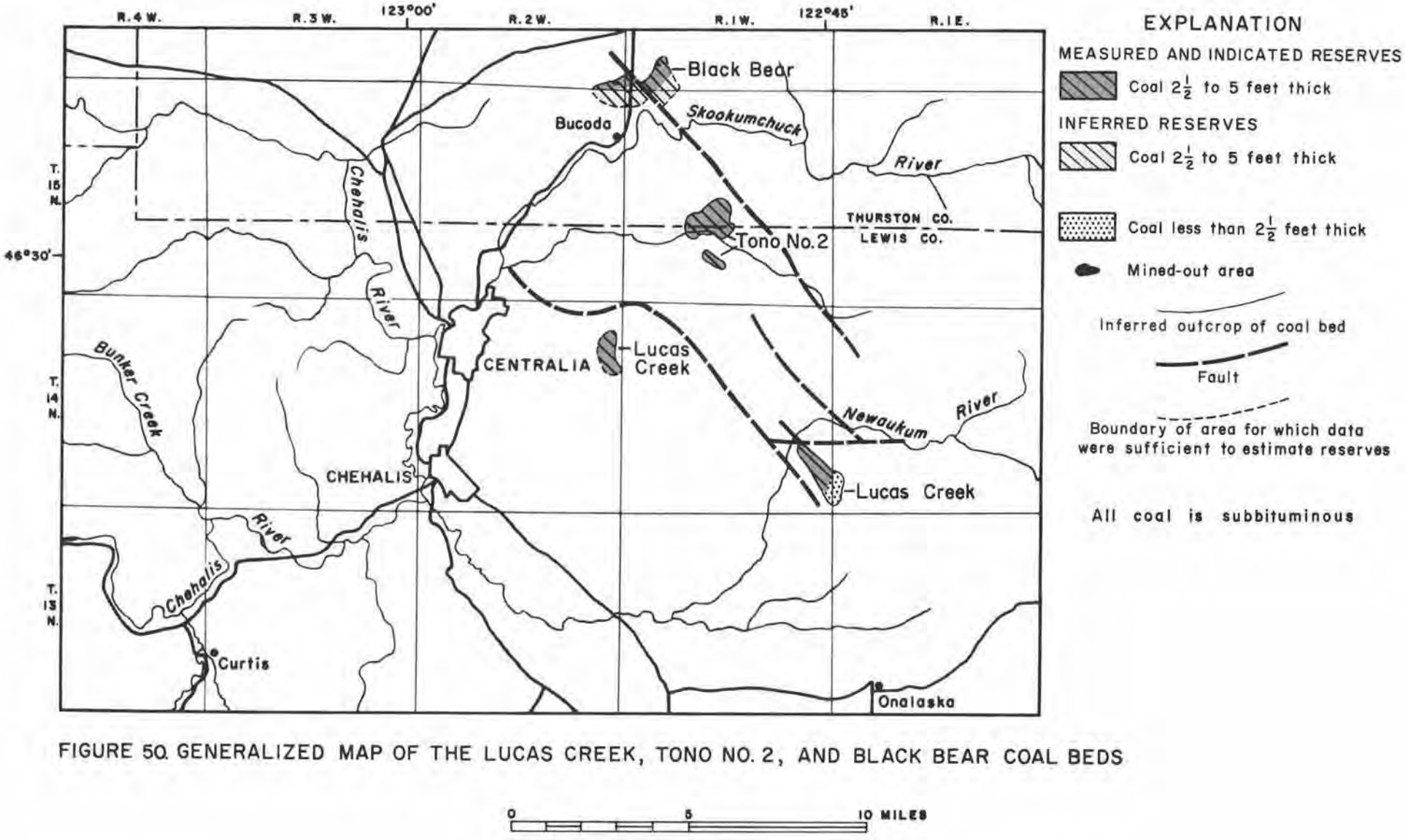


FIGURE 50. GENERALIZED MAP OF THE LUCAS CREEK, TONO NO. 2, AND BLACK BEAR COAL BEDS

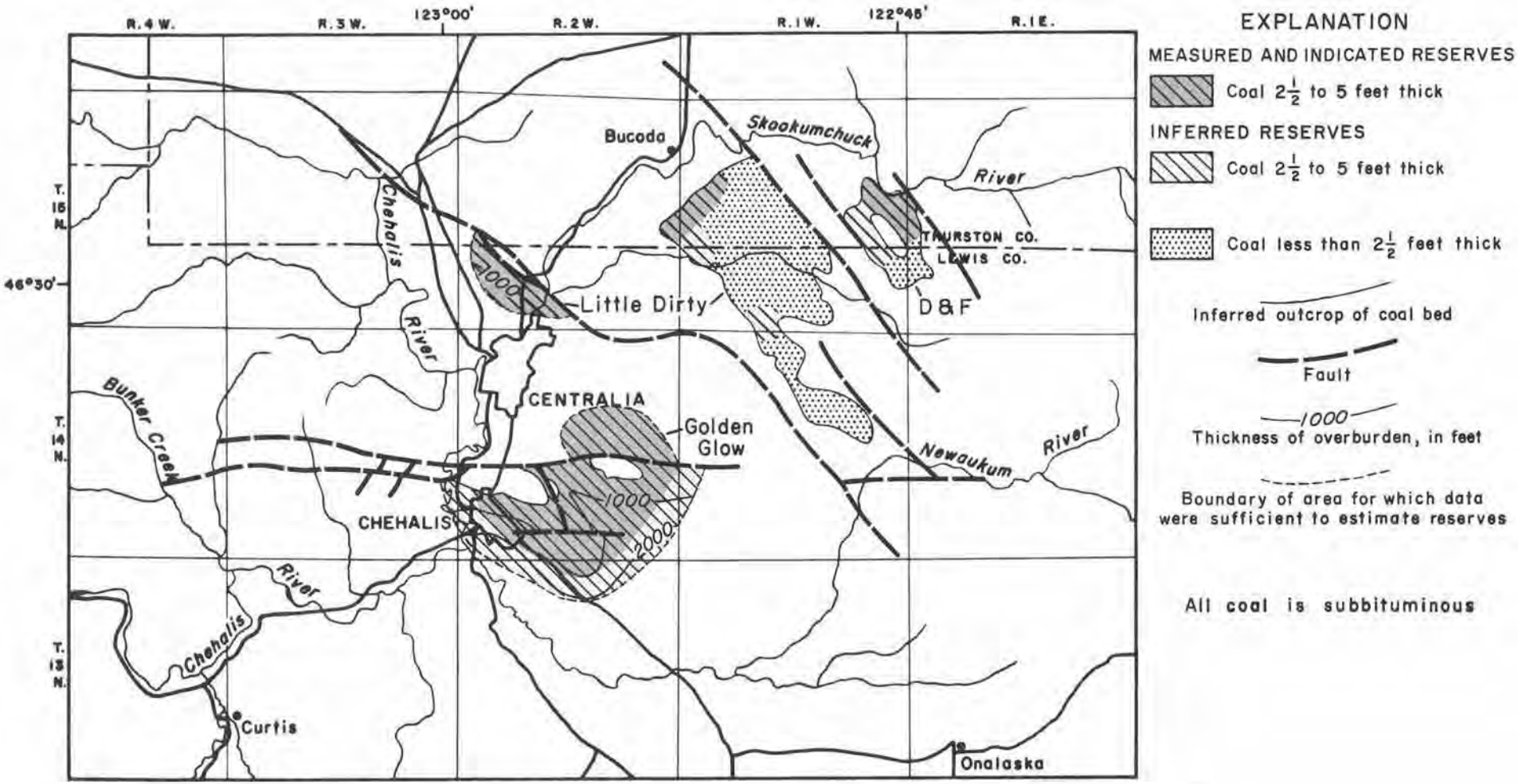


FIGURE 51. GENERALIZED MAP OF THE GOLDEN GLOW, D&F, AND LITTLE DIRTY COAL BEDS

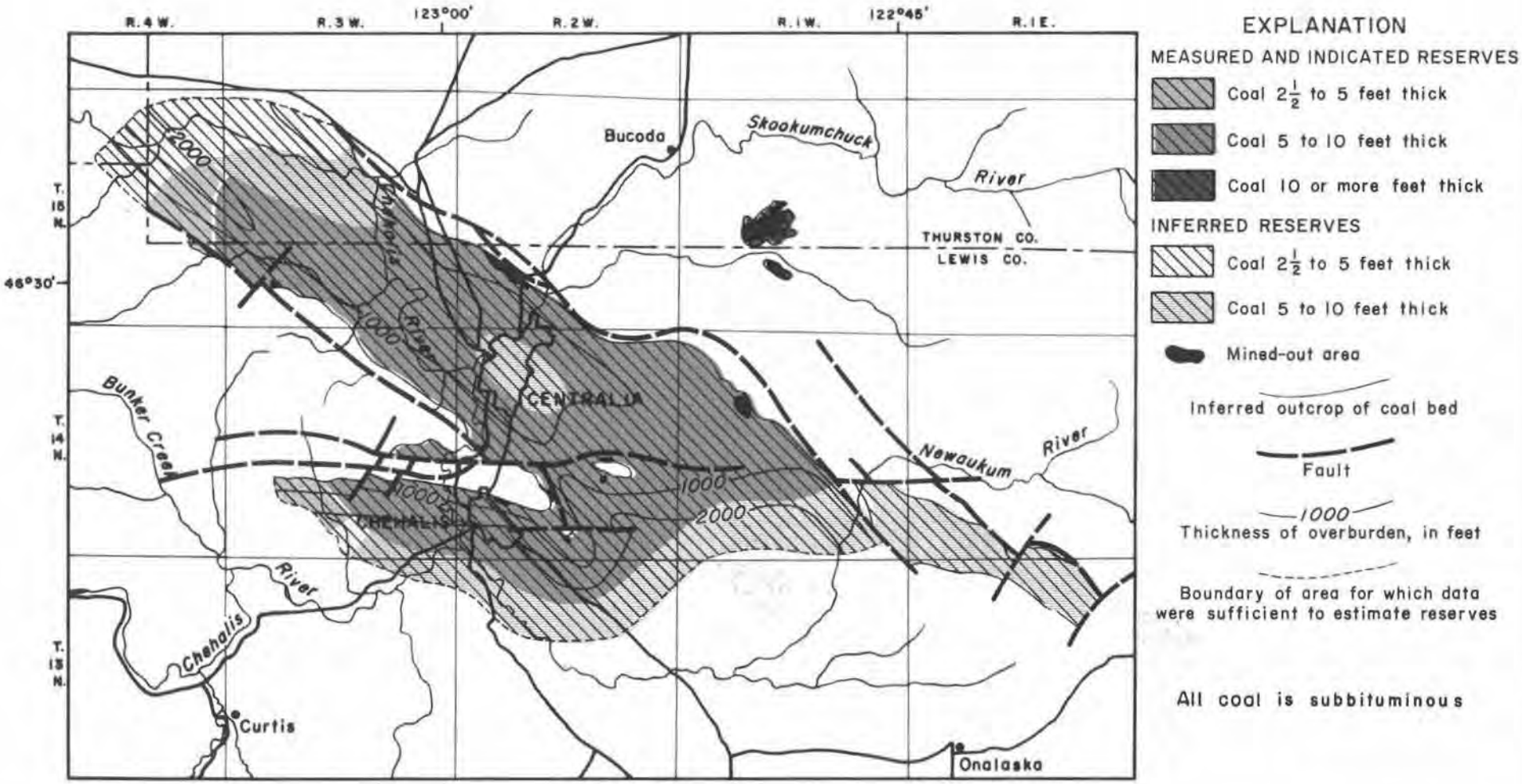


FIGURE 52. GENERALIZED MAP OF THE TONO NO. 1 COAL BED

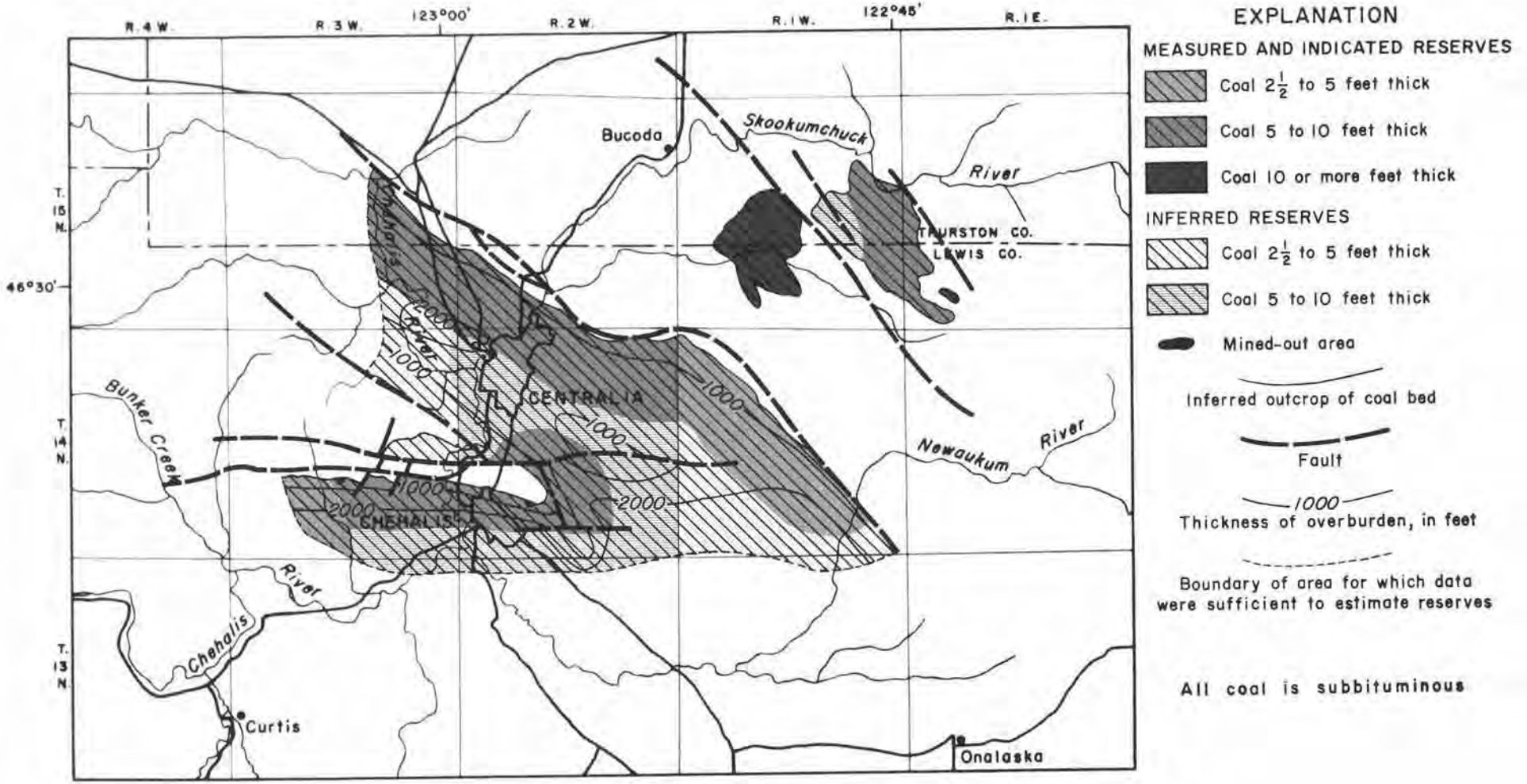


FIGURE 53. GENERALIZED MAP OF THE UPPER THOMPSON COAL BED

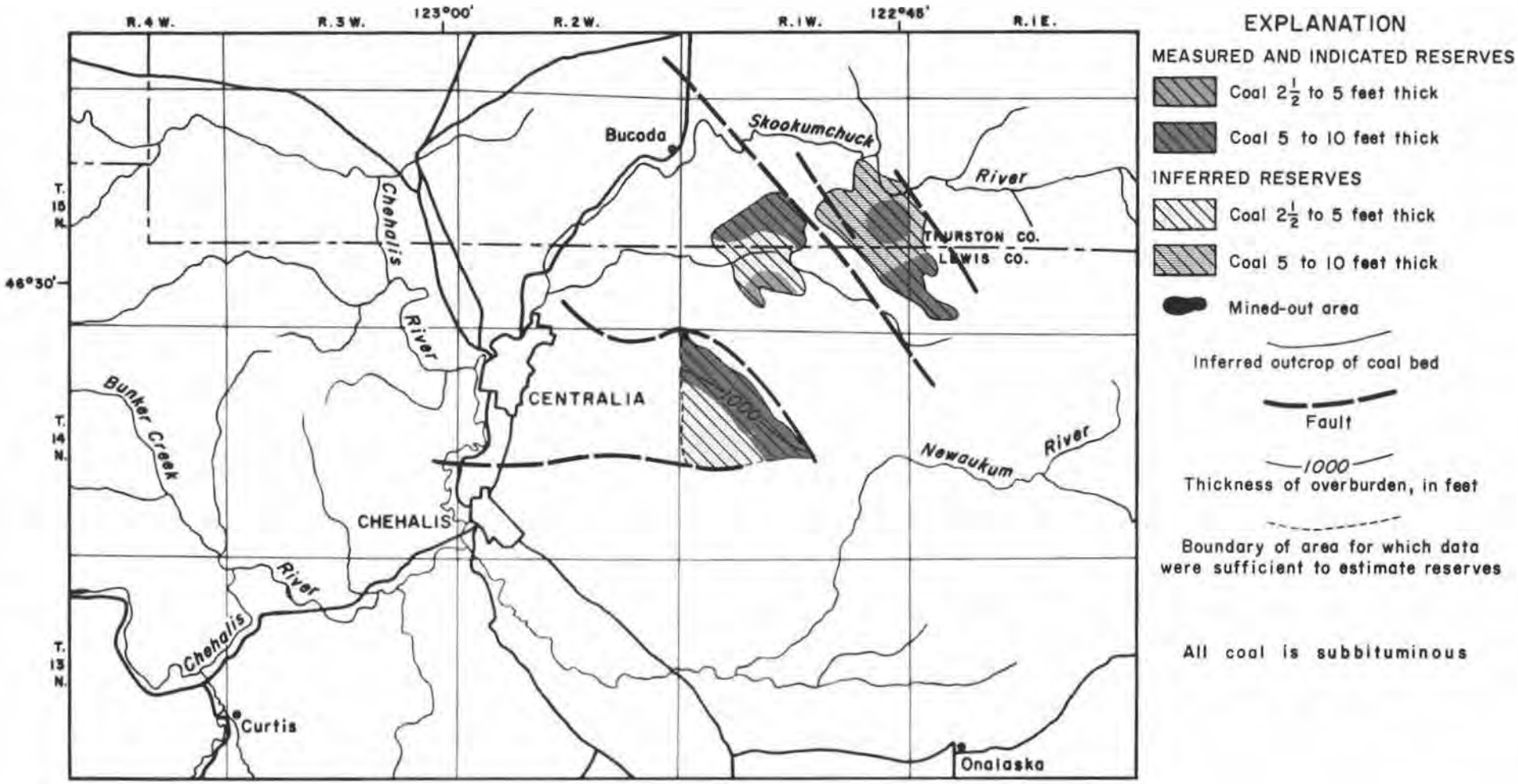


FIGURE 54. GENERALIZED MAP OF THE LOWER THOMPSON COAL BED

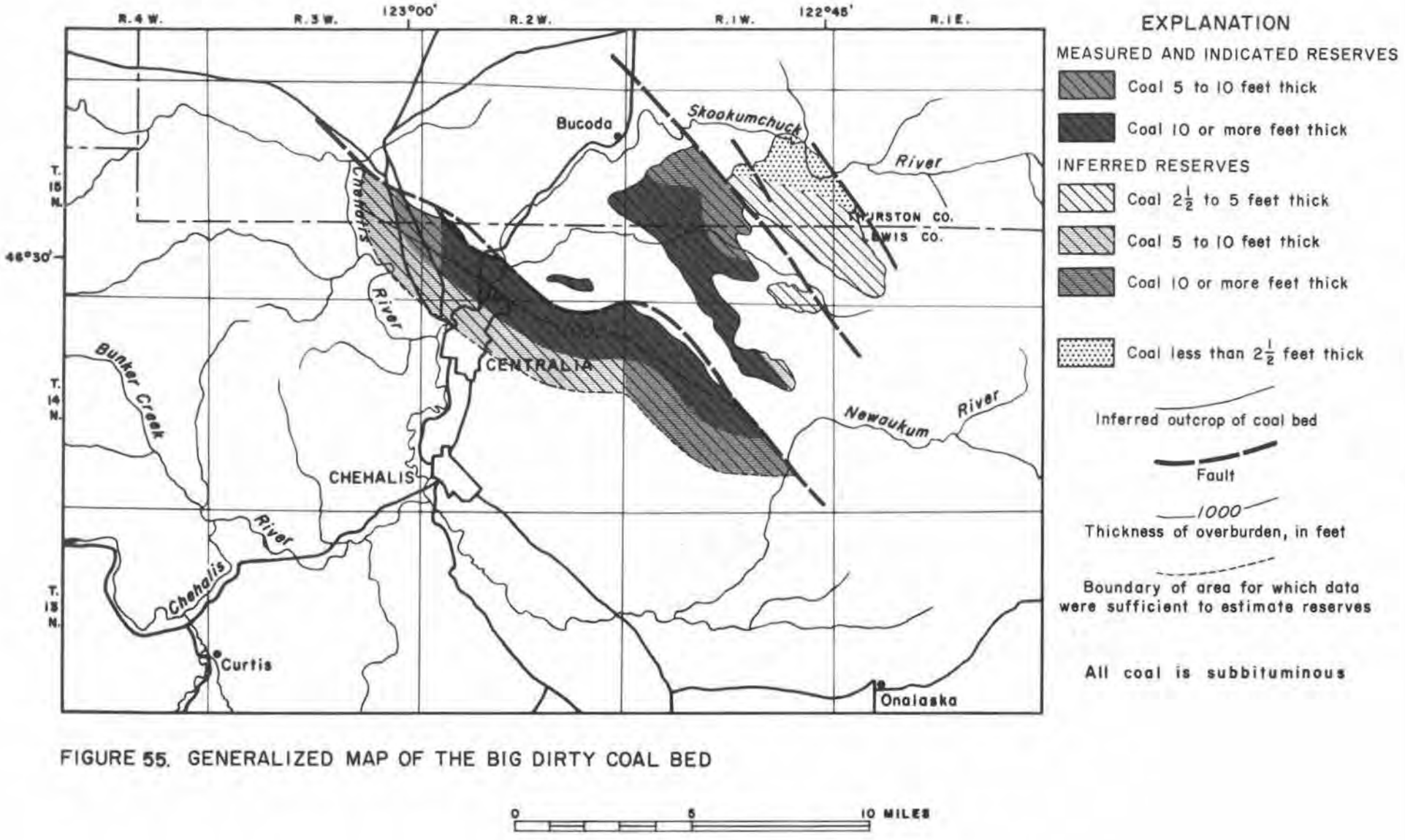


FIGURE 55. GENERALIZED MAP OF THE BIG DIRTY COAL BED

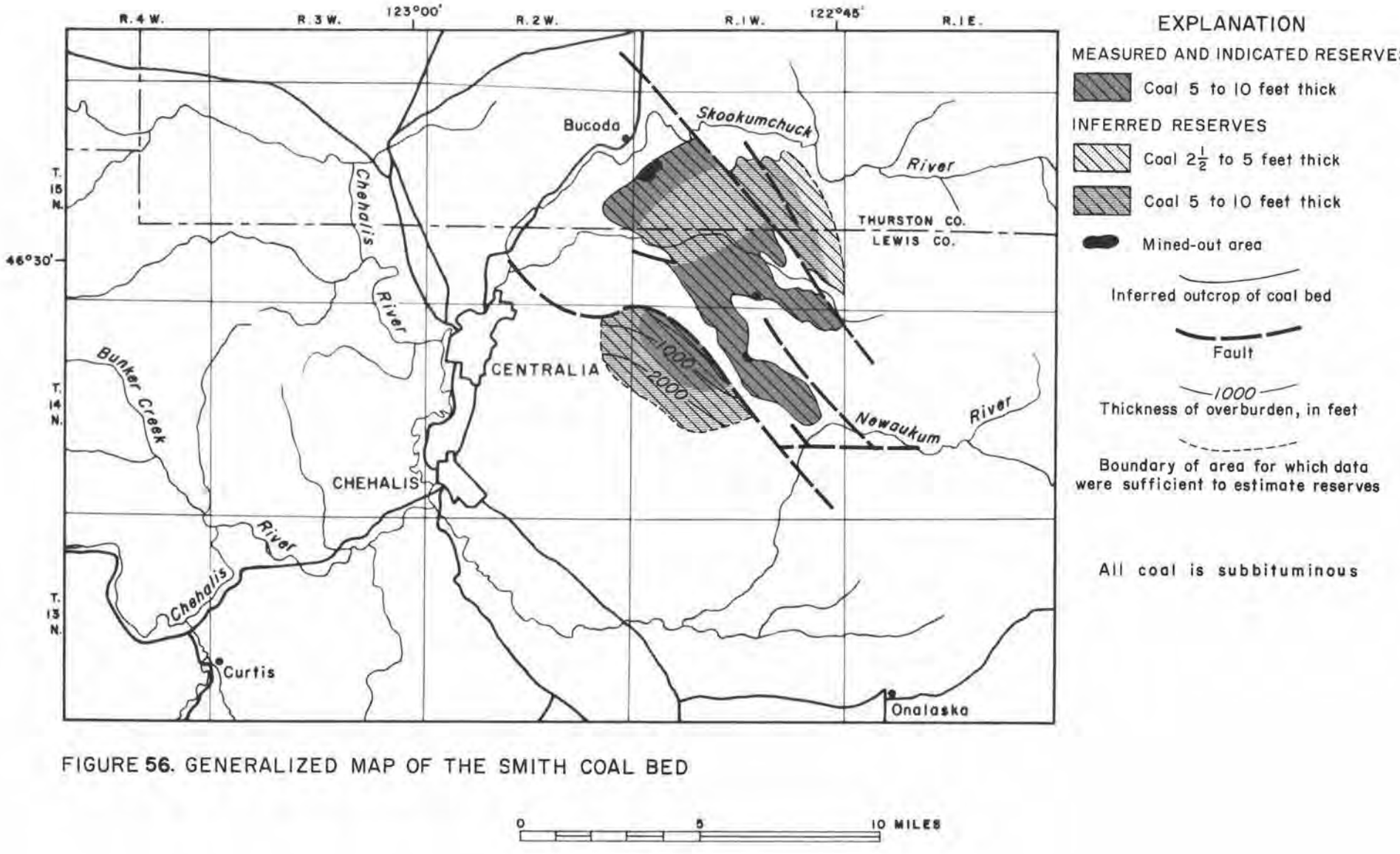


FIGURE 56. GENERALIZED MAP OF THE SMITH COAL BED

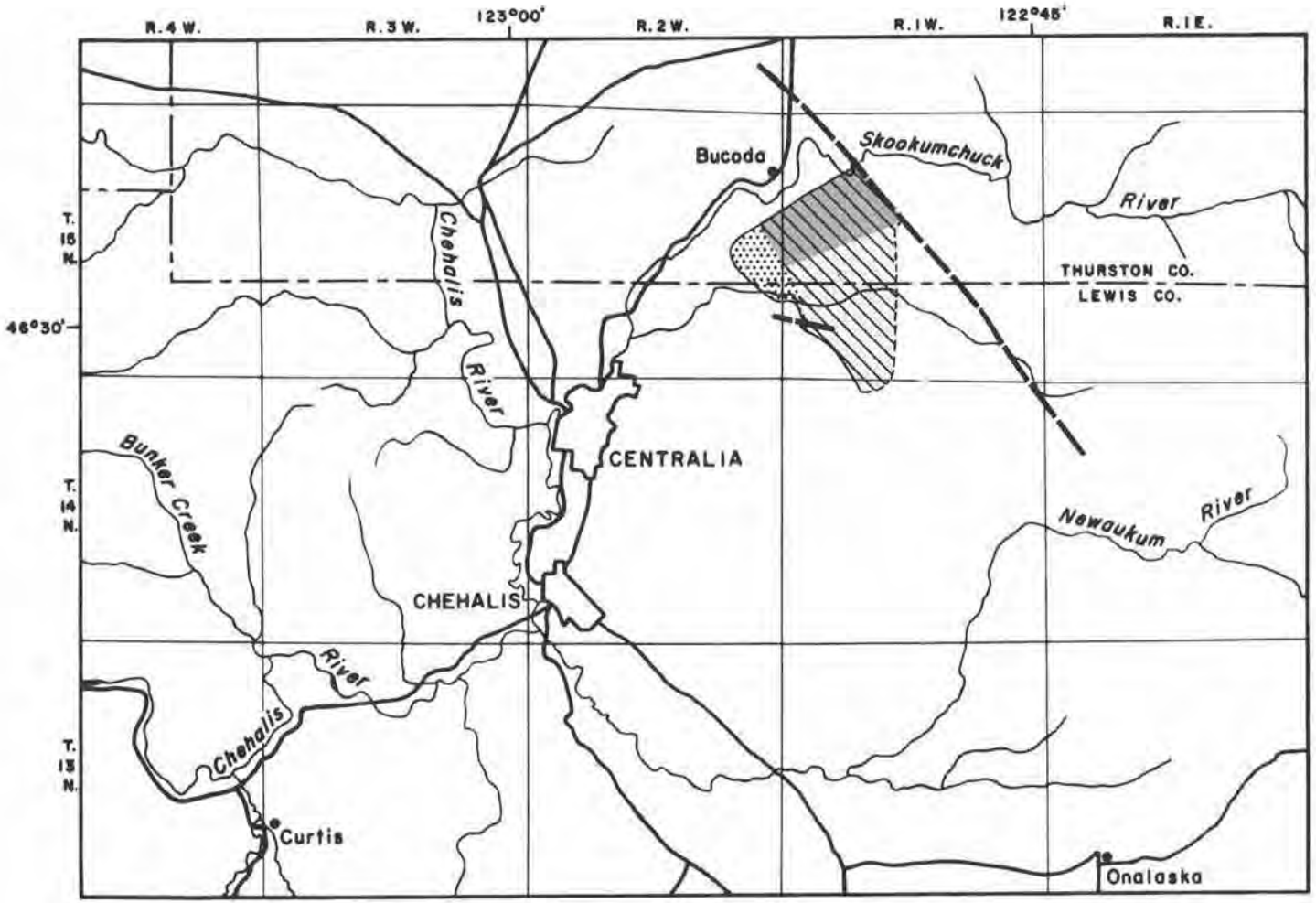


FIGURE 57. GENERALIZED MAP OF THE PENITENTIARY COAL BED

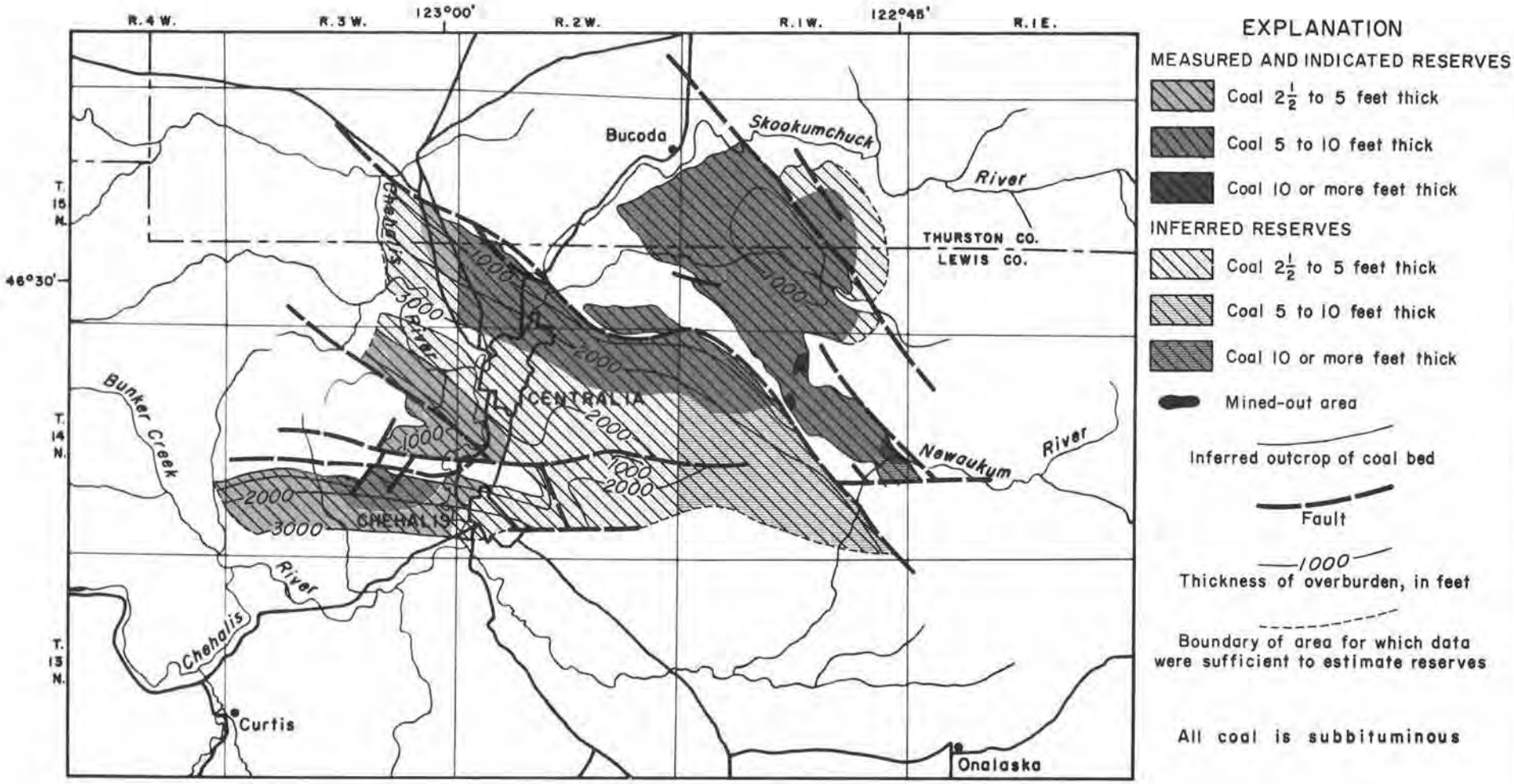


FIGURE 58. GENERALIZED MAP OF THE MENDOTA COAL BED

Table 29.—Estimated remaining reserves of coal in the Centralia-Chehalis district, Washington, as of January 1, 1960, by township and bed

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 13 N., R. 1 E.													
Tono No. 1	0-1,000	-----	-----	-----	-----	-----	24.17	-----	24.17	-----	24.17	-----	24.17
T. 13 N., R. 1 W.													
Tono No. 1	2,000-3,000	-----	-----	-----	-----	-----	0.99	-----	0.99	-----	0.99	-----	0.99
Upper Thompson	1,000-2,000	-----	-----	-----	-----	2.60	-----	-----	2.60	2.60	-----	-----	2.60
	2,000-3,000	-----	-----	-----	-----	.32	-----	-----	.32	.32	-----	-----	.32
Bed total		-----	-----	-----	-----	2.92	-----	-----	2.92	2.92	-----	-----	2.92
Township total		-----	-----	-----	-----	2.92	0.99	-----	3.91	2.92	0.99	-----	3.91
T. 13 N., R. 2 W.													
Golden Glow	0-1,000	0.44	-----	-----	0.44	-----	-----	-----	-----	0.44	-----	-----	0.44
	1,000-2,000	-----	-----	-----	-----	7.74	-----	-----	7.74	7.74	-----	-----	7.74
	2,000-3,000	-----	-----	-----	-----	2.09	-----	-----	2.09	2.09	-----	-----	2.09
Bed total		0.44	-----	-----	0.44	9.83	-----	-----	9.83	10.27	-----	-----	10.27
Tono No. 1	0-1,000	-----	0.58	-----	0.58	-----	-----	-----	-----	-----	0.58	-----	0.58
	1,000-2,000	-----	14.18	-----	14.18	-----	-----	-----	-----	-----	14.18	-----	14.18
	2,000-3,000	-----	18.94	-----	18.94	-----	50.80	-----	50.80	-----	69.74	-----	69.74
Bed total		-----	33.70	-----	33.70	-----	50.80	-----	50.80	-----	84.50	-----	84.50
Upper Thompson	1,000-2,000	-----	-----	-----	-----	-----	2.25	-----	2.25	-----	2.25	-----	2.25
	2,000-3,000	-----	-----	-----	-----	-----	10.35	-----	10.35	-----	10.35	-----	10.35
Bed total		-----	-----	-----	-----	-----	12.60	-----	12.60	-----	12.60	-----	12.60
Township total		0.44	33.70	-----	34.14	9.83	63.40	-----	73.23	10.27	97.10	-----	107.37
T. 13 N., R. 3 W.													
Tono No. 1	2,000-3,000	-----	-----	-----	-----	-----	11.47	-----	11.47	-----	11.47	-----	11.47
Upper Thompson	2,000-3,000	-----	-----	-----	-----	-----	5.94	-----	5.94	-----	5.94	-----	5.94
Township total		-----	-----	-----	-----	-----	17.41	-----	17.41	-----	17.41	-----	17.41
T. 14 N., R. 1 E.													
Tono No. 1	0-1,000	-----	-----	-----	-----	-----	19.89	-----	19.89	-----	19.89	-----	19.89
Mendota	0-1,000	-----	-----	-----	-----	-----	-----	1.20	1.20	-----	-----	1.20	1.20
Township total		-----	-----	-----	-----	-----	19.89	1.20	21.09	-----	19.89	1.20	21.09
T. 14 N., R. 1 W													
Lucas Creek	0-1,000	3.95	-----	-----	3.95	-----	-----	-----	-----	3.95	-----	-----	3.95
Golden Glow	0-1,000	-----	-----	-----	-----	2.00	-----	-----	2.00	2.00	-----	-----	2.00
	1,000-2,000	-----	-----	-----	-----	1.57	-----	-----	1.57	1.57	-----	-----	1.57
Bed total		-----	-----	-----	-----	3.57	-----	-----	3.57	3.57	-----	-----	3.57
Tono No. 1	0-1,000	-----	45.72	-----	45.72	-----	7.22	-----	7.22	-----	52.94	-----	52.94
	1,000-2,000	-----	53.98	-----	53.98	-----	16.22	-----	16.22	-----	70.20	-----	70.20
	2,000-3,000	-----	-----	-----	-----	-----	19.59	-----	19.59	-----	19.59	-----	19.59
Bed total		-----	99.70	-----	99.70	-----	43.03	-----	43.03	-----	142.73	-----	142.73
Upper Thompson	0-1,000	4.81	-----	-----	4.81	2.01	-----	-----	2.01	6.82	-----	-----	6.82
	1,000-2,000	5.28	-----	-----	5.28	28.99	-----	-----	28.99	34.27	-----	-----	34.27
	2,000-3,000	1.43	-----	-----	1.43	10.96	-----	-----	10.96	12.39	-----	-----	12.39
Bed total		11.52	-----	-----	11.52	41.96	-----	-----	41.96	53.48	-----	-----	53.48
Lower Thompson	0-1,000	-----	16.48	-----	16.48	-----	-----	-----	-----	-----	16.48	-----	16.48
	1,000-2,000	-----	12.07	-----	12.07	76.28	-----	-----	76.28	76.28	12.07	-----	88.35
Bed total		-----	28.55	-----	28.55	76.28	-----	-----	76.28	76.28	28.55	-----	104.83
Big Dirty	0-1,000	-----	-----	85.58	85.58	2.24	2.25	-----	4.49	2.24	2.25	85.58	90.07
	1,000-2,000	-----	-----	13.01	13.01	-----	-----	187.15	187.15	-----	-----	200.16	200.16
Bed total		-----	-----	98.59	98.59	2.24	2.25	187.15	191.64	2.24	2.25	285.74	290.23
Little Dirty	0-1,000	-----	-----	-----	-----	0.36	-----	-----	0.36	0.36	-----	-----	0.36
Smith	0-1,000	-----	32.00	-----	32.00	-----	60.88	-----	60.88	-----	92.88	-----	92.88
	1,000-2,000	-----	20.63	-----	20.63	-----	26.48	-----	26.48	-----	47.11	-----	47.11
	2,000-3,000	-----	-----	-----	-----	-----	20.40	-----	20.40	-----	20.40	-----	20.40
Bed total		-----	52.63	-----	52.63	-----	107.76	-----	107.76	-----	160.39	-----	160.39
Penitentiary	0-1,000	-----	-----	-----	-----	0.60	-----	-----	0.60	0.60	-----	-----	0.60
Mendota	0-1,000	-----	30.15	3.84	33.99	0.44	21.67	4.80	26.91	0.44	51.82	8.64	60.90
	1,000-2,000	-----	20.51	-----	20.51	-----	28.93	-----	28.93	-----	49.44	-----	49.44
	2,000-3,000	-----	4.29	-----	4.29	-----	113.50	-----	113.50	-----	117.79	-----	117.79
Bed total		-----	54.95	3.84	58.79	0.44	164.10	4.80	169.34	0.44	219.05	8.64	228.13
Township total		15.47	235.83	102.43	353.73	125.45	317.14	191.95	634.54	140.92	552.97	294.38	988.27

Table 29.—Estimated remaining reserves of coal in the Centralia-Chehalis district, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 14 N., R. 2 W.													
Lucas Creek	0-1,000	2.44	-----	-----	2.44	-----	-----	-----	-----	2.44	-----	-----	2.44
Golden Glow	0-1,000	39.21	-----	-----	39.21	1.07	-----	-----	1.07	40.28	-----	-----	40.28
	1,000-2,000	25.99	-----	-----	25.99	9.04	-----	-----	9.04	35.03	-----	-----	35.03
	2,000-3,000	-----	-----	-----	-----	11.29	-----	-----	11.29	11.29	-----	-----	11.29
Bed total		65.20	-----	-----	65.20	21.40	-----	-----	21.40	86.60	-----	-----	86.60
Tono No. 1	0-1,000	-----	161.74	-----	161.74	-----	-----	-----	-----	-----	161.74	-----	161.74
	1,000-2,000	-----	65.84	-----	65.84	-----	28.17	-----	28.17	-----	94.01	-----	94.01
	2,000-3,000	-----	16.81	-----	16.81	-----	6.53	-----	6.53	-----	23.34	-----	23.34
Bed total		-----	244.39	-----	244.39	-----	34.70	-----	34.70	-----	279.09	-----	279.09
Upper Thompson	0-1,000	-----	93.67	-----	93.67	-----	47.46	-----	47.46	-----	141.13	-----	141.13
	1,000-2,000	-----	48.04	-----	48.04	-----	43.21	-----	43.21	-----	91.25	-----	91.25
	2,000-3,000	-----	1.19	-----	1.19	-----	30.85	-----	30.85	-----	32.04	-----	32.04
Bed total		-----	142.90	-----	142.90	-----	121.52	-----	121.52	-----	264.42	-----	264.42
Big Dirty	0-1,000	-----	-----	17.78	17.78	-----	-----	-----	-----	-----	-----	17.78	17.78
	1,000-2,000	-----	-----	61.98	61.98	-----	36.09	-----	36.09	-----	36.09	61.98	98.07
Bed total		-----	-----	79.76	79.76	-----	36.09	-----	36.09	-----	36.09	79.76	115.85
Smith	0-1,000	-----	-----	-----	-----	-----	3.30	-----	3.30	-----	3.30	-----	3.30
	1,000-2,000	-----	-----	-----	-----	-----	7.93	-----	7.93	-----	7.93	-----	7.93
	2,000-3,000	-----	-----	-----	-----	-----	4.15	-----	4.15	-----	4.15	-----	4.15
Bed total		-----	-----	-----	-----	-----	15.38	-----	15.38	-----	15.38	-----	15.38
Mendota	0-1,000	0.30	5.08	-----	5.38	3.04	-----	-----	3.04	3.34	5.08	-----	8.42
	1,000-2,000	14.47	13.33	-----	27.80	69.20	-----	-----	69.20	83.67	13.33	-----	97.00
	2,000-3,000	-----	17.43	-----	17.43	21.80	-----	-----	21.80	21.80	17.43	-----	39.23
Bed total		14.77	35.84	-----	50.61	94.04	-----	-----	94.04	108.81	35.84	-----	144.65
Township total		82.41	423.13	79.76	585.30	115.44	207.69	-----	323.13	197.85	630.82	79.76	908.43
T. 14 N., R. 3 W.													
Golden Glow	0-1,000	-----	-----	-----	-----	1.15	-----	-----	1.15	1.15	-----	-----	1.15
Tono No. 1	0-1,000	2.61	9.60	-----	12.21	-----	-----	-----	-----	2.61	9.60	-----	12.21
	1,000-2,000	3.71	14.34	-----	18.05	-----	-----	-----	-----	3.71	14.34	-----	18.05
	2,000-3,000	1.39	13.57	-----	14.96	2.46	36.10	-----	38.56	3.85	49.67	-----	53.52
Bed total		7.71	37.51	-----	45.22	2.46	36.10	-----	38.56	10.17	73.61	-----	83.78
Upper Thompson	0-1,000	3.87	8.35	-----	12.22	8.71	-----	-----	8.71	12.58	8.35	-----	20.93
	1,000-2,000	5.79	17.93	-----	23.72	3.10	16.55	-----	19.65	8.89	34.48	-----	43.37
	2,000-3,000	1.86	12.80	-----	14.66	.87	10.89	-----	11.76	2.73	23.69	-----	26.42
Bed total		11.52	39.08	-----	50.60	12.68	27.44	-----	40.12	24.20	66.52	-----	90.72
Mendota	0-1,000	15.18	6.09	-----	21.27	-----	-----	-----	-----	15.18	6.09	-----	21.27
	1,000-2,000	17.33	10.42	-----	27.75	-----	-----	-----	-----	17.33	10.42	-----	27.75
	2,000-3,000	11.60	4.23	-----	15.83	23.86	-----	-----	23.86	35.46	4.23	-----	39.69
Bed total		44.11	20.74	-----	64.85	23.86	-----	-----	23.86	67.97	20.74	-----	88.71
Township total		63.34	97.33	-----	160.67	40.15	63.54	-----	103.69	103.49	160.87	-----	264.36
T. 14 N., R. 4 W.													
Mendota	0-1,000	0.77	-----	-----	0.77	-----	-----	-----	-----	0.77	-----	-----	0.77
	1,000-2,000	.40	-----	-----	.40	-----	-----	-----	-----	.40	-----	-----	.40
Bed total		1.17	-----	-----	1.17	-----	-----	-----	-----	1.17	-----	-----	1.17
T. 15 N., R. 1 E.													
D & F	0-1,000	1.70	-----	-----	1.70	-----	-----	-----	-----	1.70	-----	-----	1.70
Upper Thompson	0-1,000	-----	17.49	1.24	18.73	-----	-----	-----	-----	-----	17.49	1.24	18.73
Lower Thompson	0-1,000	-----	7.63	-----	7.63	-----	4.49	-----	4.49	-----	12.12	-----	12.12
Big Dirty	0-1,000	-----	-----	-----	-----	14.06	-----	-----	14.06	14.06	-----	-----	14.06
Township total		1.70	25.12	1.24	28.06	14.06	4.49	-----	18.55	15.76	29.61	1.24	46.61
T. 15 N., R. 1 W.													
D & F	0-1,000	5.85	-----	-----	5.85	4.27	-----	-----	4.27	10.12	-----	-----	10.12
Tono No. 1	0-1,000	-----	-----	5.12	5.12	-----	-----	-----	-----	-----	-----	5.12	5.12
Tono No. 2	0-1,000	6.43	-----	-----	6.43	-----	-----	-----	-----	6.43	-----	-----	6.43
Upper Thompson	0-1,000	-----	35.92	51.06	86.98	-----	11.85	-----	11.85	-----	47.77	51.06	98.83
Lower Thompson	0-1,000	2.21	25.23	-----	27.44	10.08	20.21	-----	30.29	12.29	45.44	-----	57.73
Big Dirty	0-1,000	-----	-----	172.35	172.35	17.51	-----	50.38	67.89	17.51	-----	222.73	240.24
Little Dirty	0-1,000	3.25	-----	-----	3.25	3.34	-----	-----	3.34	6.59	-----	-----	6.59
Smith	0-1,000	-----	57.25	-----	57.25	6.24	63.41	-----	69.65	6.24	120.66	-----	126.90
Penitentiary	0-1,000	13.73	-----	-----	13.73	12.03	-----	-----	12.03	25.76	-----	-----	25.76

Table 29.—Estimated remaining reserves of coal in the Centralia-Chehalis district, Washington, as of January 1, 1960, by township and bed—Continued

Coal bed	Overburden (in feet)	Reserves, in millions of short tons, in beds of thickness shown											
		Measured and indicated				Inferred				All categories			
		2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 15 N., R. 1 W.—continued													
Mendota	0-1,000	-----	94.89	-----	94.89	11.63	-----	-----	11.63	11.63	94.89	-----	106.52
	1,000-2,000	-----	31.04	-----	31.04	-----	-----	-----	-----	-----	31.04	-----	31.04
Bed total		-----	125.93	-----	125.93	11.63	-----	-----	11.63	11.63	125.93	-----	137.56
Black Bear	0-1,000	0.23	-----	-----	0.23	2.94	-----	-----	2.94	3.17	-----	-----	3.17
Township total		31.70	244.33	228.53	504.56	68.04	95.47	50.38	213.89	99.74	339.80	278.91	718.45
T. 15 N., R. 2 W.													
Tono No. 1	0-1,000	-----	26.27	-----	26.27	-----	-----	-----	-----	-----	26.27	-----	26.27
	1,000-2,000	-----	8.72	-----	8.72	-----	-----	-----	-----	-----	8.72	-----	8.72
Bed total		-----	34.99	-----	34.99	-----	-----	-----	-----	-----	34.99	-----	34.99
Upper Thompson	0-1,000	-----	21.03	-----	21.03	-----	-----	-----	-----	-----	21.03	-----	21.03
	1,000-2,000	-----	14.67	-----	14.67	-----	-----	-----	-----	-----	14.67	-----	14.67
Bed total		-----	35.70	-----	35.70	-----	-----	-----	-----	-----	35.70	-----	35.70
Big Dirty	0-1,000	-----	4.60	29.34	33.94	-----	-----	-----	-----	-----	4.60	29.34	33.94
	1,000-2,000	-----	16.17	5.13	21.30	-----	1.80	-----	1.80	-----	17.97	5.13	23.10
Bed total		-----	20.77	34.47	55.24	-----	1.80	-----	1.80	-----	22.57	34.47	57.04
Little Dirty	0-1,000	8.03	-----	-----	8.03	-----	-----	-----	-----	8.03	-----	-----	8.03
	1,000-2,000	5.93	-----	-----	5.93	-----	-----	-----	-----	5.93	-----	-----	5.93
Bed total		13.96	-----	-----	13.96	-----	-----	-----	-----	13.96	-----	-----	13.96
Smith	0-1,000	-----	6.76	-----	6.76	-----	-----	-----	-----	-----	6.76	-----	6.76
Penitentiary	0-1,000	2.13	-----	-----	2.13	-----	-----	-----	-----	2.13	-----	-----	2.13
Mendota	0-1,000	-----	35.83	-----	35.83	-----	-----	-----	-----	-----	35.83	-----	35.83
	1,000-2,000	-----	18.30	-----	18.30	-----	-----	-----	-----	-----	18.30	-----	18.30
	2,000-3,000	-----	5.73	-----	5.73	-----	-----	-----	-----	-----	5.73	-----	5.73
Bed total		-----	59.86	-----	59.86	-----	-----	-----	-----	-----	59.86	-----	59.86
Black Bear	0-1,000	-----	-----	-----	-----	79.54	-----	-----	79.54	79.54	-----	-----	79.54
Township total		16.09	158.08	34.47	208.64	79.54	1.80	-----	81.34	95.63	159.88	34.47	289.98
T. 15 N., R. 3 W.													
Tono No. 1	0-1,000	-----	33.02	-----	33.02	4.36	10.57	-----	14.93	4.36	43.59	-----	47.95
	1,000-2,000	-----	80.34	-----	80.34	6.53	52.85	-----	59.38	6.53	133.19	-----	139.72
	2,000-3,000	-----	2.64	-----	2.64	-----	-----	-----	-----	-----	2.64	-----	2.64
Bed total		-----	116.00	-----	116.00	10.89	63.42	-----	74.31	10.89	179.42	-----	190.31
Upper Thompson	0-1,000	-----	3.61	-----	3.61	-----	-----	-----	-----	-----	3.61	-----	3.61
	1,000-2,000	-----	7.24	-----	7.24	-----	-----	-----	-----	-----	7.24	-----	7.24
	2,000-3,000	-----	-----	-----	-----	13.10	-----	-----	13.10	13.10	-----	-----	13.10
Bed total		-----	10.85	-----	10.85	13.10	-----	-----	13.10	13.10	10.85	-----	23.95
Big Dirty	0-1,000	-----	5.27	-----	5.27	-----	5.60	-----	5.60	-----	10.87	-----	10.87
	1,000-2,000	-----	1.87	-----	1.87	-----	13.36	-----	13.36	-----	15.23	-----	15.23
Bed total		-----	7.14	-----	7.14	-----	18.96	-----	18.96	-----	26.10	-----	26.10
Mendota	0-1,000	4.12	-----	-----	4.12	3.06	-----	-----	3.06	7.18	-----	-----	7.18
	1,000-2,000	3.08	-----	-----	3.08	1.05	-----	-----	1.05	4.13	-----	-----	4.13
	2,000-3,000	-----	-----	-----	-----	9.00	-----	-----	9.00	9.00	-----	-----	9.00
Bed total		7.20	-----	-----	7.20	13.11	-----	-----	13.11	20.31	-----	-----	20.31
Township total		7.20	133.99	-----	141.19	37.10	82.38	-----	119.48	44.30	216.37	-----	260.67
T. 15 N., R. 4 W.													
Tono No. 1	0-1,000	5.99	0.97	-----	6.96	2.03	-----	-----	2.03	8.02	0.97	-----	8.99
	1,000-2,000	4.65	1.03	-----	5.68	15.19	-----	-----	15.19	19.84	1.03	-----	20.87
	2,000-3,000	2.86	2.15	-----	5.01	1.90	-----	-----	1.90	4.76	2.15	-----	6.91
Bed total		13.50	4.15	-----	17.65	19.12	-----	-----	19.12	32.62	4.15	-----	36.77
T. 16 N., R. 1 W.													
Black Bear	0-1,000	1.75	-----	-----	1.75	0.35	-----	-----	0.35	2.10	-----	-----	2.10
T. 16 N., R. 2 W.													
Black Bear	0-1,000	3.02	-----	-----	3.02	-----	-----	-----	-----	3.02	-----	-----	3.02
Grand total		237.79	1,355.66	446.43	2,039.88	512.00	898.37	243.53	1,653.90	749.79	2,254.03	689.96	3,693.78

Coal Mining

More than 9 million tons of coal has been mined from the Centralia-Chehalis district since the 1870's. Of this amount, more than 7.5 million tons has been from the Tono No. 1 coal bed; most of the remainder has been from the Mendota coal bed. In 1960, four mines were operating in the area but produced only about 15,000 tons. In the southwestern part of T. 15 N., R. 1 W., coal has been mined by stripping at three mines, the Tono mine in the NW¼ section 21, the Penn-Bucoda mine in the NW¼ section 18, and the Royal mine in the SW¼ section 20. The Tono mine, the largest strip-mining operation in southwestern Washington, had a maximum production of about 21,000 tons of coal per year.

A large tract of land south of the line of outcrop of the Big Dirty coal bed in the S½ section 18 and the NW¼ section 19 is apparently favorable for strip mining. In this area the Big Dirty coal bed dips gently to the southeast, essentially parallel to the slope of the hills. According to Yancey and Geer (1961, p. 1-2), 70 million tons of strippable coal reserves, most of which are in the Big Dirty coal bed, have been proved by 22,700 feet of drilling. They report that the Big Dirty coal bed averages 39½ feet in thickness in this area and contains 29 partings which aggregate 7 feet in thickness. Near the axes of broader folds in the Centralia-Chehalis district, other areas suitable for strip mining may exist; however, extensive shallow drilling would have to be undertaken to outline the areas.

Summary of Reserves

The total reserves of coal remaining in the ground in the Centralia-Chehalis district as of January 1, 1960, are estimated to be 3,694 million tons. The total reserves given here exceed those given by Snavely and others (1958) by approximately 150 million tons, owing to the incorporation of additional data. All the reserves are classified as subbituminous in rank, although some of the coal in the area is lignitic in rank because of variations in the composition of the coal along the strike of the beds. Approximately 57 percent of the total estimated coal in the district is classified as measured and indicated and about 43 percent as inferred. The reserve figures by township and bed are shown in table 29, and a summary by township is shown in table 36, on page 112.

EASTERN LEWIS COUNTY COAL DEPOSITS

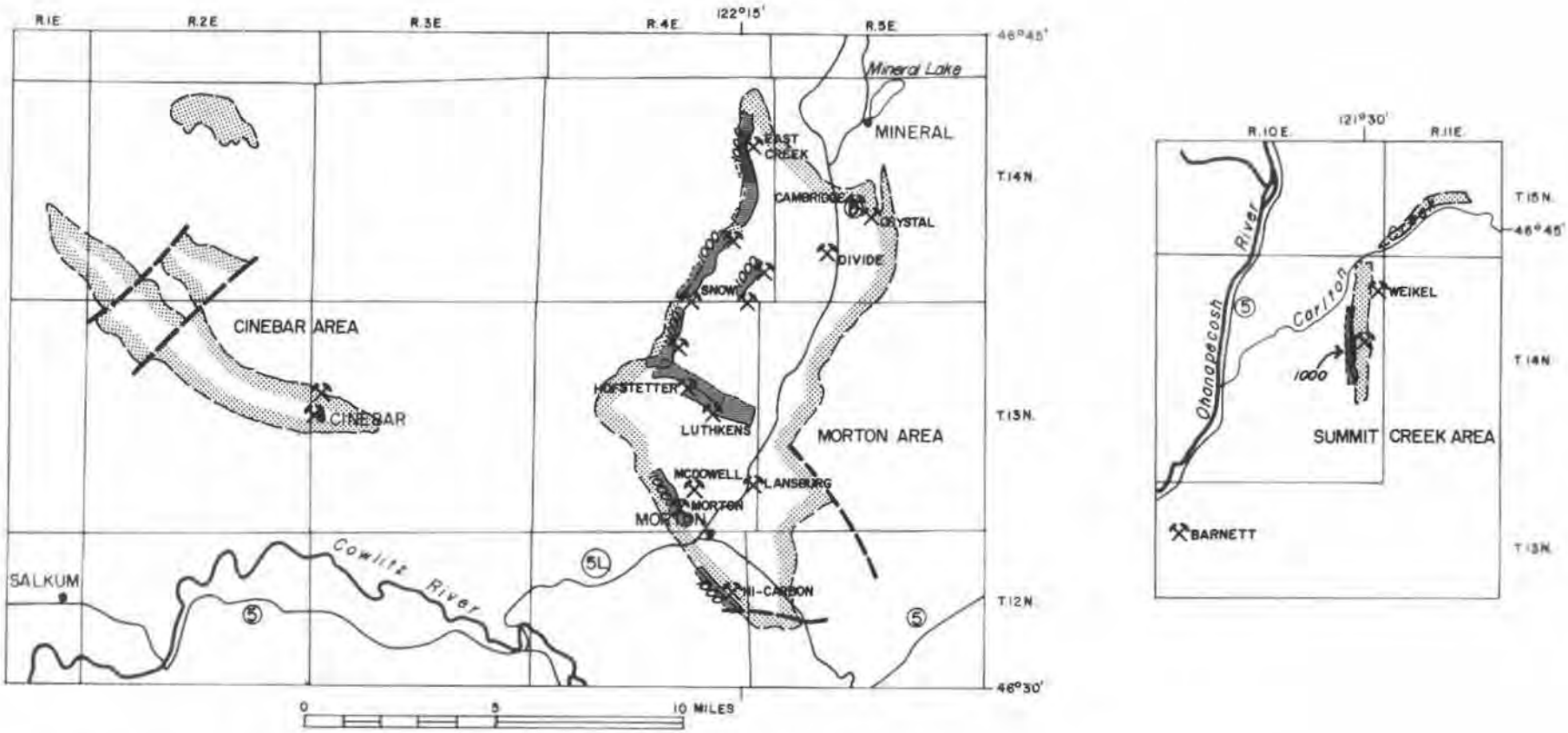
Coal-bearing sedimentary rocks crop out in the vicinity of Cinebar, Morton, and Summit Creek in eastern Lewis County. The extent of these areas, as shown on figure 59, is based on reconnaissance mapping carried out for use in this report by Howard D. Gower in the Cinebar and Morton areas and by J. A. Ellingson, of the Washington Division of Mines and Geology, in the Summit Creek area. Other information presented here concerning these areas has been summarized from a report by Culver (1919, p. 103-130). The analyses of coal samples from these areas as shown in table 30 indicate that the coal ranges in rank from high-volatile C bituminous to high-volatile A bituminous.

Cinebar area.—In the Cinebar area, the coal beds occur in rocks of middle to late Eocene age. The extent of coal beds along the strike and down dip is problematical, and a given coal bed cannot be identified with one exposed a few hundred yards along the strike. Probably the coal has been subjected to such severe deformation that it is of little value. One prospect tunnel in the area is reported to be about 1,900 feet long and to have encountered 10 coal beds. Information on the coal in this area is insufficient to allow for estimation of reserves. Although analyses of coal samples are not available, the coal is reported to be of bituminous rank.

Table 30.—Averages of analyses (as-received basis) of coal samples from eastern Lewis County, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. Source of analyses is Fieldner and others, 1931)

Location			Mine or prospect	Coal bed	Proximate (percent)				Sulfur (percent)	Btu	Number of analyses used in obtaining average
Sec.	T.	R.			M	VM	FC	Ash			
12	12 N.	4 E.	Hi-Carbon ----	----------	6.1	34.9	40.9	17.9	0.9	10,765	2
10	13 N.	4 E.	Unnamed ------	----------	13.5	21.7	49.6	15.2	.4	------	1
14	13 N.	4 E.	Luthkens ------	----------	8.5	27.3	44.8	19.4	.3	10,500	1
			Hofstetter -----	----------	8.1	4.6	62.3	25.0	.3	9,820	1
13	14 N.	4 E.	East Creek ----	No. 2 ----------	4.2	26.7	51.6	17.4	1.2	11,630	2
				No. 3 ----------	6.4	34.4	37.6	20.7	.6	10,160	3
				No. 4 ----------	7.5	31.9	37.2	23.4	.9	9,540	2
26	14 N.	4 E.	Unnamed ------	----------	9.1	27.8	33.2	29.9	.6	8,060	1
34	14 N.	4 E.	Snow --------	----------	11.2	31.2	47.2	10.4	.6	11,160	1
36	14 N.	4 E.	Unnamed ------	----------	9.3	14.4	30.6	45.7	.7	5,740	1
				----------	7.7	11.7	54.1	26.5	1.1	9,740	1
21	14 N.	5 E.	Crystal -------	----------	6.3	32.5	38.9	22.3	.6	9,990	1
7	13 N.	10 E.	Barnett -------	----------	7.4	5.0	51.8	35.8	.8	8,200	1
1	14 N.	10 E.	Weikel -------	No. 6 ----------	4.2	10.5	51.2	34.1	.5	8,890	1
13	14 N.	10 E.	Unnamed ------	No. 6 ----------	4.2	7.8	71.0	17.1	.6	11,963	3



EXPLANATION

BITUMINOUS COAL RESERVES

MEASURED AND INDICATED

Coal 42 or more inches thick

INFERRED

Coal 42 or more inches thick

1000

Thickness of overburden, in feet

Inferred outcrop of coal bed

Boundary of area for which data were sufficient to estimate reserves

SNOW

Mine or prospect

Approximate limit of coal-bearing rocks
Coal reserves are overlain in places by younger volcanic rocks

Inferred fault

FIGURE 59. COAL AREAS IN EASTERN LEWIS COUNTY

Morton area.—The coal deposits of the Morton area occur in the Puget Group of Eocene age. The coal-bearing rocks have been intruded by igneous rocks, which have intensely sheared some of the coal beds, but which may have also improved the rank of coal locally through increased devolatilization. The coal in the area is mostly of high-volatile bituminous rank, but some near anthracite or natural coke in composition has been found in the immediate vicinity of intrusive igneous rocks. The ash content of the coal in the Morton area ranges from 10.4 to 45.7 percent and averages 20 percent; the moisture content ranges from 4.2 to 13.5 percent and averages 8 percent; the sulfur content ranges from 0.3 to 1.2 percent and averages 0.7 percent.

Coal beds have been found throughout most of the area that contains sedimentary rocks, but at present it is not possible to correlate from one outcrop or prospect to another. Several mines in the area have been operated to a limited extent; the most productive of these is the East Creek, or Ladd, mine southwest of Mineral, where at least three coal beds have been mined. Coal reserves for the area are estimated to be about 44 million tons (table 31).

Summit Creek area.—The Summit Creek area consists of a narrow west-dipping belt of sedimentary rocks of Eocene age. The coal has been subjected to deformation, and some of it is reported to have been transformed to anthracite. It has a high ash content, which ranges from 17.1 to 35.8 percent and averages 26 percent. The moisture content ranges from 4.2 to 7.4 percent and averages 5 percent. The sulfur content ranges from 0.6 to 0.8 percent and averages 0.6 percent.

Although several thick coal beds have been reported to occur in the Summit Creek area, a detailed section measured by J. A. Ellingson showed only one coal bed of minable thickness. This area has been actively prospected, but only a small amount of mining has been done. Reserves of coal are estimated to be less than 4 million tons.

Table 31.-- Estimated remaining reserves of coal in the eastern Lewis County coal areas, Washington, as of January 1, 1960, by township and bed
(Overburden less than 1,000 feet)

Coal bed	Reserves, in millions of short tons, in beds of thickness shown											
	Measured and indicated				Inferred				All categories			
	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total	14 to 28 inches	28 to 42 inches	42 or more inches	Total
T. 12 N., R. 4 E.												
Unnamed	------	------	------	------	------	------	3.22	3.22	------	------	3.22	3.22
T. 13 N., R. 4 E.												
Unnamed	------	------	------	------	------	------	4.29	4.29	------	------	4.29	4.29
Unnamed	------	------	------	------	------	------	3.49	3.49	------	------	3.49	3.49
Unnamed	------	------	------	------	------	------	6.70	6.70	------	------	6.70	6.70
Unnamed	------	------	------	------	------	------	3.06	3.06	------	------	3.06	3.06
Township total	------	------	------	------	------	------	17.54	17.54	------	------	17.54	17.54
T. 14 N., R. 4 E.												
Ladd No. 2	------	------	1.79	1.79	------	------	3.26	3.26	------	------	5.05	5.05
Ladd No. 3	------	------	1.61	1.61	------	------	2.94	2.94	------	------	4.55	4.55
Ladd No. 4	------	------	1.70	1.70	------	------	3.10	3.10	------	------	4.80	4.80
Unnamed	------	------	------	------	1.62	------	------	1.62	1.62	------	------	1.62
Unnamed	------	------	------	------	------	------	4.77	4.77	------	------	4.77	4.77
Unnamed	------	------	------	------	------	------	2.02	2.02	------	------	2.02	2.02
Township total	------	------	5.10	5.10	1.62	------	16.09	17.71	1.62	------	21.19	22.81
T. 14 N., R. 10 E.												
Unnamed	------	------	1.92	1.92	------	------	1.83	1.83	------	------	3.75	3.75
Grand total	------	------	7.02	7.02	1.62	------	38.68	40.30	1.62	------	45.70	47.32

KELSO-CASTLE ROCK AREA, COWLITZ AND LEWIS COUNTIES

Geographic and Geologic Setting

The Kelso-Castle Rock area is in southwestern Lewis County and north-central and western Cowlitz County (fig. 2). The coal beds occur in the Cowlitz Formation of late Eocene age and the Toutle Formation of late Eocene and early Oligocene age. In this area the coal-bearing rocks are gently folded into broad, northwest- and west-trending anticlines and synclines. The dip of the beds generally ranges from 10° to 20°, but dips as high as 45° have been measured locally. The rocks are faulted, but most of the faults have displacements of only a few feet.

The information presented here has been summarized in part from a report by Roberts (1958), which was based on surface mapping of coal beds supplemented by a small amount of exploration drilling.

Coal Beds

Four coal beds are known in the Cowlitz formation in the area east of the Cowlitz River; these are the Leavell, Schuff, and two unnamed beds. The Schuff coal bed is too thin to be of commercial value, and reserves are not estimated for it. Little is known about the geology of the area west of the Cowlitz River, and the coal beds cannot be correlated between mines, prospects, or outcrops. Therefore, west of the Cowlitz River, the number of coal beds and their stratigraphic positions cannot be determined. Detailed geologic mapping supplemented by core drilling will be necessary before the coal reserves of this part of the area can be evaluated adequately.

The Toutle Formation is confined to the area east of the Cowlitz River. Coal beds in the Toutle Formation for which reserves have been calculated are the Cedar Creek Nos. 1, 2, and 3; Silver Lake; and Walker coal beds (Roberts, 1958). The stratigraphic relation between the Silver Lake and Walker coal beds and the Cedar Creek coal beds is not known, and considerable test drilling of the area separating the two localities will be necessary before a satisfactory correlation can be made. The coal outcrop lines and the location and classification of reserves of the coal beds in the Kelso-Castle Rock area are shown on figure 60, on page 107.

Physical and chemical properties.—The coals in the Kelso-Castle Rock area range in rank from lignite to subbituminous. The coal in the Cowlitz Formation ranges in rank from lignite to subbituminous B, but it is commonly subbituminous C. The coal in the Toutle Formation is lignite. Chemical analyses of the various coal beds are given in table 32. All the coals have high moisture contents, ranging from 16.3 to 39.4 percent and averaging about 28 percent, and ash contents ranging from 5.9 to 34.1 percent and averaging about 16 percent. The high moisture content causes the coals to break into small pieces upon exposure to air. The coals of the Cowlitz Formation have an average heat content of 7,500 Btu, whereas the coals of the Toutle Formation have an average heat content of 6,000 Btu.

Coal Mining

A few mines have been developed in the Kelso-Castle Rock area, but none of them were operating as of January 1, 1960, and very little information about past mining has been recorded. Past production in the area is negligible, and reserves for the area are therefore given in terms of original rather than remaining reserves.

Table 32.—Analyses (as-received basis) of coal samples from the Kelso-Castle Rock area, Washington

(M—moisture; VM—volatile matter; FC—fixed carbon; Btu—British thermal units. (1) Smith, 1911; (2) Fieldner and others, 1931; (3) Roberts, 1958)

Location			Mine or prospect	Coal bed	Sample number	Proximate (percent)				Sulfur (percent)	Btu	Source of data
Sec.	T.	R.				M	VM	FC	Ash			
18	9 N.	1 W.	Chapin -------	Leavell ---------	D96792	25.0	32.0	35.9	7.1	0.4	8,240	(3)
7	9 N.	2 W.	Cherry Creek --	Cherry Creek ----	A56015	24.1	30.8	33.2	11.9	1.0	7,850	(2)
11	9 N.	2 W.	Idleman -------	Leavell ---------	D97231	39.4	26.4	28.3	5.9	.7	6,160	(3)
--	9 N.	3 W.	----------	Unnamed --------	6760	22.2	33.3	27.1	17.4	4.0	------	(1)
			----------	--- do ----------	6761	16.3	36.3	30.1	17.4	4.6	------	(1)
18	10 N.	1 E.	Reed and Simpson	Walker (?) ------	------	23.8	24.9	17.2	34.1	---	------	(3)
30	10 N.	1 E.	Silver Lake ----	Silver Lake ------	D99818	32.0	22.7	17.1	28.2	.9	4,520	(3)
12	10 N.	1 W.	Walker -------	Walker ---------	D99819	38.2	24.9	29.8	7.1	.2	6,810	(3)
22	10 N.	2 W.	Fuller --------	Unnamed --------	E6497	19.9	19.8	32.5	27.8	.6	7,250	(3)
27	10 N.	2 W.	Schuff --------	Schuff ----------	D97232	22.3	32.0	35.7	10.0	2.5	8,140	(3)
15	11 N.	1 E.	Graham and Medley	Cedar Creek No. 1	C7246	32.5	26.6	24.7	16.2	.5	6,200	(3)
--	11 N.	1 E.	----------	--- do[a/] --------	------	30.3	28.6	26.2	14.9	.5	6,680	(3)
19	11 N.	1 W.	----------	Unnamed --------	E6228	36.3	26.3	21.0	16.4	.6	5,510	(3)

a/ Average based on 18 analyses.

Cedar Creek Strippable Lignite Area

The extent of the coal beds in the Cedar Creek area in secs. 15, 16, and 22, T. 11 N., R. 1 E., has been determined from drill-hole data obtained during a drilling program conducted by the U.S. Bureau of Mines (Toenges and others, 1947), and the area is considered suitable for strip mining (fig. 61). The Cedar Creek No. 1 and No. 2 coal beds are considered strippable, but because the Cedar Creek No. 3 coal bed is lenticular and contains many partings it has not been included in the strippable reserves.

Summary of Reserves

The reserves of coal and of lignite in the Kelso-Castle Rock area total approximately 150 million tons. These reserves are shown in tables 33 and 34. All the reserves for which tonnages are calculated lie within 1,000 feet of the surface, and those for the Cedar Creek stripping area are within 60 feet of the surface.

The tonnage of lignite in the Toutle Formation was calculated by using a weight of 2,000 tons per acre-foot, because the lignite has a specific gravity of 1.47 owing to the inclusion of a large amount of volcanic debris.

In the Cedar Creek area, the Cedar Creek No. 1 coal bed is separated from the No. 2 coal bed by a bed of lapilli tuff 10 feet thick. If the Cedar Creek No. 1 coal bed were strip mined, the Cedar Creek No. 2 coal bed, which is estimated to contain 2.2 million tons of lignite between 5 and 10 feet in thickness, could also be strip mined by removing the 10-foot tuff bed.

Because of its lower heat value, its variable thickness, and the many partings (about 50 percent of the bed), the Cedar Creek No. 3 coal bed is not included in the strippable reserves. Assuming an average thickness of 12 feet, however, the bed would contain approximately 3.2 million tons of lignite in the Cedar Creek stripping area. The three Cedar Creek lignite beds are superimposed, and the location of reserves in the Cedar Creek No. 2 and the Cedar Creek No. 3 coal beds is the same as that shown for the Cedar Creek No. 1 coal bed on figures 60 and 61.

The points for which information is available on coal in the area west of the Cowlitz River are widely spaced, and all the reserves are classed as inferred. Reserves were calculated around mines, prospects, and outcrops for which the thickness of coal is known. A number of other coal occurrences are reported in the literature but no thickness figures are given. No reserves could be calculated for these beds.

Table 33.—Estimated original reserves of subbituminous coal in the Kelso-Castle Rock area, Washington, by township and bed

Subbituminous bed	Reserves, in millions of short tons, in beds of thickness shown Overburden less than 1,000 feet											
	Measured and indicated				Inferred				All categories			
	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 8 N., R. 1 W.												
Unnamed	-----	-----	-----	-----	0.77	-----	-----	0.77	0.77	-----	-----	0.77
T. 8 N., R. 2 W.												
Unnamed	-----	-----	-----	-----	-----	3.46	-----	3.46	-----	3.46	-----	3.46
Unnamed	-----	-----	-----	-----	1.52	-----	-----	1.52	1.52	-----	-----	1.52
Township total	-----	-----	-----	-----	1.52	3.46	-----	4.98	1.52	3.46	-----	4.98
T. 9 N., R. 1 W.												
Leavell	0.25	-----	-----	0.25	2.59	-----	-----	2.59	2.84	-----	-----	2.84
T. 9 N., R. 2 W.												
Leavell	1.07	-----	-----	1.07	2.02	-----	-----	2.02	3.09	-----	-----	3.09
Cherry Creek	-----	-----	-----	-----	4.48	-----	-----	4.48	4.48	-----	-----	4.48
Red Ash	-----	-----	-----	-----	-----	1.98	-----	1.98	-----	1.98	-----	1.98
Unnamed	.17	-----	-----	.17	4.11	-----	-----	4.11	4.28	-----	-----	4.28
Township total	1.24	-----	-----	1.24	10.61	1.98	-----	12.59	11.85	1.98	-----	13.83
T. 9 N., R. 3 W.												
Unnamed	-----	-----	-----	-----	-----	2.13	-----	2.13	-----	2.13	-----	2.13
All townships												
Grand total	1.49	-----	-----	1.49	15.49	7.57	-----	23.06	16.98	7.57	-----	24.55

Table 34.—Estimated original reserves of lignite in the Kelso-Castle Rock area, Washington, by township and bed

Lignite bed	Reserves, in millions of short tons, in beds of thickness shown Overburden less than 1,000 feet											
	Measured and indicated				Inferred				All categories			
	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total	2.5 to 5.0 feet	5.0 to 10.0 feet	10.0 or more feet	Total
T. 10 N., R. 1 E.												
Silver Lake	-----	2.52	-----	2.52	-----	-----	-----	-----	-----	2.52	-----	2.52
Walker	-----	9.80	-----	9.80	-----	10.25	-----	10.25	-----	20.05	-----	20.05
Township total	-----	12.32	-----	12.32	-----	10.25	-----	10.25	-----	22.57	-----	22.57
T. 10 N., R. 1 W.												
Silver Lake	-----	14.44	-----	14.44	-----	-----	-----	-----	-----	14.44	-----	14.44
Walker	-----	1.69	-----	1.69	-----	1.78	-----	1.78	-----	3.47	-----	3.47
Unnamed	-----	-----	10.88	10.88	-----	-----	-----	-----	-----	-----	10.88	10.88
Unnamed	-----	-----	2.13	2.13	-----	-----	-----	-----	-----	-----	2.13	2.13
Township total	-----	16.13	13.01	29.14	-----	1.78	-----	1.78	-----	17.91	13.01	30.92
T. 11 N., R. 1 E.*												
Cedar Creek No. 1	-----	-----	-----	-----	-----	-----	27.04	27.04	-----	-----	27.04	27.04
Cedar Creek No. 2	-----	-----	-----	-----	-----	14.24	-----	14.24	-----	14.24	-----	14.24
Cedar Creek No. 3	-----	-----	-----	-----	-----	-----	18.70	18.70	-----	-----	18.70	18.70
Township total	-----	-----	-----	-----	-----	14.24	45.74	59.98	-----	14.24	45.74	59.98
T. 11 N., R. 1 W.												
Unnamed	-----	-----	-----	-----	-----	0.50	-----	0.50	-----	0.50	-----	0.50
T. 11 N., R. 2 W.												
Unnamed	-----	-----	-----	-----	-----	2.61	-----	2.61	-----	2.61	-----	2.61
All townships												
Grand total	-----	28.45	13.01	41.46	-----	29.38	45.74	75.12	-----	57.83	58.75	116.58

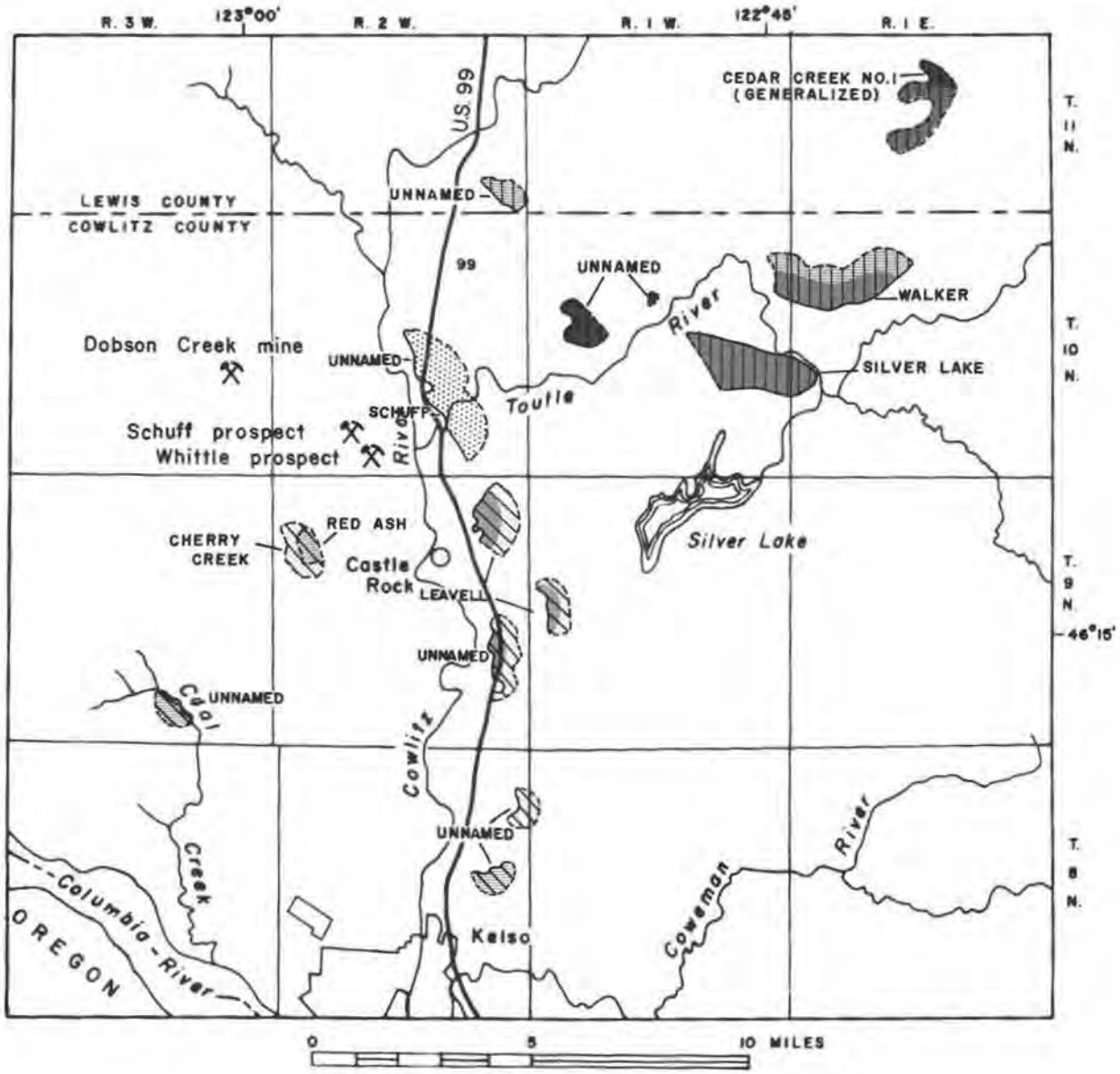
* Does not include lignite in the Cedar Creek strippable lignite area in secs. 15, 16, and 22.

Table 35.—Estimated original reserves of strippable lignite in the Cedar Creek area, secs. 15, 16, and 22, T. 11 N., R. 1 E., Kelso-Castle Rock area, Washington

Lignite bed	Overburden (in feet)	Reserves, in thousands of short tons, in beds of thickness shown[a/]			
		5.0 to 10.0 feet	10.0 to 20.0 feet	20.0 or more feet	Total
Cedar Creek No. 1	0-20	20	773	897	1,690
	20-40	167	177	1,445	1,789
	40-60	-----	451	1,925	2,376
Bed total	-----	187	1,401	4,267	5,855
Cedar Creek No. 2[b/]	-----	2,201	-----	-----	2,201
Grand total	-----	2,388	1,401	4,267	8,056

a/ Lignite less than 5 feet thick is not present in this area. Sufficent data are available to allow use of these more detailed thickness categories.

b/ If the Cedar Creek No. 1 bed were removed, the Cedar Creek No. 2 bed could then be mined by stripping methods after removing a 10-foot bed of tuff that separates the two lignite beds.



EXPLANATION

SUBBITUMINOUS COAL — LIGNITE
MEASURED AND INDICATED RESERVES

Coal 2½ to 5 feet thick

Lignite 5 to 10 feet thick

Lignite 10 or more feet thick

Coal less than 2½ feet thick

Inferred outcrop of coal bed

Boundary of area for which data were sufficient to estimate reserves

INFERRED RESERVES

Coal 2½ to 5 feet thick

Lignite 5 to 10 feet thick

Coal 5 to 10 feet thick

Lignite 10 or more feet thick

LEAVELL
Name of coal bed

Mine or prospect

FIGURE 60. GENERALIZED MAP SHOWING LOCATION AND CLASSIFICATION OF COAL RESERVES IN THE KELSO-CASTLE ROCK AREA

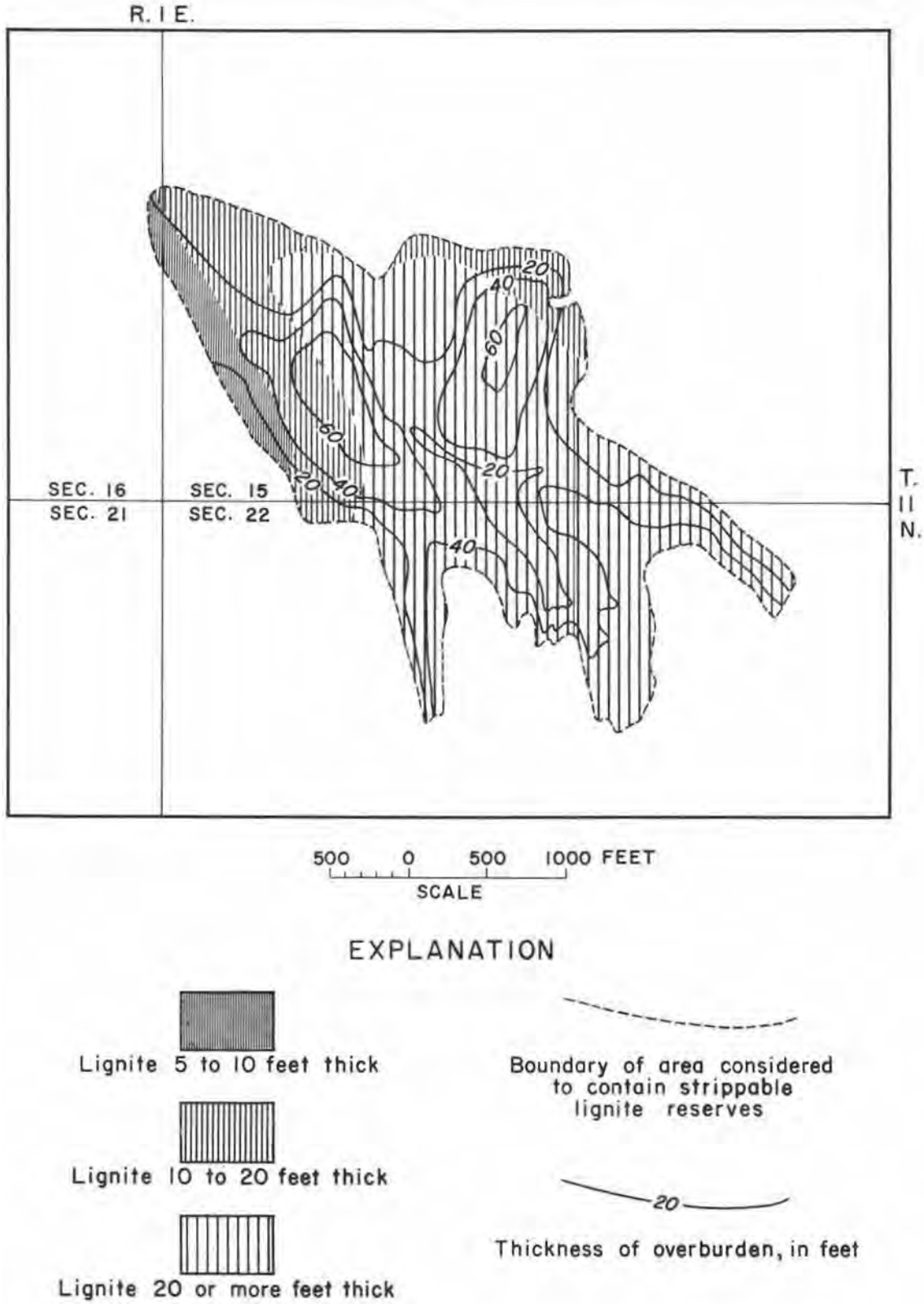


FIGURE 61. Map showing location and classification of strippable lignite reserves in the Cedar Creek No. 1 bed, Kelso-Castle Rock area, Washington

MISCELLANEOUS OCCURRENCES OF COAL IN WASHINGTON

Many scattered occurrences of coal outside the major coal-bearing areas in Washington are known or have been reported (fig. 1). A summary of these, including a brief description, evaluation, and references to source data, has been compiled by Valentine (1949, p. 27, pl. 9). Little is known about most of these localities inasmuch as their existence is known only through claims filed in the offices of county auditors or through their having been mentioned in field notes. A brief summary of those that have been described in published literature, together with the references to the sources, is given below.

Asotin County.—Lignite interstratified with Columbia River Basalt has been discovered at several localities along the Grande Ronde River in the southern part of the county, and openings have been made on the beds. In sec. 12, T. 36 N., R. 4 E., a bed of lignite 20 feet thick was measured. This lignite is probably in landslide blocks. The true position of the lignite beds is at greater elevations above the river, and lignite-bearing rocks may underlie a wide area. (Russell, 1901, p. 122-127).

Chelan County.—Two coal beds were penetrated in an oil and gas test well in sec. 26, T. 22 N., R. 20 E., at a depth of about 2,000 feet. The coal beds were reported to be about 6 feet thick and of subbituminous or bituminous rank. In sec. 21, T. 22 N., R. 20 E., a small amount of coal was produced prior to 1934 from the Dry Gulch mine. The coal mined is 4 feet thick and occurs in carbonaceous shale and sandstone. A coal bed, in sec. 29, T. 33 N., R. 21 E., with a maximum thickness of 1 foot, and probably of subbituminous rank, was developed to a small extent in 1908 (Huntting, 1943, p. 51 and 52). Lower Tertiary and (or) Cretaceous continental sedimentary rocks, possibly coal-bearing, that have been referred to the Swauk Formation underlie part of Chelan County. These rocks should be studied to evaluate their possibilities as coal-bearing rocks.

Clallam County.—An occurrence of coal in Clallam County has been described by Gower (1960). On the basis of a bituminous coal bed averaging 22 inches in thickness that he found cropping out along the nose of a small syncline in sec. 25, T. 32 N., R. 12 W., and in sec. 30, T. 32 N., R. 11 W., inferred reserves totaling 128,000 tons have been estimated for the county.

San Juan County.—On Waldron Island in San Juan County, small amounts of coal were discovered at three different horizons in a well drilled to a depth of 1,500 feet. On Orcas Island, small pockets of coal were found in lignitic leaf-bearing shales, and small beds of semianthracite have been discovered on the northeast side of the island, but no coal of commercial importance has been developed. The stratigraphic section of rocks on Sucia Island is reported to be similar to that of the coal-bearing rocks at Nanaimo, British Columbia, and was considered worth investigating for coal possibilities (McLellan, 1927, p. 174).

Snohomish County.—A small amount of subbituminous coal has been mined southeast of Arlington in T. 31 N., R. 5 E. The coal-bearing rocks are probably of Oligocene age (Glover, 1936, p. 30).

A narrow northwest-trending band, 1 to 3 miles wide, of lower Tertiary or possibly Cretaceous continental sedimentary rocks extends across the eastern part of the county. These may be contiguous with the coal-bearing rocks of the Rick Creek area of Skagit County and should be considered as possible coal-bearing rocks. Most of western Snohomish County is covered by glacial drift, but there are several small outcrop areas of probable lower Tertiary continental sedimentary rocks. It is possible that the coal-bearing rocks of western Skagit County, the continental sedimentary rocks exposed in western Snohomish County, and the coal-bearing rocks of King County are part of a continuous north- to northwest-trending belt of coal-bearing rocks that is, in most places, covered by glacial drift. The possibility of coal reserves beneath the glacial deposits of western Snohomish County should be explored by core drilling.

Spokane County.—In the center of sec. 24, T. 25 N., R. 44 E., near Spokane, a horizontal bed of very carbonaceous shale containing numerous leaf imprints crops out. A tunnel was driven several hundred feet into this shale in an unsuccessful search for coal (Glover, 1941, p. 272).

Stevens County.—A mine was operated at one time in sec. 28, T. 31 N., R. 40 E., on a coal bed that occurs in shale between two igneous flows. The coal is of subbituminous rank and, including several partings, is about 4 feet thick. A similar coal bed occurs in the southwest part of the county (Glover, 1936, p. 30).

POSSIBLE ADDITIONAL RESERVES NOT INCLUDED IN ESTIMATES

In the State of Washington, specific information about the occurrence, quality, and thickness of coal beds is lacking for large areas of known coal-bearing rocks. Because of this scarcity of specific information, in this report the coal reserves could be estimated for only about one-third of the known area of coal-bearing rock (fig. 62). In addition, much of the area for which coal reserves have been estimated contains additional coal in beds of unknown thickness and extent. Detailed surface and subsurface geologic studies are needed for these coal-bearing areas. When such detailed geologic information becomes available, the estimated coal reserves will be substantially increased.

Possibly other large areas of coal-bearing rocks are concealed beneath a mantle of glacial drift or alluvium (fig. 62). The principal areas where such conditions may exist are: north of Enterprise in the northwest part of Whatcom County, in a north- to northwest-trending belt along the west side of the Cascade Range between the Skagit and King County areas, between the King and Pierce County areas, and between the Centralia-Chehalis coal district and the Kelso-Castle Rock area. No doubt many of these

areas contain significant coal deposits within 3,000 feet of the surface. Ultimately all these areas should be tested by core drilling to determine their coal-reserve potential.

In addition, large areas in Chelan and Kittitas Counties and smaller areas in eastern King and Snohomish Counties are underlain by lower Tertiary or Cretaceous continental sedimentary rocks that have been referred to the Swauk Formation. These rocks have been intensely deformed in most places and are of doubtful value as possible commercial sources of coal. However, some of these rocks may contain significant amounts of coal, and they should be examined.

It is evident that the reserve estimates presented in this report, which are based on specific data, are minimum estimates and that they will be increased in the future as additional information is acquired through detailed geologic studies. It is hoped that this report will provide an incentive and serve as a guide for further detailed investigations.

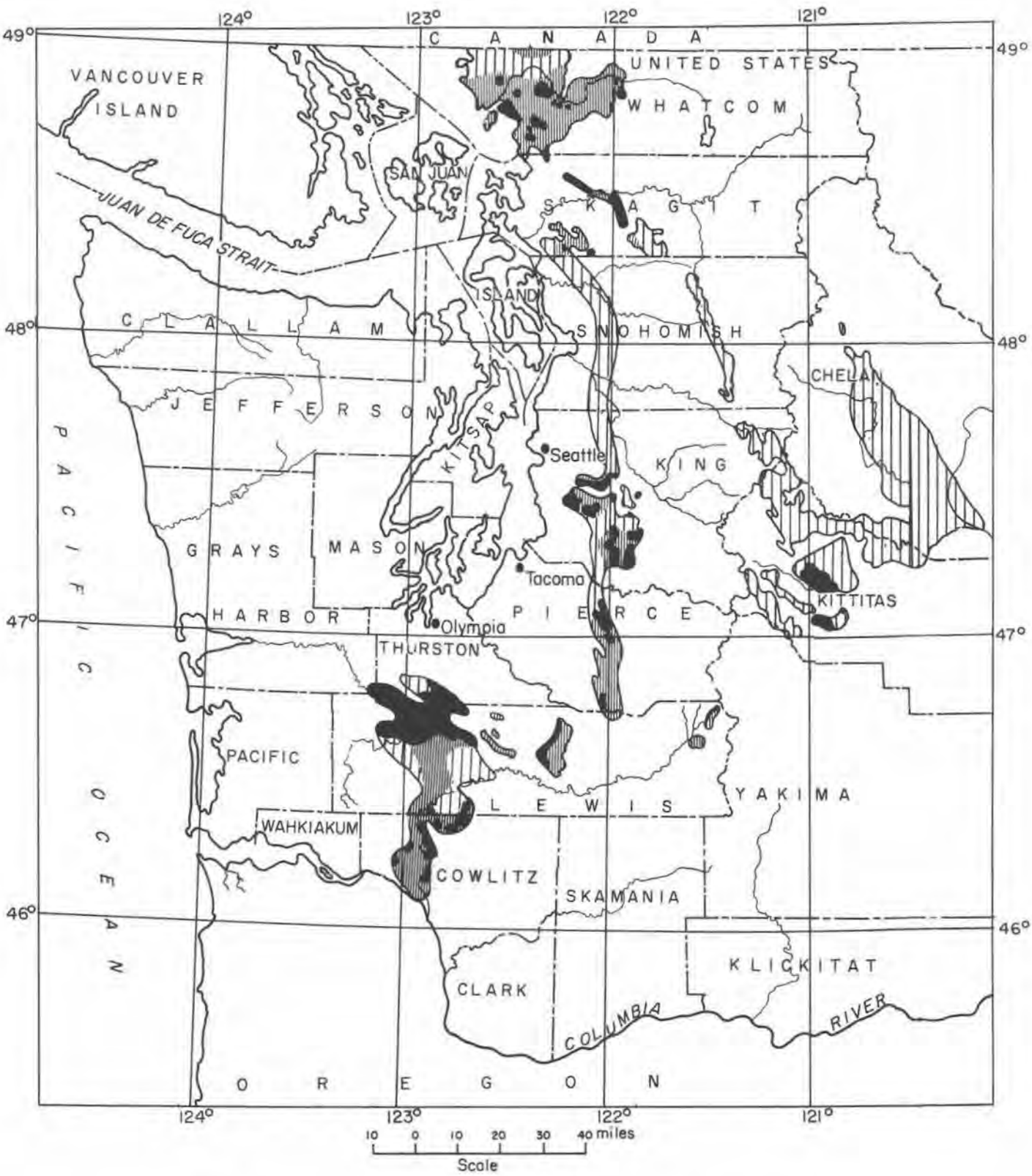


FIGURE 62. INDEX MAP OF WASHINGTON SHOWING KNOWN AND POSSIBLE AREAS OF COAL-BEARING ROCKS

Table 36.—Summary of estimated remaining reserves of coal in Washington by county and township

(In millions of short tons)

[Rank: A, anthracite; B, bituminous; S, subbituminous; L, lignite]

Rank	Township and range	Measured and indicated				Inferred				All categories			
		Thin	Intermediate	Thick	Total	Thin	Intermediate	Thick	Total	Thin	Intermediate	Thick	Total
						Whatcom County							
B	36 N., 4 E.	-----	5.36	-----	5.36	1.75	2.62	-----	4.37	1.75	7.98	-----	9.73
B	37 N., 3 E.	-----	6.88	1.03	7.91	.74	11.11	0.34	12.19	.74	17.99	1.37	20.10
B	37 N., 4 E.	6.76	2.22	10.99	19.97	10.30	9.39	4.72	24.41	17.06	11.61	15.71	44.38
B	38 N., 2 E.	12.27	-----	29.43	41.70	6.35	-----	22.97	29.32	18.62	-----	52.40	71.02
B	38 N., 3 E.	3.79	4.57	13.60	21.96	3.45	19.56	51.53	74.54	7.24	24.13	65.13	96.50
B	38 N., 4 E.	1.32	3.54	5.14	10.00	2.15	4.02	3.27	9.44	3.47	7.56	8.41	19.44
B	39 N., 2 E.	-----	-----	-----	-----	3.58	2.68	15.65	21.91	3.58	2.68	15.65	21.91
B	39 N., 3 E.	-----	8.17	-----	8.17	-----	18.55	-----	18.55	-----	26.72	-----	26.72
B	39 N., 4 E.	-----	2.93	-----	2.93	1.45	5.89	-----	7.34	1.45	8.82	-----	10.27
A	39 N., 7 E.	-----	-----	-----	-----	1.00	3.30	.50	4.80	1.00	3.30	.50	4.80
	County total	24.14	33.67	60.19	118.00	30.77	77.12	98.98	206.87	54.91	110.79	159.17	324.87
						Skagit County							
B	33 N., 4 E.	-----	-----	-----	-----	-----	0.37	-----	0.37	-----	0.37	-----	0.37
B	33 N., 5 E.	-----	-----	-----	-----	-----	.33	-----	.33	-----	.33	-----	.33
B	34 N., 5 E.	-----	-----	-----	-----	0.78	-----	-----	.78	0.78	-----	-----	.78
B	34 N., 6 E.	-----	-----	11.06	11.06	19.64	-----	59.65	79.29	19.64	-----	70.71	90.35
B	34 N., 7 E.	-----	-----	-----	-----	30.85	-----	93.71	124.56	30.85	-----	93.71	124.56
B	35 N., 4 E.	-----	-----	-----	-----	.40	.16	.34	.90	.40	.16	.34	.90
B	35 N., 5 E.	24.94	10.33	21.38	56.65	34.15	14.15	29.27	77.57	59.09	24.48	50.65	134.22
B	35 N., 6 E.	1.15	-----	21.63	22.78	1.77	-----	53.78	55.55	2.92	-----	75.41	78.33
B	36 N., 4 E.	-----	-----	-----	-----	23.64	9.79	20.26	53.69	23.64	9.79	20.26	53.69
B	36 N., 5 E.	-----	-----	-----	-----	10.32	4.27	8.84	23.43	10.32	4.27	8.84	23.43
	County total	26.09	10.33	54.07	90.49	121.55	29.07	265.85	416.47	147.64	39.40	319.92	506.96
						Kittitas County							
B	18 N., 15 E.	10.81	-----	-----	10.81	28.56	-----	-----	28.56	39.37	-----	-----	39.37
B	19 N., 15 E.	-----	-----	-----	-----	-----	2.25	10.95	13.20	-----	2.25	10.95	13.20
B	19 N., 16 E.	-----	-----	-----	-----	1.10	-----	.43	1.53	1.10	-----	.43	1.53
B	20 N., 14 E.	.88	7.00	6.58	14.46	4.74	17.92	11.58	34.24	5.62	24.92	18.16	48.70
B	20 N., 15 E.	-----	3.83	61.78	65.61	1.25	73.95	35.98	111.18	1.25	77.78	97.76	176.79
B	20 N., 16 E.	-----	-----	-----	-----	-----	.05	1.17	1.22	-----	.05	1.17	1.22
B	21 N., 14 E.	-----	.21	-----	.21	.20	.58	-----	.78	.20	.79	-----	.99
	County total	11.69	11.04	68.36	91.09	35.85	94.75	60.11	190.71	47.54	105.79	128.47	281.80
						Pierce County							
B	15 N., 6 E.	-----	-----	-----	-----	-----	-----	13.41	13.41	-----	-----	13.41	13.41
B	17 N., 6 E.	2.46	3.42	-----	5.88	2.13	2.40	-----	4.53	4.59	5.82	-----	10.41
B	18 N., 6 E.	6.35	2.74	25.61	34.70	6.06	7.16	79.56	92.78	12.41	9.90	105.17	127.48
B	19 N., 6 E.	5.85	19.34	66.90	92.09	8.42	27.24	82.90	118.56	14.27	46.58	149.80	210.65
	County total	14.66	25.50	92.51	132.67	16.61	36.80	175.87	229.28	31.27	62.30	268.38	361.95
						King County							
S	20 N., 6 E.	-----	0.41	-----	0.41	-----	0.69	-----	0.69	-----	1.10	-----	1.10
B[a]	21 N., 6 E.	8.08	8.95	16.61	33.64	11.31	26.12	86.21	123.64	19.39	35.07	102.82	157.28
B[b]	21 N., 7 E.	2.98	6.29	33.02	42.29	6.88	8.16	66.16	81.20	9.86	14.45	99.18	123.49
B[c]	22 N., 6 E.	.05	.93	10.66	11.64	.26	1.45	33.75	35.46	.31	2.38	44.41	47.10
B	22 N., 7 E.	-----	.49	12.81	13.30	.66	4.58	26.92	32.16	.66	5.07	39.73	45.46
S	23 N., 4 E.	-----	-----	-----	-----	.57	-----	-----	.57	.57	-----	-----	.57
S[d]	23 N., 5 E.	8.68	8.12	.47	17.27	29.59	33.18	2.02	64.79	38.27	41.30	2.49	82.06
S[e]	23 N., 6 E.	5.24	2.78	-----	8.02	10.62	24.85	-----	35.47	15.86	27.63	-----	43.49
B	23 N., 7 E.	-----	.91	5.75	6.66	1.67	2.08	7.11	10.86	1.67	2.99	12.86	17.52
S	24 N., 5 E.	20.61	31.28	-----	51.89	23.52	9.10	-----	32.62	44.13	40.38	-----	84.51
S	24 N., 6 E.	40.24	35.77	-----	76.01	56.49	92.59	-----	149.08	96.73	128.36	-----	225.09
	County total	85.88	95.93	79.32	261.13	141.57	202.80	222.17	566.54	227.45	298.73	301.49	827.67

a/ Includes 34.45 million tons of subbituminous coal
b/ Includes 6.56 million tons of subbituminous coal
c/ Includes 0.57 million tons of subbituminous coal
d/ Includes 2.49 million tons of bituminous coal
e/ Includes 0.39 million tons of bituminous coal

Table 36.—Summary of estimated remaining reserves of coal in Washington by county and township—Continued

(In millions of short tons)
[Rank: A, anthracite; B, bituminous; S, subbituminous; L, lignite]

Rank	Township and range	Measured and indicated				Inferred				All categories			
		Thin	Intermediate	Thick	Total	Thin	Intermediate	Thick	Total	Thin	Intermediate	Thick	Total
						Lewis County (Includes part of Thurston County)							
L	11 N., 1 E.	-----	-----	-----	-----	-----	14.24	45.74	59.98	-----	14.24	45.74	59.98
L	11 N., 1 W.	-----	-----	-----	-----	-----	.50	-----	.50	-----	.50	-----	.50
L	11 N., 2 W.	-----	-----	-----	-----	-----	2.61	-----	2.61	-----	2.61	-----	2.61
B	12 N., 4 E.	-----	-----	-----	-----	-----	-----	3.22	3.22	-----	-----	3.22	3.22
S	13 N., 1 E.	-----	-----	-----	-----	-----	24.17	-----	24.17	-----	24.17	-----	24.17
B	13 N., 4 E.	-----	-----	-----	-----	-----	-----	17.54	17.54	-----	-----	17.54	17.54
S	13 N., 1 W.	-----	-----	-----	-----	2.92	.99	-----	3.91	2.92	.99	-----	3.91
S	13 N., 2 W.	0.44	33.70	-----	34.14	9.83	63.40	-----	73.23	10.27	97.10	-----	107.37
S	13 N., 3 W.	-----	-----	-----	-----	-----	17.41	-----	17.41	-----	17.41	-----	17.41
S	14 N., 1 E.	-----	-----	-----	-----	-----	19.89	1.20	21.09	-----	19.89	1.20	21.09
B	14 N., 4 E.	-----	-----	5.10	5.10	1.62	-----	16.09	17.71	1.62	-----	21.19	22.81
B	14 N., 10 E.	-----	-----	1.92	1.92	-----	-----	1.83	1.83	-----	-----	3.75	3.75
S	14 N., 1 W.	15.47	235.83	102.43	353.73	125.45	317.14	191.95	634.54	140.92	552.97	294.38	988.27
S	14 N., 2 W.	82.41	423.13	79.76	585.30	115.44	207.69	-----	323.13	197.85	630.82	79.76	908.43
S	14 N., 3 W.	63.34	97.33	-----	160.67	40.15	63.54	-----	103.69	103.49	160.87	-----	264.36
S	14 N., 4 W.	1.17	-----	-----	1.17	-----	-----	-----	-----	1.17	-----	-----	1.17
S	15 N., 1 E.	1.70	25.12	1.24	28.06	14.06	4.49	-----	18.55	15.76	29.61	1.24	46.61
S	15 N., 1 W.	31.70	244.33	228.53	504.56	68.04	95.47	50.38	213.89	99.74	339.80	278.91	718.45
S	15 N., 2 W.	16.09	158.08	34.47	208.64	79.54	1.80	-----	81.34	95.63	159.88	34.47	289.98
S	15 N., 3 W.	7.20	133.99	-----	141.19	37.10	82.38	-----	119.48	44.30	216.37	-----	260.67
S	15 N., 4 W.	13.50	4.15	-----	17.65	19.12	-----	-----	19.12	32.62	4.15	-----	36.77
S	16 N., 1 W.	1.75	-----	-----	1.75	.35	-----	-----	.35	2.10	-----	-----	2.10
S	16 N., 2 W.	3.02	-----	-----	3.02	-----	-----	-----	-----	3.02	-----	-----	3.02
	County total	237.79	1,355.66	453.45	2,046.90	513.62	915.72	327.95	1,757.29	751.41	2,271.38	781.40	3,804.19
						Cowlitz County							
S	8 N., 1 W.	-----	-----	-----	-----	0.77	-----	-----	0.77	0.77	-----	-----	0.77
S	8 N., 2 W.	-----	-----	-----	-----	1.52	3.46	-----	4.98	1.52	3.46	-----	4.98
S	9 N., 1 W.	0.25	-----	-----	0.25	2.59	-----	-----	2.59	2.84	-----	-----	2.84
S	9 N., 2 W.	1.24	-----	-----	1.24	10.61	1.98	-----	12.59	11.85	1.98	-----	13.83
S	9 N., 3 W.	-----	-----	-----	-----	-----	2.13	-----	2.13	-----	2.13	-----	2.13
L	10 N., 1 E.	-----	12.32	-----	12.32	-----	10.25	-----	10.25	-----	22.57	-----	22.57
L	10 N., 1 W.	-----	16.13	13.01	29.14	-----	1.78	-----	1.78	-----	17.91	13.01	30.92
	County total	1.49	28.45	13.01	42.95	15.49	19.60	-----	35.09	16.98	48.05	13.01	78.04
						All Counties							
	State total	401.74	1,560.58	820.91	2,783.23	875.46	1,375.86	1,150.93	3,402.25	1,277.20	2,936.44	1,971.84	6,185.48

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