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ABSTRACT

The Matanuska Valley of south-central Alaska contains relatively small but important reserves of coal within the Chickaloon Formation of Early Tertiary age. Identified resources amount to about 90 million metric tons, and hypothetical-resource estimates range to 450 million metric tons. Most of the potentially minable resources are concentrated in the Eska-Moose (Wishbone Hill) and Chickaloon fields.

Coals of the Chickaloon Formation formed in paludal swamps of continental alluvial plains. Coal beds have locally been named and correlated between mines in the Wishbone Hill and Chickaloon districts. The average maximum thickness of coal beds of the Matanuska Valley is 2.5 m but locally range to over 9 m. The relative complexity of structure increases eastward in the region. Coals of the Anthracite Ridge field are highly folded and faulted and contain abundant igneous intrusions. The rank of coals increases from subbituminous and high-volatile bituminous in the lower Matanuska Valley, to medium- and low-volatile bituminous in the central Matanuska Valley, and finally to low-volatile bituminous, semianthracite, and anthracite coals of the upper Matanuska Valley.

The quality of Matanuska Valley coals is high compared to other Alaskan coals, but is generally similar to those of the Alaska Peninsula and Bering River fields. Sulfur contents are uniformly low (less 1 percent) but ash contents are typically relatively high (mean of 20 percent). Mean heating values are about 10,700 Btu per pound on an as-received basis. Matanuska Valley coals generally have lower contents of Mn, Zn, B, As, Ni, Pb, Zr, Cu, Sn, Co, Cr, La, Y, Ga, and Be than other coals, but show higher contents of F, Sc, V, Br, I, Cs, Sm, Eu, and Th than other U.S. coals.

Coal overburdens of the Matanuska Valley are very low in pyritic sulfur (mean content 0.02 percent). Problems with acidic, sodic, or saline minesoils are not anticipated based on recent research. Future mine reclamation programs should be very successful.

The near-term coal-development potential in the Matanuska Valley is high, particularly in the Wishbone Hill district. Because of the relatively small coal-resource base of the region, mine size will be limited to less than 1.0 million metric ton per year.

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INTRODUCTION

LOCATION AND ACCESSIBILITY

The Matanuska coal field is located in the Matanuska Valley of south-central Alaska (Figure 1). It is an area immediately adjacent to the Matanuska River and containing mainly Mesozoic sedimentary rocks and the Tertiary coal-bearing rocks that are described in this paper (Figure 2). The Matanuska Valley extends eastward from the head of Cook Inlet and separates the Chugach Mountains on the south from the Talkeetna Mountains on the north. The Matanuska coal field lies east of the Little Susitna field and west of the Copper River lowland. It is one of the two major historic coal-producing fields of Alaska, and has been subdivided into three main districts---Wishbone Hill, Chickaloon, and Anthracite Ridge (Barnes and Payne, 1956). The field is 9.5 to 13 km wide, 80 km long, and has an area of at least 500 km^2, and lies 80 to 160 km northeast of Anchorage. Its western end is 40 to 80 km northeast of tidewater, and the center of the coal field is 240 km from Seward by rail. The general trend of the coal field is N. 70°E, and it is located at 61° north latitude (Apell, 1944; Kreig and Associates, 1983).

Figures 1 and 2---NEAR HERE

The lower Matanuska Valley is traversed by the Alaska Railroad. The Glenn Highway transects the Matanuska Valley passing 3 km south of Wishbone Hill and connects the Anchorage-Palmer Highway with the Richardson Highway and interior Alaska.

DISTRIBUTION OF COAL-BEARING ROCKS

The Matanuska Valley contains a number of distinct coal-bearing areas or isolated fields. Merritt and Belowich (1984) identified five major fields---Eska-Moose, Young Creek, Castle Mountain, Chickaloon, and Anthracite Ridge (Figure 3). The Chickaloon Formation covers up to 1000 km^2 of the valley from Moose Creek to Packsaddle Gulch, but probably less than a quarter of this is underlain by potentially minable coal deposits.

Figure 3---NEAR HERE

Tsadaka Canyon or lower Moose Creek contains the first significant coal exposures of the valley and are located about 29 km from the mouth of the Matanuska River. The Eska-Moose field is situated from Moose Creek eastward to the valley of Eska Creek. The Young Creek field is located about 11 to 13 km east of Eska Creek, mainly in the upper part of Young Creek valley. It is intermediate in position between Eska-Moose and Castle Mountain fields. Other than the deposits on the north flank of Red Mountain, the coal occurrences of the Young Creek field are too small to warrant detailed examination (Barnes, 1962a).

The Castle Mountain field is located south of Castle Mountain, westward to Kings River and northward to Edwardson's Gulch. Southeast of this field is the Chickaloon field, which is situated both north and south of the Matanuska River and includes a large part of the valley of the Chickaloon River several kilometers south of Castle Mountain and Puddingstone Hill. The Chickaloon River coal outcrops are about 60 km from the mouth of the Matanuska River. The deposits of lower Coal Creek are also included in the Chickaloon field. East of the Chickaloon field, no further evidences of coal are found until reaching the Anthracite Ridge district.

Coal outcrops cover several small areas on the south flank of Anthracite Ridge about 80 km from the mouth of the Matanuska River. These deposits contain predominantly anthracitic and high-grade bituminous coal, and have been included in the Anthracite Ridge field.

STRUCTURAL GEOLOGY AND REGIONAL TECTONISM

Matanuska Valley is considered a northeastern arm of the larger Cook Inlet basin. The valley forms a structural trough 8 to 16 km wide and 80 km long, and narrows toward the northeast. This trough was named the Matanuska geosyncline by Payne (1955; Figure 4). The Talkeetna and Seldovia geanticlines flank the Matanuska geosyncline on the north and south respectively (Grantz, 1964). The general trend of major structural elements in the Matanuska Valley is northeast and east. This can be seen from the generalized aeromagnetic map of Figure 5. The Matanuska Valley is part erosional as well as structural. The present valley was escavated by the Matanuska Glacier during repeated advances in the Pleistocene and later by the Matanuska River (Grantz, 1964).

Figures 4 and 5---NEAR HERE

Matanuska Valley is located in the forearc terrane of the Alaska-Aleutian volcanic arc (Bruhn and Pavlis, 1981). The geologic history of this region as a marine depositional trough ended by orogeny in Paleocene and early Eocene time. Neogene faulting in the Matanuska Valley was extensive and caused by subduction of the Pacific plate beneath the convergent margin of the North American plate. Neogene deformation occurred mainly as a result of movement on multiple sets of faults that transcut the terrane. The east-northeast trending Castle Mountain fault, named by Barnes and Payne (1956) and an unnamed fault separating the Matanuska and Chickaloon Formations along the south side of the Matanuska River show evidence for substantial vertical movement. The high-angle Castle Mountain fault, perhaps the dominant structural feature of Matanuska Valley, can be traced for tens of kilometers and had several kilometers of Neogene displacement. Grantz (1964) describes right-lateral separation along the fault throughout Mesozoic and Early Tertiary time and a large vertical separation since Oligocene time. The southern border of Matanuska Valley is not obviously a single fault but a number of faults that have acted to produce in part the low-lying position of the block. North-trending transcurrent faults are present throughout Matanuska Valley, and some extend across the Castle Mountain fault and into the flanks of the Talkeetna Mountains (Bruhn and Pavlis, 1981). Several tear faults cut across the axis of Wishbone Hill syncline, having developed at least in part contemporaneously with the folding. The strike faults have locally caused elimination or repetition of strata. Strata are also affected by a large number of faults with a small throw; these sometimes cut the axes of folds. Slickensides with shallow and deep grooves and striations give evidence for complex fault movements.

The Chickaloon Formation has been considerably folded and faulted since its deposition. Deformation of coal-bearing rocks increases eastward with only slight folding and faulting in the western part of the field. Complex folding, faulting, and shearing characterize the eastern part of the field and coals become progressively higher in grade eastward in the valley. Chickaloon Formation rocks are only moderately indurated even when severely deformed (Grantz, 1964). Coals of Matanuska Valley have a complex structural geology compared to mine areas of the contiguous 48 states, and are strongly folded and deformed compared to subbituminous and lignite beds of the Susitna lowland to the west. Many minor faults and flexures in the Chickaloon Formation do not carry through into the overlying Wishbone and Tsadaka Formations, which are generally characterized by greater competence and resistance to deformation.

The relatively parallel zones of major faulting bordering Tertiary and Cretaceous rocks of the Matanuska Valley on the north and south separate these rocks from older and more highly deformed metamorphic and intrusive rocks of the mountains (Barnes and Payne, 1956). Formations of the valley are a part of the downfaulted block compressed between dioritic rocks of the Talkeetna Mountains on the north, and metamorphosed sediments, volcanics, and intrusive rocks of the Chugach Mountains on the south. Upper Cretaceous and Tertiary rocks unconformably overlie older Mesozoic rocks (Bruhn and Pavlis, 1981).

Chickaloon Formation rocks strike generally parallel to the easterly-northeasterly trend of Matanuska Valley being N. 60°E. west of the Chickaloon River and N. 75° to 90° E. east of Chickaloon River. Dips of strata are variable but show a tendency toward steep angles throughout most of the area. Coal beds are nearly vertical and overturned in places, as for example on the north bank of lower Chickaloon River. Some areas show a relatively continuous uniform dip for considerable distances. Folding of Chickaloon Formation rocks is predominantly open but locally can be sharp, of an asymmetric character, fairly complex, or unpredictable in nature.

Dike intrusions have contributed to the progressive devolatilization of the coals of the Matanuska Valley. These intrusives are abundant in the eastern part of the field, less abundant in the central part, and of only very minor occurrence in the western part.

Structure has significantly affected the lateral continuity of coals of the Chickaloon Formation in the Matanuska Valley. They have been crumpled and have pinched out laterally incident to folding in the region. However, rapid change in coal bed thickness is also due in part to the original lenticular character of the sediments.

STRUCTURE OF THE WISHBONE HILL DISTRICT

The Wishbone Hill district occupies the western part of the Matanuska coal field. The district takes its name from a prominent synclinal ridge that extends some 11 km northeastward from Moose Creek to Eska Creek. The topographic feature of Wishbone Hill is the surficial expression of the Wishbone Hill syncline, a canoe-shaped open fold. This topographic high is bounded on the north and south by narrow erosional troughs. Resistant, curving ridges of Wishbone Formation conglomerate crop out on both limbs of the syncline, which converge just west of Eska Creek resulting in the 'wishbone' form. The axis of the syncline has been traced eastward beyond Eska Creek, where it is broken by transverse faulting, the ridge-forming conglomerate has been eroded away, and the structure has little topographic expression (Apell, 1944; Alaska Geological Society, 1964).

The general strike of rocks of the Wishbone Hill district is south 55° to 80° west, the same trend as Matanuska River, mountain fronts, and structural lines. The dip of beds along the axis of the syncline varies from a few degrees to nearly 90° in local areas of tight folding and in some faulted blocks. Common dips of beds on the south limb vary from 12° to 30°; the north limb is generally more steeply dipping (25° to 35°). The synclinal axis plunges to the southwest from 10° to a maximum of 25°; because of this plunge, strata higher in the coal series crop out progressively to the west.

A period of tectonism occurred prior to deposition of Wishbone Formation as indicated by the angular unconformity at the base of the unit. The Wishbone Hill syncline was formed in the period between the deposition of the Wishbone and Tsadaka Formations; this is indicated by truncation and erosion of folded strata in the Wishbone and Chickaloon Formations (Clardy, 1982). The Chickaloon Formation is less competent than the overlying conglomerates and has been affected by numerous smaller faults and subsidiary folds.

Faults of the Wishbone Hill district are generally steeply dipping or vertical. Strikes of the faults vary from N. 25° E. in the eastern part of the district to about N. 45° W. on Moose Creek. The Castle Mountain fault forms the northern boundary of the district separating it from the Talkeetna Mountains. The fault trace is marked by a zone of crushing in the Arkose Ridge and Chickaloon

Formations about 300 m wide along the south slope of Arkose Ridge and Eska Mountain. It has brought the Arkose Ridge Formation up into contact with the Chickaloon Formation along the northern edge of the district. Considering the thickness of the intervening Matanuska Formation, this would indicate a vertical displacement of at least 1200 m. Between the Castle Mountain fault and the north limb of Wishbone Hill syncline, exposed beds of Chickaloon Formation dip at relatively high angles mainly to the southeast.

The Wishbone Hill syncline has been cut by a number of transverse faults which divide the region into a series of blocks (Bain, 1946). The north-trending tear faults on Wishbone Hill offset the axis and limbs of the syncline at a number of places and probably represent late secondary shears related to deformation along the Castle Mountain fault system (Bruhn and Pavlis, 1981). Although displacements are usually no more than 100 m, they can be as much as 600 m, mainly horizontal (Alaska Geological Society, 1964).

The coal beds of the Wishbone Hill district crop out around the margins of Wishbone Hill and extend to considerable depths. They are found on both flanks and around the noses of the syncline. This synclinal structure has considerably affected the commercial development of coal deposits in various parts of the district. The most productive mines---Eska and Evan Jones---were situated on the east end of the gentler dipping south limb. The structure in the Evan Jones mine was comparatively simple and allowed for relatively continuous coal development there for nearly 50 years (Alaska Geological Society, 1964).

STRUCTURE OF CHICKALOON DISTRICT

Complex structure is general to the Chickaloon district which has been subjected to extensive rock movements. Faulting is more common than in the Wishbone Hill district. The strata are also considerably folded. Because of the structural complexity and abrupt changes in the character of the coal beds, the cost of future mining will be high. The Chickaloon area has been broken by one main fault and a series of smaller parallel faults that limit the known maximum strike length of principal coal beds to 180 m. Structure is broadly synclinal considering the coal beds on both sides of the Matanuska River in the vicinity of Chickaloon. Igneous intrusives, which crop out in isolated masses, may be encountered in this area at any time in the process of mining.

Chickaloon Formation rocks on Coal Creek lie in a syncline whose axial trace strikes in a northeast and southwest direction. Coals are typically inclined 40° to 75°, but near the axis of the syncline the strata dip at right angles. Intrusive masses appear to be smaller in the Coal Creek area than they are elsewhere in the Chickaloon field.

STRUCTURE OF ANTHRACITE RIDGE DISTRICT

The Anthracite Ridge district contains a coal basin with a broad synclinal trough structure. The axis of this major syncline appears to cross the Chickaloon River about a mile northeast of Chickaloon, extends northeast to Rush Lake, and then southeast toward lower Packsaddle Gulch (Capps, 1927). The southern limit of the Chickaloon Formation outcrop belt in the Anthracite Ridge field is marked by an escarpment with steep cliffs and cascading streams.

The general structural trend in the Anthracite Ridge field is parallel to the axis of the valley. Dips of 50° to 90° are common. Chickaloon Formation beds have undergone a great amount of compression in the vicinity of the Anthracite Ridge fault (Capps, 1927), which is an extension of the Castle Mountain fault. Toward the summit of Anthracite Ridge, folds become more closely crowded together. Belts of closely crumpled beds have been superimposed on the major synclinal structure of the region. Many of the folds are overturned, and their upper parts have largely been removed by erosion. Coal beds are exposed along the uneroded remnants of the close folds. These coal beds have been crushed and shattered with included fragments of bone and shale.

Upper Matanuska Valley is essentially a large graben, a block that has been down-dropped between two major faults. Besides the large Anthracite Ridge fault bordering the valley on the north, another large fault cuts along the lower slopes of the Chugach Mountains and forms the southern boundary of the field. Chickaloon Formation rocks are most severely deformed adjacent to these major faults of large displacement.

Chickaloon Formation rocks in the Anthracite Ridge field have been extensively intruded by both large and small dikes and sills. Most of the intrusive masses are of a sill-like character. The massive diabase injections particularly have caused increases in the rank of the coal throughout the region.

LITHOSTRATIGRAPHY

There are over 3,000 m of Cretaceous through Oligocene-age sedimentary rocks exposed in Matanuska Valley. This sedimentary package of rocks forms part of a thick succession of marine and continental rocks in the Cook Inlet basin (Clardy, 1982). Tertiary rocks of Matanuska Valley include the coal-bearing Chickaloon Formation and overlying Wishbone and Tsadaka Formations (Table 1). Coal-bearing rocks occupy several irregularly shaped areas comprising about 1000 km^2 of the Matanuska basin west of Hicks Creek and east of Moose Creek. Natural exposures are not numerous since they are easily eroded into smooth slopes and often covered by glacial, alluvial, and colluvial materials. Streams are locally entrenched in Chickaloon Formation rocks forming outcrops in adjacent bluffs. The best exposures are found along the banks of the Matanuska River and its tributary streams. The Chickaloon Formation is more extensively outcropped on the north side of the Matanuska River.

Table 1---NEAR HERE

The Chickaloon Formation is at least 1500 m thick in the Matanuska Valley (Clardy, 1982). The formation differs from Kenai Group strata of the Susitna lowland in age, lithology, and structure, presence of associated intrusives, and in the character of interstratified coal seams. The Chickaloon Formation consists of a lower sequence of conglomerate and lithic sandstone and an upper sequence of siltstone and coal (Clardy, 1982). The unit exhibits rapid variations in lithologic character, alternation of beds, and irregularity of sequence along strike. Locally, alternating series of thin-bedded sandstone and shale occur, whereas elsewhere beds are gradational through fine, medium, to coarse sediments. Individual beds are lenticular and laterally discontinuous because of depositional thickening and thinning.

Shales are most abundant in the Chickaloon Formation although sandstone predominates in the lower half. The shales vary from gray and drab to dark bluish gray and black. They are feldspathic and contain brown mica, little quartz, minor pyrite, and abundant carbonaceous material. Their relatively high content of black organic material contrasts with younger Tertiary shales of other basins. The shales are often sandy and gritty and vary in grain size along bedding (Capps, 1927; Apell, 1944). Although bedding is generally poorly developed and joint planes are not well defined, they are locally laminated and sometimes fissile. Pressure and movements have caused slickensiding and slabbing of shale units. Interbeds include sandstone strata and coal and bone streaks and veinlets. The shales are soft and inclined to break with conchoidal fracture, disintegrate fairly easily on exposure, and tend to cave when coal is removed. Concretionary iron carbonate or ironstone in thin layers, lenses, fairly persistent beds, nodules, nodule trains, and irregularly distributed masses from a few inches to several feet is common in Chickaloon Formation shales and some coal beds.

Chickaloon Formation sandstones are typically gray to yellowish and locally exhibit a greenish-gray tone. They sometimes show a 'salt-and-pepper' texture and contain shale fragments. They vary from relatively soft, slightly indurated to fairly well-consolidated, hard and dense rocks. Sandstones are thick-bedded in the basal part of the formation. Grain size and composition also varies considerably within and between beds. They often form an aggregate of partly decomposed and angular grains. Feldspathic sandstones contain abundant fairly fresh grains. Chloritic sandstones are greenish and form a greenstone with high rock fragments. Disseminated shreds of white mica are common in some sandstones. Predominantly, the sandstones appear to have been derived from a granitic body, possibly a diorite batholith.

A few thin beds of fine-grained conglomerate are scattered irregularly throughout the Chickaloon Formation, are of rather abrupt occurrence and are not limited to a particular horizon.

These coarse-grained sediments are harder and more resistant than the fine-grained rocks. The conglomerates contain well-rounded to subangular small (typically less 1.3 cm) pebbles of quartz and chert.

Several series of important coal beds occur in the upper portion of the Chickaloon Formation. This coal-bearing strata resembles to a degree the Paleozoic coal measures of the Appalachian region. All coals of the Chickaloon Formation are part of the same general sequence and do not differ significantly in age. There is no evidence to indicate that coals at the east end of the field were more deeply buried than those on the west (Barnes, 1962b). However, coals in different parts of the field have not been closely correlated. The character of the coal beds vary within short distances as do the sandstone and shale units. Correlation of stratigraphic sections is based on lithology, sequence of beds, and thickness of stratigraphic intervals (Payne and Hopkins, 1944). Complicating factors to correlation are numerous faults, relative similarity of many beds, and lenticularity of individual beds (Tuck, 1937).

There is little evidence for natural burning of coal beds in Matanuska Valley mainly because of the relatively lower volatile matter contents and bituminous rank. Natural burning is more prevalent in Alaskan subbituminous coal and lignite possessing high volatile matter contents. There are a few occurrences of whitened shales in the Matanuska Valley that are similar in appearance to porcelanite (which forms by natural baking), but these may be due to mineralized water circulating through porous zones in the rocks.

Volcanic ash partings can be observed in outcropping coal seams and often have been encountered in drill holes of the Matanuska coal field. Originally these partings consisted of feldspar and biotite phenocrysts in a glassy and pumiceous ash. The glassy portion of the ash has usually completely altered to a bentonite and the biotite has altered to a grayish brown type of flaky kaolinitic clay containing some iron-associated carbonaceous material. Although some kaolinitic partings naturally formed in ancient swamplike environments, many of these bentonitic and kaolinitic partings (the latter termed tonsteins) clearly originated as volcanic ash-fall tuffs.

The Chickaloon Formation was named by Martin and Katz (1912), forms the lowermost exposed Tertiary unit of Matanuska Valley (Alaska Geological Society, 1964), and is Paleocene to early Eocene in age (Barnes and Payne, 1956). It contains an abundant and well-preserved fossil flora in shales and sandy shales. Petrified wood occurs locally and impressions of fossil leaves are abundant in the roof rock of coal seams. The fossil flora includes 38 modern genera among which are redwood (metasequoia), oak, alder, walnut, willow, cottonwood, cypress, and dogwood (Barnes and Payne, 1956; Figure 6). Martin and Katz originally assigned the formation to the Eocene Epoch based on its flora. Wolfe and others (1966) studied the fossil plants of the Chickaloon flora and believe that it indicates a warm and temperate Paleocene to early Eocene depositional period.

Figure 6---NEAR HERE

The stratigraphic relationships of the Chickaloon Formation with older rocks is complex. The unit unconformably overlies marine Upper Cretaceous beds of the Matanuska Formation. The only observable contacts of the Chickaloon and Matanuska Formations in the Matanuska Valley are along faults. Northeastward from Knik Arm to the Little Susitna field, the Chickaloon Formation underlies Kenai Group strata or their equivalents (Conwell and others, 1982).

Barnes and Payne (1956) made two significant stratigraphic changes for the Wishbone Hill district: 1) the series of arkosic shales and conglomerates of Arkose Ridge Formation were placed at the base of the Matanuska Formation and considered to be Late Cretaceous in age; the Arkose Ridge Formation was earlier considered Tertiary in age and in part equivalent to the Chickaloon Formation; and 2) the Eska conglomerate was divided on the basis of lithologic differences and the presence of an unconformity between them into the Wishbone Formation (lower unit) and Tsadaka Formation (upper unit). The Chickaloon Formation grades upward into conglomerates of Wishbone Formation in the Wishbone Hill district (Barnes, 1962a; Alaska Geological Society, 1964).

The Chickaloon Formation crops out mainly in peripheral areas around the great mass of conglomerate that covers the central part of Wishbone Hill. Exposures of coal beds are generally limited to the more deeply incised streams and steeper hillsides, and to strip mine areas on the north flank of Wishbone Hill. In the western part of the Wishbone Hill district, the Chickaloon Formation is exposed along Moose Creek, where the minimum estimated thickness of strata below the coal-bearing section is over 1000 m. The lower part of the Chickaloon Formation is exposed east and north of Wishbone Hill along Eska, Gloryhole, and Knob Creeks, where faulting and folding have likely resulted in some duplication of strata (Barnes and Payne, 1956; Alaska Geological Society, 1964).

Groups (series or zones) of coal beds can be correlated from one part of a district to another but individual beds can be traced only between different mines within a district. Four coal beds in folded and disrupted Chickaloon Formation strata lying on opposite sides of the strike-slip Premier fault have been locally correlated by palynology over a distance of 600 m. Based on the sporomorph assemblage present, a Paleocene age was assigned to this coal-bearing section (Ames and Riegel, 1962). The Premier series in the Wishbone Hill district have been radiometrically dated on minerals separated from volcanic ash partings in these coals. The average of the ages was about 55 m.y. which indicates a late Paleocene to early Eocene age for the Premier series (Conwell and others, 1982).

Several other thin and persistent layers of clay or claystone that are valuable in correlation are found in the Chickaloon Formation of the Wishbone Hill district. The 'Eska Marker,' probably a tonstein, is located just below the roof of the Eska coal bed and consists of one or two thin (generally less 2.5 cm), light-colored, hard clay bands. On the north slope of Wishbone Hill, a light colored claystone which shows characteristics of a bentonite by swelling to a foot or more of plastic clay, may represent a decomposed volcanic ash (Barnes and Payne, 1956).

Coal beds in the Chickaloon district appear to lie in the middle of the Chickaloon Formation (Wolfe and others, 1966); there appears to be at least 600 m of Chickaloon Formation beds below the coal and an equal amount between the coal and the overlying Wishbone Formation. There are approximately 1200 m of Chickaloon Formation rocks covering both the northern and southern limbs of the Coal Creek syncline.

The Chickaloon Formation is over 600 m thick in the Anthracite Ridge district and unconformably overlies Upper Cretaceous marine sedimentary rocks. There are many good exposures of the unit along gulches that drain the high-relief south slope of Anthracite Ridge. The outcrops consist chiefly of shale with minor sandstone and conglomerate, and includes three coal zones in the lower 450 to 500 m. Although the strata are folded and faulted, their discontinuity was also effected by the nature of the original deposits. Shales in the area are dark gray to black, carbonaceous, and weather with conchoidal fracture. Sandstones are gray to yellowish, feldspathic, fairly well consolidated; a basal sandstone is greenish gray, chloritic, and thick bedded. Conglomerate beds are scattered throughout the formation and include well-rounded quartz and chert pebbles. A 9- to 15-m thick light-colored band crops out around the central part of the ridge and grades westward into a coarse sandstone underlain by a white hardened shale. The three coal zones contain typical coal beds from 0.3 to 3.0-m thick and that grade laterally into claystone or shale and generally thin westward. The upper and middle coal zones crop out in the basin of Muddy Creek. All three coal zones are exposed on lower Purinton Creek, where many small intrusive bodies cut across coal beds altering their rank and minability.

TERTIARY INTRUSIVE ROCKS

Numerous dikes and sills intrude Tertiary sedimentary rocks of Matanuska Valley and are present throughout almost all coal-bearing areas. The areal distribution of larger intrusives have been mapped. Intrusive rocks are less abundant on the west in the lower Matanuska Valley; only a few small basic dikes are known in the Moose Creek-Eska Creek area. In central and eastern Matanuska Valley, Tertiary coal-bearing rocks have been extensively intruded. The intrusives form trap ridges in the Anthracite Ridge area (Barnes and Payne, 1956; Wolfe and others, 1966).

Intrusive rocks are believed to represent one general period of Neogene volcanic activity. The intrusions appear to antedate the disturbance which caused the maximum folding of the Chickaloon Formation. Igneous rocks are intruded partly parallel to the axes of folding as long and fairly persistent dikes. The thickness of the intrusives ranges from centimeters to 100 m or more; most sills and dikes are less than 5-m thick.

The intrusives include both basic and felsic rocks. Diabase is most abundant and a few minor sills and dikes are vesicular and basaltic. Dense, dark gray to black or greenish diorite porphyries, andesites, and gabbros are also present. Pliocene(?) basalt flows overlie the Wishbone Formation unconformably on Castle Mountain and are intercalated with pyroclastic rocks.

The appearance of intrusive rocks varies due to the degree of coarseness or granularity, arrangement of minerals, and in the order of crystallization. They vary considerably in granularity. Thicker sills tend to be coarser grained in the middle portion, which is chiefly a textural rather than mineralogical differentiation. The intrusives range from coarse-grained gabbros in which component minerals are clearly visible to fine-grained basalts. Coarse-grained diabases are composed of plagioclase feldspar (approximate composition of laboradorite) considerably altered to sericite and chlorite, augite over half of which is altered to chlorite, and magnetite. The fine-grained diabases are near the texture of basalt, plagioclase feldspar nearly unaltered, iron oxides altered to hydroxides, and the remainder of the matrix almost completely altered to carbonates. The surfaces of some larger sills are vesicular or amygdaloidal with patches of zeolites (Waring, 1936).

Felsitic intrusive rocks mostly form sills and follow bedding planes of sediments. Diabase and gabbro are more laccolithic in form and occur in roughly lenticular masses doming the strata and sending out sill and dike leaders into the adjacent rock. Larger intrusive masses have greater effects due to the size and number of apophyses in the form of sills in or along bedding plane surfaces of coal beds. If they have spread for a considerable distance in contact with a coal, they can render large portions of it worthless by completely devolatilizing it. The effects of small dikes and sills generally do not extend far and don't affect coal seriously; if they are a meter or more away, the coal is generally unimpaired or may be improved in quality (Martin and Katz, 1912; Chapin, 1920).

Contact phenomena of dikes or sills with coal usually include the production of a dense hard coke. Natural coking effects can be observed in outcrops or beds on the south limb of Coal Creek syncline, south slope of Castle Mountain, Chickaloon area, Gravel Creek vicinity, and Kings River. The coal adjacent to the intrusive assumes a prismatic structure, and at all points the prisms are perpendicular to the plane of the intrusion. Diabase changes from a dark-greenish trap to a felsitic variety resembling aplite or quartz porphyry. Strong contact metamorphism by dikes or sills adjacent to shales indurated and baked them into a hard, dense, fine-grained porcelanite zone to several centimeters or less than a meter thick (Hill, 1923; Merritt, 1985).

In general, coal may locally or areally be improved in chemical character by intrusive effects, but overall is more likely to deteriorate or be destroyed. The presence of thick sills in the Matanuska Valley coal-bearing rocks appears to be principally responsible for upgrading coal rank eastward. In the western part of Matanuska Valley, where igneous intrusives are generally absent, the coals are of high-volatile bituminous rank. In the eastern part of Matanuska Valley, where igneous intrusives are prevalent, the coals are high-rank bituminous, semianthracite, and anthracite (Chapin, 1920).

Intrusive rocks in the Matanuska Valley have and will continue to complicate engineering and economic mining. They have resulted in making an undetermined percentage of coal areas of doubtful value. There are probably many intrusive masses that do not outcrop but would be encountered during mining; they may necessitate a change in mine plan or possibly shut down operations. This is essentially what forced the closure of the Chickaloon mine of central Matanuska Valley. In the Wishbone Hill district, there are no igneous rock bodies that have significantly hampered past mining operations or affected the quality of large blocks of coal.

In central and eastern Matanuska Valley, intrusive rocks have seriously affected the quality and ultimate minability of the coal deposits (Alaska Geological Society, 1964).

DEPOSITIONAL ENVIRONMENTS AND PROVENANCE

The coal-bearing Chickaloon Formation of the Matanuska Valley comprises continental fresh-water deposits that accumulated under temperate humid climatic conditions in Paleocene to early Eocene depocenters northeast of Cook Inlet basin. Sediments were deposited on an extensive interior plain of little or no gradient only slightly above sea level (Barnes and Payne, 1956). The lower part of the Chickaloon Formation formed in fluvial braided to meandering stream environments (Table 2); deposition tended to be relatively rapid. The upper part of the Chickaloon Formation formed in fluvial meandering to paludal environments. Different parts of the succession are indicative of alternating periods of weak and strong orogenic movements. In general, uplift of source regions began a new cycle of clastic deposition (Payne, 1945).

Table 2---NEAR HERE

Kirschner and Lyon (1973) interpreted a significant stratigraphic change and a regional unconformity based on heavy mineralogy and lithology at the end of Chickaloon deposition. They proposed a distant source north of the present Alaska Range for Chickaloon and Tsadaka Formation sediments. Clardy (1974) however proposed a nearby source for both the Wishbone and Tsadaka Formations and probably also for the Chickaloon Formation based on interpretation of grain size and heavy and light mineral assemblages. The major change in provenance from a predominantly volcanic source terrane for the Wishbone Formation and a plutonic source for the Tsadaka Formation is regional in scope and represents a major structural-stratigraphic event in the entire Cook Inlet basin (Clardy, 1982).

Second-order sedimentary cycles in the coal measures began with the dominance of river sedimentation forming coarse-grained, cross-bedded sandstone with lenticular conglomerate at the base grading upward into finer clastics containing a few widely spaced coal beds. Fine sandstone, siltstone, and silty claystone were deposited during flood events on this broad plain. Abundant fossilized leaves, twigs, and trunks of plants and trees that lived on and between the flood plains were preserved throughout the deposits. Thicker claystone beds were deposited in stagnant flood plain lakes and ponds, and thinner clay beds in coals represent a temporary cessation of bog conditions.

Quiescence in source regions led to relative long-sustained regional swamp conditions forming series of closely spaced coal beds. Individual lenticular coal beds which wedge out laterally and are found in relative stratigraphic isolation in sandstone, siltstone, and claystone sections were deposited in flood plain bogs when river sedimentation still held sway. Streams became sluggish and drainages ponded causing the water table to rise during periods of swamp domination. Bony coal, bone, and coaly claystone formed when flood waters had temporary and limited access to the swamps. The degree of dominance of bog conditions varied locally as reflected in wide lateral variation in the proportion of coal to clastic beds. For example, the Premier series thickens with increased clastic content in the eastern part of the Wishbone Hill district. In the Paleocene, this area was periodically subjected to the influx of flood plain silts, whereas areas to the west were more sheltered (Barnes and Payne, 1956; Payne and Hopkins, 1944). Lower ash coal beds formed in areas of swamps inaccessible to flood waters. Transitions occur from cleaner coal within basin centers to ashy coal and clay along basin rim areas (Waring, 1936).

COAL PETROLOGY

Matanuska Valley coals show petrologic compositions high in vitrinite with minor inertinite and liptinite contents. Tables 3-5 list maceral compositions for Matanuska coals of different rank.

Tables 3-5---NEAR HERE

The vitrinite group content in Matanuska Valley bituminous coals ranges from 89 percent to near 100 percent (volume percent, mineral-matter-free basis), and the mean content is about 96 percent in the 56 samples analyzed (Table 3). Vitrinite and vitrodetrinite are the main macerals of the group. Corpocollinites, gelinite, and pseudovitrinite are of very minor occurrence. Semianthracite-anthracite (Table 4) and subbituminous coals (Table 5) show similarly high vitrinite contents.

Inertinites show a mean content over 1 percent in both bituminous and semianthracite-anthracite coals of the Matanuska Valley, but range up to over 4 percent (volume, mineral-matter-free basis). Fusinite, semifusinite, sclerotinite, macrinite, and inertodetrinite are all present in these high rank coals but consistently average less 0.3 percent each. Matanuska Valley subbituminous coals show similar inertinite contents.

Liptinites (or exinites) occur as minor constituents in coals of the Matanuska Valley. The mean liptinite content in the bituminous coals is 3 percent, but in the semianthracite-anthracite coals it is only 0.1 percent. In the bituminous coals, liptinites range to about 9.5 percent but to only 1.0 percent in the anthracitic ranks. The few subbituminous coals analyzed show a range in liptinite content from 2.2 to 8.8 percent. Liptodetrinite, resinite, and suberinite are the most abundant liptinite maceral types, and exsudatinite, cutinite, sporinite, and alginite are very rare.

Figure 7 shows a ternary diagram for maceral compositions of Matanuska Valley coal samples. Maceral group proportions are plotted by rank in an enlarged-scale triangular diagram beginning at the established 89 percent vitrinite base level. In general, the bituminous coals exhibit the broadest distribution in this plot. The anthracitic coals plot near the vitrinite end member and the subbituminous coals fall relatively closer to the liptinite end member.

Figure 7---NEAR HERE

Mean-maximum vitrinite reflectance values ($\bar{R}om$) for Matanuska Valley coal samples are summarized in Figure 8. Reflectance increases with the rank of a coal as indicated in Figure 9 by the plot of $\bar{R}om$ vs. dry, ash-free carbon content. Reflectance values in Matanuska Valley samples show a broad range from 0.47 to 5.34 percent, and generally support the rank grades (subbituminous B to meta-anthracite) assigned by coal quality assessment. Considering that these samples are from outcrops containing weathered and oxidized coal, vitrinite reflectance should be considered a more reliable measure of rank than proximate analysis data.

Figures 8 and 9---NEAR HERE

Vitrinite reflectance values increase from the lower to upper Matanuska Valley (Figure 10). This generally corresponds to rank increases eastward in the valley. The generalized isopach map also shows a lowering in vitrinite reflectance around the margins of the Matanuska basin. However, this has not been demonstrated conclusively because of the amount of data used in constructing this illustration.

Figure 10---NEAR HERE

The petrology of Matanuska Valley coals is consistent with their interpreted origin in Early Tertiary paludal (swamp) environments associated with a continental-fluvial depositional system. It also reflects the strong influence of post-depositional thermal effects that have progressively more severely altered coal maceral assemblages eastward in the region.

Locally, the thermal effects of contact metamorphism have produced natural coke. Merritt (1985) discussed an occurrence of natural coke at the Castle Mountain mine and estimated temperatures of formation at 450° to 500° C. Fracturing due to rapid cooling produced locally well-developed prisms at the site (Figure 11). The apparent rank of the highly altered coal was established as anthracite.

Figure 11---NEAR HERE

COAL QUALITY

Matanuska Valley coals analyzed during this study show that rank varies from subbituminous B to meta-anthracite (Figure 12). The range in various rank indicators are: 1) vitrinite reflectance from 0.47 to 5.34 percent; 2) dry, mineral-matter-free volatile matter content from 7 to 47 percent; 3) dry, ash-free fixed carbon from 52 to 93 percent; 4) bed moisture from 2.5 to 15 percent; and 5) moist, mineral-matter free heating value from 11,400 to 15,100 Btu/lb.

Figure 12---NEAR HERE

Ash content is the most variable quality parameter exhibiting a broad range from 2 to 47 percent on an as-received basis (Table 6). Ash content varies between beds and in different areas. This can be seen in Table 7, which compares the contents of ash and sulfur and the heating values of coals at mines in the Wishbone Hill and Chickaloon districts. In addition, the content of ash generally appears to increase toward the margins of the Matanuska basin (Figure 13). Some coals in the Moose Creek area, coals of the southern Young Creek field and adjacent to Kings River of the central Matanuska Valley, and anthracitic coals of the Anthracite Ridge field show the lowest ash contents.

Tables 6 and 7, Figure 13---NEAR HERE

The total sulfur content of Matanuska Valley coals is low (less 1 percent) in all samples analyzed (Figure 14). Organic sulfur is typically the most abundant form in Matanuska Valley coals as it is in most Alaskan coals. Although sulfates can locally be observed on coal seam surfaces, weathered outcrop samples of Matanuska Valley coals in general show very low sulfate sulfur contents. The mean and maximum contents of total sulfur in Matanuska Valley coals on a moisture- and ash-free basis are respectively 0.7 and 1.3 percent (Figure 15). The isopach map of Figure 16 indicates that total sulfur in coals decreases toward the margins of the Matanuska basin. It tends to be relatively lower in the Eska-Moose field of the western Matanuska Valley and to be relatively higher in the Chickaloon and Anthracite Ridge fields; this would be expected because of the introduction of sulfide minerals with igneous intrusions.

Figures 14-16---NEAR HERE

Coals become progressively devolatilized upward (eastward) in the Matanuska Valley (Figure 17). It is unclear whether the volatile matter content actually increases toward the margins of the Matanuska basin as shown. More data is needed to confirm this inference. Fixed carbon content and calorific value are generally known to increase eastward in the Matanuska Valley with gradation in rank (Figures 18 and 19). The anthracite of the Anthracite Ridge field is similar to that of the Bering River field but slightly lower in quality compared to Pennsylvania anthracite (Table 8).

Figures 17-19, Table 8---NEAR HERE

Scatter plots of paired proximate and rank-indicative variables for Matanuska Valley coal samples show the direct relationship of heating value and fixed carbon content (Figure 20) and the inverse relationship of ash and fixed carbon contents (Figure 21). Matanuska Valley coals analyzed show that they predominantly contain moderate to high ash contents, but also include some low ash coals, very high ash coals, and impure coals (Figure 21).

Figures 20 and 21---NEAR HERE

The major-oxide composition of Matanuska Valley bituminous coals generally falls within the ranges established for bituminous coals elsewhere in the world (Table 9). Most of the inorganic matter in the coals is accounted for by silica, aluminum, iron, calcium, and phosphorous oxides. The mean contents for the major oxides are listed in Table 10, and show relatively high abundances of CaO and P_2O_5. P_2O_5 is particularly significant because of its importance in steelmaking processes.

Tables 9 and 10---NEAR HERE

The general relationship of the given oxides with rank are also shown in Table 10. SiO_2 and Al_2O_3 often vary with the total ash content of coal. The silica content here decreases significantly with increasing rank, but alumina reveals no clear relationship. Fe_2O_3, CaO, P_2O_5, MgO, SO_3, BaO, SrO, and Mn_3O_4 appear to increase in content in Matanuska Valley coals with increasing rank, whereas K_2O decreases as does silica with increasing rank.

The free-swelling indices (FSI) of Matanuska Valley coals indicate that most are noncaking and nonswelling (Figure 22). However, several samples exhibit some degree of swelling; these include coals from Coal Creek, Chickaloon River, and Muddy Creek. Only one sample from the region (Castle Mountain mine No. 1 seam) was strongly caking; it had a FSI of 7.5. Rao (1976) reported a FSI of 8 for this seam. The FSI of a coal may also be used as a preliminary indication of its potential coking quality. Warfield and others (1966) found that an unblended reduced-ash sample of the No. 1 seam produced a strong coke of foundry quality, and that a 30 percent blend of the coal with a Utah-base coal also produced a reasonably good coke.

Figure 22---NEAR HERE

Ash-fusibility tests yield the melting temperatures and deformational changes in an ash cone of a particular coal sample. Ash-fusion temperatures vary with the ash content of coals and is generally less for low-rank coals. However, because of the variability in coals and their inherent ash content and character, tests are required on individual coals. Table 11 compares ash-fusion temperatures for various United States coal-ash samples in a 4-point (reducing atmosphere only) test. Matanuska Valley coals show the highest temperatures. High-melting and -fusing ash of these coals may indicate their preferred utilization in dry-bottom type furnaces where they would not have a tendency to stick in the ash hopper and be difficult to remove (Corriveau and Schapiro, 1979). Conversely, low-fusing coals tend to form clinkers in static fuel beds and cause slag deposition on furnace walls and boiler tubes, but are preferred in slag-tap pulverized fuel and cyclone furnaces where the ash is removed from the bottom of the furnace in a liquid state. The few Matanuska Valley samples included in this comparison and the results shown do not allow broad generalizations to be made in this case. It is generally known that the iron content of ash has an inverse relationship with initial deformation and softening temperatures (Figure 23); that is, as the total iron content increases, initial deformation and softening temperatures are concurrently lowered.

Table 11, Figure 23---NEAR HERE

The American Society of Metallurgical Engineers (ASME) has derived a series of parameters that have been used to determine the fouling and slagging properties of coals for boiler use (Schmidt, 1979, p. 53-54). Major oxide ash-analysis results are used in the derivative equations. In general, coals can be divided into two broad groups based on ash analysis: 1) coals with bituminous-type ash, wherein the Fe_2O_3 content is greater than the CaO + MgO content; and 2) coals with lignite-type ash, wherein the Fe_2O_3 content is less than the CaO + MgO content. Eastern U.S. coals generally have bituminous type ash, whereas western U.S. coals generally have lignite type ash. Of the 40 Matanuska Valley coals examined, they split fairly evenly between bituminous-type ash and lignite-type ash. This designation does not correlate with rank. Matanuska Valley subbituminous coals showed predominantly lignite-type ash (5:2), bituminous coals more often showed bituminous-type ash (13:11), and anthracite coals had predominantly lignite-type ash (7:2).

Schmidt (1979) states that since the ASME parameters were mainly developed for eastern U.S. coals, they may not be applicable to western U.S. coals. Indeed, he affirms that slagging and fouling factors related to coal-fired boilers are not applicable to western coals. Based on the fouling factor and Na_2O content, Matanuska Valley coals indicate the possibility of low to high fouling characteristics. Based on the T_{250} temperatures (temperatures at which the viscosity of slag reaches 250 poise) and slagging factors, Matanuska Valley coals indicate low to moderate slagging characteristics. Detailed analyses are required to adequately determine the likely performance of individual coals in combustion facilities. Figure 24 is a graph showing the relationship of T_{250} temperature to total base ash composition (1) and T_{250} temperature to dolomite percentage (2).

Table 24---NEAR HERE

The energy traces of X-ray fluorescence spectra of 50 Matanuska Valley raw coal samples are shown in Figure 25. Attendant instrument settings and conditions holding for the preparation of the spectra are listed. The spectra show relative semiquantitative abundances of various elements---Al, Si, P, S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, and Sr. Sample identification, rank, and the percentages of ash, S, Si, Fe, and Sr are annotated.

Figure 25---NEAR HERE

Figure 26 summarizes the range of minor element contents commonly found in Matanuska Valley coals with other coals of the world. Most elements show considerably lower abundances in Matanuska Valley coals; these include Mn, Zn, B, As, Ni, Pb, Zr, Cu, Sn, Co, Cr, La, Y, Ga, and Be. Other elements---Ti, Sr, Ba, and Mo---reveal similar abundances to other coals. Figures 27 through 29 are histograms showing the distribution of 18 additional trace and minor elements in Matanuska Valley coals. Matanuska Valley coals show higher contents of F, Sc, V, Br, I, Cs, Ce, Sm, Eu, and Th than coals of the Illinois basin, Appalachian coal fields, and western United States (Table 12). Matanuska Valley coals are lower in Ge than Illinois basin and Appalachian coals, but higher in Ge than other western U.S. coals. Matanuska Valley coals contain similar contents of Rb as Illinois basin and Appalachian coals but higher contents of

Rb than other western U.S. coals. Matanuska Valley coals contain similar contents of Cd as Illinois basin coals but higher contents of Cd than Appalachian and other western U.S. coals.

Figures 26-29, Table 12---NEAR HERE

In summary, the coals of the Chickaloon Formation of the Matanuska Valley are among the highest quality coals in Alaska. They compare favorably with coals of the Bering River, Northern Alaska, Nulato, and Chignik-Herendeen Bay fields. The relative high quality of Matanuska Valley coals is reflected in the measured values for most rank parameters including calorific value, fixed carbon, and vitrinite reflectance. Although the coals are generally low in sulfur, their typical moderate to high ash contents will make crushing and washing necessary to produce a satisfactory commercial product.

COAL RESOURCES AND RESERVES

All coal known in Matanuska Valley occurs in the Chickaloon Formation. Coal beds of this unit are generally 1 to 3 m thick but locally are found to near 12 m. Regional geologic structure complicates the calculation and estimation of coal resources in a given block and in the valley as a whole. Most resource analysts acknowledge that there could be substantial undiscovered underground coal deposits in areas of the Matanuska Valley. The coal resources of the region have been estimated by various authors. Barnes (1967) estimated the total coal resources of Matanuska Valley at 274 million tons. McGee and O'Connor (1975) estimated total coal resources at 248 million tons. Sanders (1981) states that although the probable total coal resources are close to 500 million tons, only about 100 million tons of this has been identified. Merritt and Belowich (1984) recalculated potentially minable coal resources for the five major coal fields of Matanuska Valley (Table 13) at three levels of assurance (high, moderate, and low) and projected to a depth (overburden limit) of 150 m. They arrived at figures of about 80, 120, and 180 million short tons respectively at the three levels of assurance.

Table 12. Comparison of arithmetic mean, minimum, and maximum values for certain trace-element contents in Matanuska Valley coals with Illinois basin, eastern United States, and western United States coals [in ppm; 1=arithmetic mean; 2=minimum value; 3=maximum value; and 4=number of samples].

Element	Illinois Basin*				Appalachian coal fields*				Western United States*				Matanuska Valley			
	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)
Fluorine (F)	67	29	140	(113)	89	50	150	(23)	62	19	140	(29)	374	51	710	(24)
[illegible] (Se)	[illegible]	1.2	7.7	(56)	5.1	1.6	9.3	(14)	1.8	0.50	4.5	(22)	23	0.5	100	(31)
[illegible]	[illegible]	[illegible]	90	(113)	38	14	73	(23)	14	4.8	43	(29)	80	2	340	(31)
[illegible] (Ge)	6.9	1.0	43	(113)	1.6	0.10	6.0	(23)	0.91	0.10	3.0	(29)	1.4	0.3	7	(29)
Bromine (Br)	13	0.6	52	(113)	12	0.71	26	(23)	4.7	0.50	25	(29)	27	0.7	630	(30)
Rubidium (Rb)	19	2.0	46	(56)	22	9.0	63	(14)	4.6	0.30	29	(22)	19	1	97	(31)
Cadmium (Cd)	2.2	0.1	65	(93)	0.24	0.10	0.60	(23)	0.18	0.10	0.60	(29)	1.9	0.4	11	(29)
Iodine (I)	1.7	0.24	14	(56)	1.7	0.33	4.9	(14)	0.52	0.20	1.0	(22)	3.7	0.4	15	(30)
Cesium (Cs)	1.4	0.5	3.6	(56)	2.0	0.40	6.2	(14)	0.42	0.02	3.8	(22)	4.0	0.2	12	(25)
Cerium (Ce)	14	4.4	46	(56)	25	11	42	(14)	11	2.8	30	(22)	29	2	120	(31)
Samarium (Sm)	1.2	0.4	1.8	(56)	2.6	0.87	4.3	(14)	0.61	0.22	1.4	(21)	4.8	2	17	(28)
Europium (Eu)	0.26	0.1	0.87	(56)	0.52	0.16	0.92	(14)	0.20	0.07	0.80	(22)	0.70	0.3	2	(24)
Thorium (Th)	2.1	0.71	5.1	(56)	4.5	1.8	9.0	(14)	2.3	0.62	5.7	(22)	8.8	3	35	(26)

*From Gluskoter and others, 1977.

Table 13. Estimates of potentially minable coal resources of the Matanuska coal field (in millions of short tons to projected depth of 150 m and in beds over 0.75-m thick; from Merritt and Belowich, 1984).

Field	High assurance	Moderate assurance	Low assurance
Eska-Moose	32.5	45	60
Young Creek	2.5	5	8
Castle Mountain	6.5	10	25
Chickaloon	20.5	30	40
Anthracite Ridge	4.5	10	20
Other (scattered)	14.5	20	30
Total	81	120	183

Table 13---NEAR HERE

ESKA-MOOSE (WISHBONE HILL) FIELD

The Eska-Moose field extends from Moose Creek on the west to Knob Creek on the east, and includes an area of about 13 km long and 2.5 km wide. Its western end is about 10 km north of Palmer. West of Moose Creek, the Chickaloon Formation becomes thinner; strata are more flat-lying and less broken by faults but there are no coals of workable thickness.

The general stratigraphic coal sequence in the district was established by mapping of Barnes and Payne (1956) and U.S. Bureau of Mines drilling and trenching (Alaska Geological Society, 1964). Coal beds are largely confined to the upper 425 m of the formation with only a few coal beds in the lower part of the formation. The beds extend upward to within 100 m (±) of the base of the Wishbone Formation. The thickness of the coal-bearing part of the formation thins westward from the Eska area. Moose Creek coal beds are found in the upper part of the Chickaloon Formation, whereas the Eska area coals occur 100 m (±) lower in the formation.

Over 20 seams with a thickness over 1 m are known to occur in the Wishbone Hill district. Although seams to 7 m thick are known, 2.5 m is the average maximum thickness of beds. Thicker beds are composites of clean coal benches separated by claystone, coaly claystone and bony coal (Alaska Geological Society, 1964). In no instance has more than about 3.5 m of coal been mined from a single bed.

The Chickaloon Formation underlies most of Wishbone Hill district, which accounts for the principal coal resources of Matanuska Valley. Barnes (1967) estimated the coal resources of the district at 112 million tons with the most readily mined 6 million tons of coal already removed; this left 106 million tons in place ---52 million tons indicated resources and 54 million tons inferred resources. Barnes' estimate excluded relatively unknown areas on the south limb of Wishbone Hill. Patsch (1981) estimated that about half of the remaining resources of the district are held under lease by the Evan Jones Coal Company which operated the Evan Jones mine from 1959 until its closure in 1968. Merritt

YOUNG CREEK FIELD

The Young Creek field contains a relatively small coal-resource base. Merritt and Belowich (1984) estimated high-, moderate, and low-assurance, potentially-minable coal resources at 2.5, 5, and 8 million short tons, respectively to a projected depth of 150 m. Outcrops of the field are found about 5 km west of Kings River near the mouth of Young Creek and also in the upper part of its valley. Two seams of unworkable thickness (0.2 and 0.3 m) crop out in a section located 5.5 km above the junction of Young Creek with Kings River. These seams locally contain tiny nodules of clay and pyrite. The beds occur in a synclinal trough with dips of 20° on the limbs.

The Young Creek field also includes the deposits of the Red Mountain area. Martin (1911) measured a section at about the 1100-m elevation on the north flank of Red Mountain. This poorly exposed section was located about 6.5 km north of the mouth of Young Creek and included over 3.5 m of coal. Martin reported the strike of these beds as N. 67° E. and the dip as 54° SE. The author trenched a coal seam at about the 1175-m level on the north side of the mountain. This bed was certainly thicker than the maximum 2.5-m thick bed previously reported on the mountain. Although possibly in a recumbent fold, the bed could be over 7.5-m thick. Analysis revealed this bed to be of high-volatile C bituminous rank.

CASTLE MOUNTAIN FIELD

The Castle Mountain field lies in the central Matanuska Valley northwest of the Chickaloon field. The character and occurrence of coals closely resembles those of the Chickaloon field, and perhaps they should be combined together as one field.

A small-scale surface mine on the south shoulder of Castle Mountain operated in the field from 1958 to 1960 and produced about 18,800 metric tons of coal from two separate opencut pits. Remaining in-place reserves are low in the immediate vicinity of the Castle Mountain mine. High-, moderate-, and low-assurance minable-coal-resource estimate projections to a depth of 150 m for the Castle Mountain field are respectively 6.5, 10, and 25 million short tons (Table 13). One 100-acre state coal lease located at the east end of the field is still active.

and Belowich (1984) estimated high-, moderate-, and low-assurance potentially minable coal resources of the Eska-Moose field at 32.5, 45, and 60 million short tons respectively to a projected depth of 150 m.

The Eska coal area lies near the east end of the district about 13 km west of the Young Creek field and 5 km above junction of Eska Creek with the Matanuska River. Coal beds of the Eska area have been identified on both limbs of the Wishbone Hill syncline and on both the east and west sides of the creek. Barnes (1951) estimated the amount of coal of minable thickness west of the Eska fault zone and above the Eska mine level at 700,000 tons. Sanders (1981) estimated remaining identified resources of the Eska area at 600,000 tons.

The adjoining Knob Creek area lies immediately east of Eska Creek. This area forms a further eastward extension of the Wishbone Hill district, and includes at least 14 coal beds ranging from 0.5 to 3.0 m in thickness. The Mrak Coal Company operated a surface mine in the area in the late 1950's and early 1960's. Barnes (1962c) estimated remaining resources in the Knob Creek area at 27 million tons but most of this only recoverable by underground mining.

The coals of the Eska-Moose field occur in four 'groups' (zones or series) of three or more beds separated by comparatively thick sections of barren strata or strata containing only thin unminable beds (Table 14). These series have been named (in descending order) the Jonesville, Premier, Eska, and Burning Bed coal groups (Barnes and Payne, 1956). The Midway coal bed occurs in the middle of the four groups; it is a rather stratigraphically isolated but persistent bed that has not been included in either of the groups. The groups are more persistant than individual beds, and have been used for correlation purposes throughout the district. Different names have been used in the past for equivalent beds or groups of beds at various mines throughout the Eska-Moose field.

Table 14---NEAR HERE

CHICKALOON FIELD

Coal deposits of the Chickaloon field cover at least 30 km^2, including most of the Chickaloon River valley south of Castle Mountain and to 8 km above its mouth. It is estimated to contain the second largest coal resource of the Matanuska Valley, and is only surpassed by the deposits of the Eska-Moose field discussed earlier. Barnes (1967) inferred 24 million tons of resources in the Chickaloon district of central Matanuska Valley. Merritt and Belowich (1984) estimated high-, moderate-, and low-assurance, potentially minable coal resources at 20.5, 30, and 40 million short tons respectively to a projected depth of 150 m (Table 13).

The coal deposits of the field were extensively explored and mapped in the first quarter of this century. A good deal of development work was also completed in the past. Early trenching and pits during exploration uncovered 19 bituminous coal beds from 0.75 m to over 3 m thick. Mining in the past has taken place at Chickaloon near the mouth of the Chickaloon River and on Coal Creek south of the Matanuska River.

The Chickaloon field is characterized by complex structure, discontinuous coal beds of indefinite correlation, and widespread igneous intrusions. The rocks dip steeply northward and strike northeastward to nearly due east from Chickaloon. These factors combine to make much of the coal of the field unminable. However, it is possible that local conditions are more favorable and that substantial reserves of minable coal are present.

ANTHRACITE RIDGE FIELD

The Anthracite Ridge field occupies a rolling upland area north of the Matanuska River and south of Anthracite Ridge between Boulder and Hicks Creeks. It is located between sharp linear fronts of the Talkeetna and Chugach Mountains. Its east end lies just west of the terminus of Matanuska Glacier. The field is 6.5 km wide by 11 km long and contains an area of about 70 km^2.

Coals are exposed at many places in the Anthracite Ridge field. These generally occur well upon the flanks of mountains at about 900 to 1200 m elevation. Capps (1927) measured sections of all accessible coal exposures of the upper Matanuska Valley. The three major outcrop areas of the field are: 1) in the southwest along lower Purinton Creek; this area contains some 65 hectares and forms the central deposits of the field; 2) along the north-central part of the ridge; and 3) in the east, in the basin of Muddy Creek, an area less than 130 hectares.

Dikes intrude across the southern boundary of Anthracite Ridge field and limits extension to the south; older non-coal-bearing rocks cut off extensions in other directions. The intrusives form a prominent scarp on the south side of Anthracite Ridge with pronounced waterfalls and cascades. The area between this scarp and the Matanuska River contains no outcrops of coal beds.

The Anthracite Ridge field contains a dozen or more coal beds in a zone of several hundred feet belonging to the lower or middle portion of the Chickaloon Formation (Richards and Waring, 1933). These beds pinch and swell and lack continuity beyond 100 m (±). Although beds 0.6-m thick or less are predominant, the average maximum thickness is 2.5 m, beds 3 m to 5 m are found locally, and two beds of 7.3- and 10.4-m maximum thicknesses have been measured at outcrops near the northwest border of the basin. Thicker coal occurrences are associated with diabase dikes.

The field includes three main coal-bearing zones---lowest, middle, and upper zones. The highest and middle zones are found in the northern part of the area along the central part of the ridge. The middle and lowest zones are found in the eastern part of the area in the basin of Muddy Creek. All three zones are found in the southwestern part of the area along lower Purinton Creek. The upper zone contains about six bituminous to semi-anthracite coal beds in a 120-m interval of sediments. The middle zone contains four or five beds aggregating 3 m of coal in a 15-m stratigraphic interval. Although beds of the middle zone are closely folded in places, they have not been appreciably altered and are of bituminous rank. The lower coal zone contains a 1.8-m bed of bituminous coal near the middle of Muddy Creek (Waring, 1936).

The coals of the Anthracite Ridge field do not extend to any significant depth. In 1932, eight diamond-core holes were drilled in the synclinal area south of the Anthracite Ridge principal outcrops. Drilling extended to over 550 m maximum depth on one hole. Although anthracite veinlets were found at considerable depths (460 m to 490 m), the drilling proved that there were no significant coal beds in that area. The reason for this is simply that no coal-forming materials of substantial quantity were deposited in this area.

A small area of anthracite coal is found on the south slope of Anthracite Ridge near the head of Purinton Creek. The known area of anthracite coal is confined to an area 0.8 km long by 0.4 km wide. The area is folded and faulted and could supply only a very small amount of anthracite or other specialty coal. Most coal beds exposed in the southern and eastern parts of the Anthracite Ridge field are relatively thin seams of bituminous rank.

Capps (1933) estimated that one 8-hectare tract in the Purinton Creek area held 750,000 tons of anthracite and semianthracite. Waring (1936) estimated that the field contained several million tons of predominantly semianthracite coal. Merritt and Belowich (1984) estimated potentially minable coal resources of the field to a projected depth of 150 m at high-, moderate, and low-assurance levels to be 4.5, 10, and 20 million short tons respectively (Table 13).

In general, the coals of the Anthracite Ridge field are not believed to hold but marginally-significant economic importance. Mining could take place only on a very small scale. The most promising areas are in the vicinity of the three branches of Purinton Creek, where the coals vary from bituminous to anthracite in rank.

OTHER AREAS

Merritt and Belowich (1984) estimated the total potentially minable coal resources of other scattered areas in the Matanuska Valley at high-, moderate-, and low-assurance levels to be 14.5, 20, and 30 million short tons respectively to a projected depth of 150 m (Table 13). These areas include deposits in the vicinity of Little Granite Creek, Carpenter Creek, Carbon Creek, and O'Brien Creek.

SUMMARY OF COAL RESOURCES

In summary, there are five small fields with significant coal deposits in Matanuska Valley and other minor resources at scattered locations. The Eska-Moose and Chickaloon fields contain about two-thirds of the estimated potentially-minable coal resources. There esists the possibility of significant undiscovered underground coal deposits in areas of Matanuska Valley.

OVERBURDEN CHARACTER AND RECLAMATION POTENTIAL

Little research has been performed to date relating to the characterization of Matanuska Valley coal overburden. Mitchell and others (1981) of the University of Alaska (Palmer) Agricultural Experiment Station have analyzed spoil bank materials from the abandoned Evan Jones mine site near Sutton and have recently conducted revegetation research---soil fertility and plant material studies. The spoil materials examined contain appreciable amounts of both coal and shale and remain nearly void of vegetation. Mining at the site ended over 15 years ago. The mine spoil materials are low in organic matter and characterized by coarse textures that have led to rapid drying of the surface zone. Inadequate moisture levels during seed germination and early plant growth have resulted in seeding failures and poor stands. Test-plot trials in 1980 revealed that irrigation and particularly mulching aided plant growth (Kreig and Associates, 1983).

The limiting chemical constraints to plant reestablishment at the site are the major plant nutrients nitrogen, phosphorous, and less significantly potassium deficiencies. A high pH (8.3) that may be controlled by a HCO_3 system yielding free carbonates may hinder the availability of phosphorous and certain micronutrients (as zinc, copper, manganese, and iron). The secondary cations calcium and magnesium appear to be satisfactory. The site is deficient in both ammonium ion (NH_4) and nitrate (NO_3). It shows no potential for the development of high levels of salt or sodium accumulation. Sodium adsorption ratios are below the range associated with poor soil structure and its resultant effects on plant growth (Mitchell and others, 1981).

Results of coal overburden analyses performed in this study are summarized in Table 15. The samples analyzed reveal variant textures; the typical sample is composed of 59 percent sand, 19 percent silt, and 22 percent clay.

Table 15---NEAR HERE

The 27 samples had a mean pH of 7.3. Sulfur contents were very low (Figure 30); the mean total sulfur content was 0.12 percent with most of this (0.11 percent) present as organic sulfur. Lime contents were also low averaging less than 1 percent. The samples showed no significant potential for the development of acidic mine spoils. Acid potential was measured based on the pyritic sulfur content and on the total sulfur in the samples. Both methods arrived at mean excess values of inherent neutralizing capacity ranging from 1.9 tons $CaC0_3$ equivalent per 1,000 tons of material (total sulfur method) to 5.4 tons $CaC0_3$ equivalent per 1,000 tons of material (pyritic sulfur method). An acid-base profile for a Wishbone Hill area coal-bearing section is shown in Figure 31 (A, top; B, bottom). Sample codes and paste pH, pyritic sulfur, total sulfur, lime, and organic matter values are annotated to the profile section for convenience in interpretation. The section shown does reveal three samples exhibiting significant deficiencies of 10 to 20 tons $CaC0_3$ equivalent per 1,000 tons of material.

Figures 30 and 31---NEAR HERE

Electrical conductivity, saturation percentage, sodium adsorption ratios, exchangeable sodium percentages, organic matter, and trace elements all fall within the limits set for good soil suitability characteristics. Levels of extractable major nutrients may indicate the necessity of soil amendments, particularly of nitrates and phosphorous and locally potassium.

Generally speaking, the overburden character of Matanuska Valley samples examined during this evaluation support conclusions of earlier research. Overall, this shows that few problems can be expected with regard to the physical and geochemical properties of these ultimate minesoil materials and that future reclamation and revegetation programs should be successful.

CONCLUSIONS

There are a large number of factors that bear on the economic viability of Matanuska Valley coal deposits. They are situated near rail, highway, and deep-water ocean transportation. The main reason for the construction of the railroad through the valley was interest in coal development. The lower Matanuska Valley has been the site of most historic production and will be the probable site of most near-term future production.

It is evident that structural complexity in the region will add to exploration, development, and mining costs. The structure in the region has had a significant influence on mining operations in the past and will continue to do so in the future. Faulting and folding complicates mining potential and directly affects the direction and extent of mining. Careful investigations of structural conditions and underground exploration will be required to determine the minability of particular tracts. In general, dips are too steep for the use of continuous miners. The numerous faults may prevent mining on certain blocks, but large and relatively undisturbed minable blocks are present in the lower Matanuska Valley. Faults with displacements of centimeters to a meter or more may not seriously interfere with mining operations. However, larger-scale faults with displacements of 100 m (±) will have a great practical import to mining. Some overlying lower quality beds may be lost by the extraction of underlying higher quality seams first. The overall quality of Matanuska Valley coals is suitable for power-generating purposes.

Mining and exploration at Chickaloon and Coal Creek have shown that several problems may be encountered in coal deposits of central Matanuska Valley. These include: 1) lack of persistence of beds along strike; 2) pinch and swell of beds within short distances; 3) numerous faults, some of large displacement; 4) presence of dikes and sills intruding the coal measures deteriorating their quality or cutting them out; 5) presence of impurities necessitating crushing and washing; 6) local abundance of coal-bed gas that may be problematic in underground mining and will necessitate adequate ventilation; and 7) steep angles-of-dip of coal beds (Capps, 1927). The latter problem resulted in the adoption of 'pitch-mining' methods at early mines in this region. By this method, coal broken from working faces moves by gravity sliding down sheet-metal-lined chutes to haulageways. Mine facilities of this type are still observable at the old Hecky mine on Coal Creek.

Although there has been considerable exploration completed on the high-rank coals in the upper Matanuska Valley, no development work has taken place, and they have not been mined because of the highly complex structure, numerous large and small intrusives cutting the coal-bearing series, and projected high mining costs. Extensive surface and underground exploration will be required to prove workable bodies of anthracite. The known area of anthracite is small and lies on high slopes of the mountain ridge ---825 m to 900m above the Matanuska River. Whether a successful anthracite mine will ever be developed at the site is questionable. Assuredly, any mine would be small-scale and supply only token amounts of high quality metallurgical or other specialty-type coal.

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FIGURE CAPTIONS

Figure 1...Alaska's coal basins, fields, and isolated occurrences.

2...Generalized geologic map of the Matanuska Valley. Modified from Grantz, 1964.

3...Major coal field subdivisions, rank, and geologic structure in the Matanuska Valley. Modified from Merritt and Belowich, 1984.

4...Major Mesozoic tectonic elements in south-central Alaska. From Payne, 1955.

5...Highly generalized aeromagnetic map of the northern portions of the Matanuska Valley. Tertiary coal-bearing and Cretaceous sedimentary rocks occupy basinal areas of lower magnetic response. The magnetic highs correspond to Mesozoic metamorphic and igneous rocks of mountainous areas flanking the valley to the north and south. The southern part of the region is unsurveyed.

6...Cretaceous and Tertiary fossil-bearing localities in the Matanuska Valley and general characteristics of the Chickaloon Formation flora. Adapted from Wolfe and others, 1966.

7...General ternary plot of petrologic data for Matanuska coal samples by rank. End members shown are the three major maceral groups.

8...Distribution of vitrinite reflectance data for Matanuska Valley coal samples. Number in parentheses indicates the total number of vitrinites counted at the given reflectance class interval.

9...Scatter plot showing the general direct relationship of mean-maximum vitrinite reflectance values ($\overline{R}om$) with percent carbon (dry, ash-free basis) in coal samples analyzed from Matanuska Valley.

10...Highly generalized isopach map of mean-maximum vitrinite reflectance variation in coal samples of Matanuska Valley.

11...Prismatically-fractured natural coke in the basal portion of the northern pit coal seam, Castle Mountain mine.

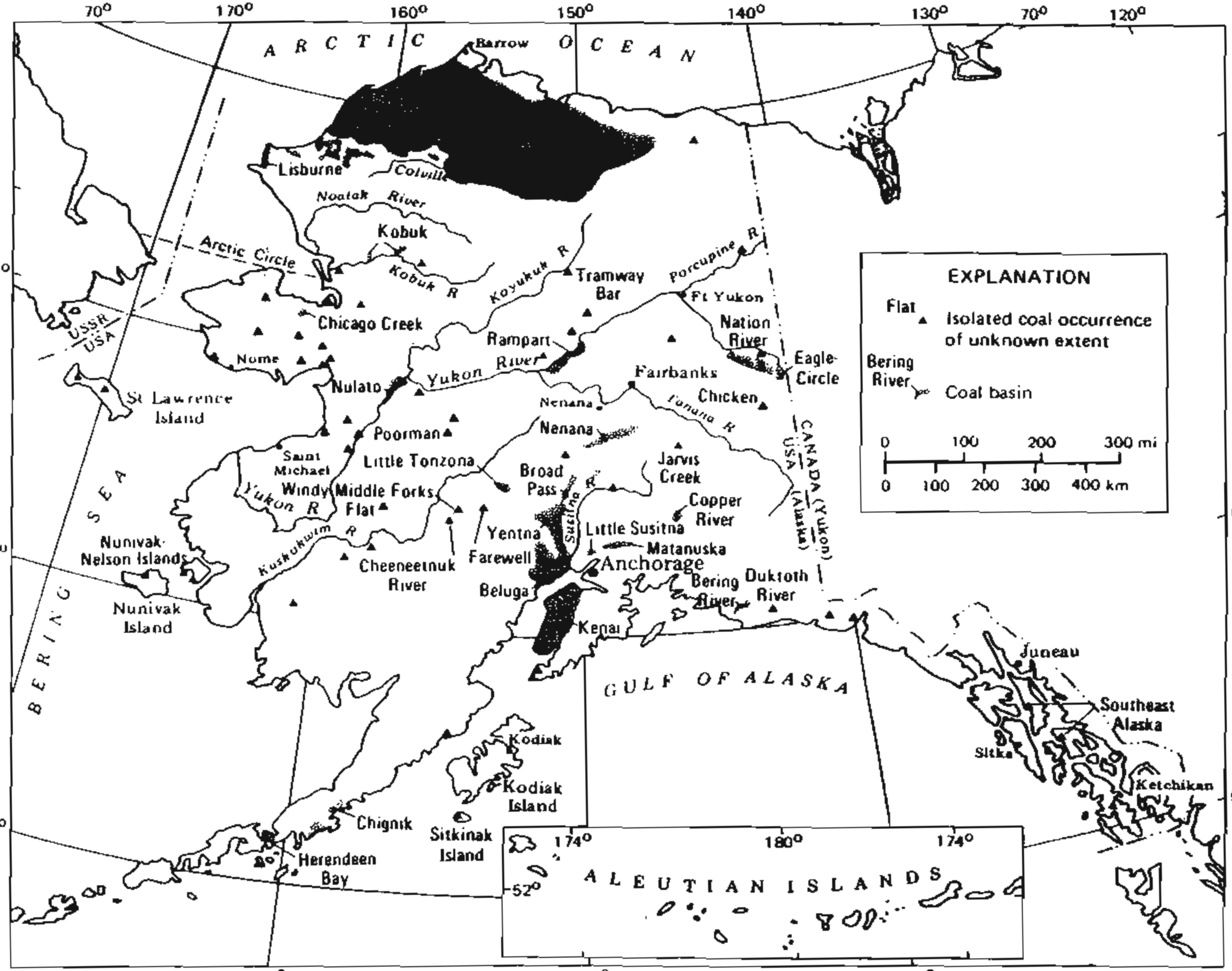
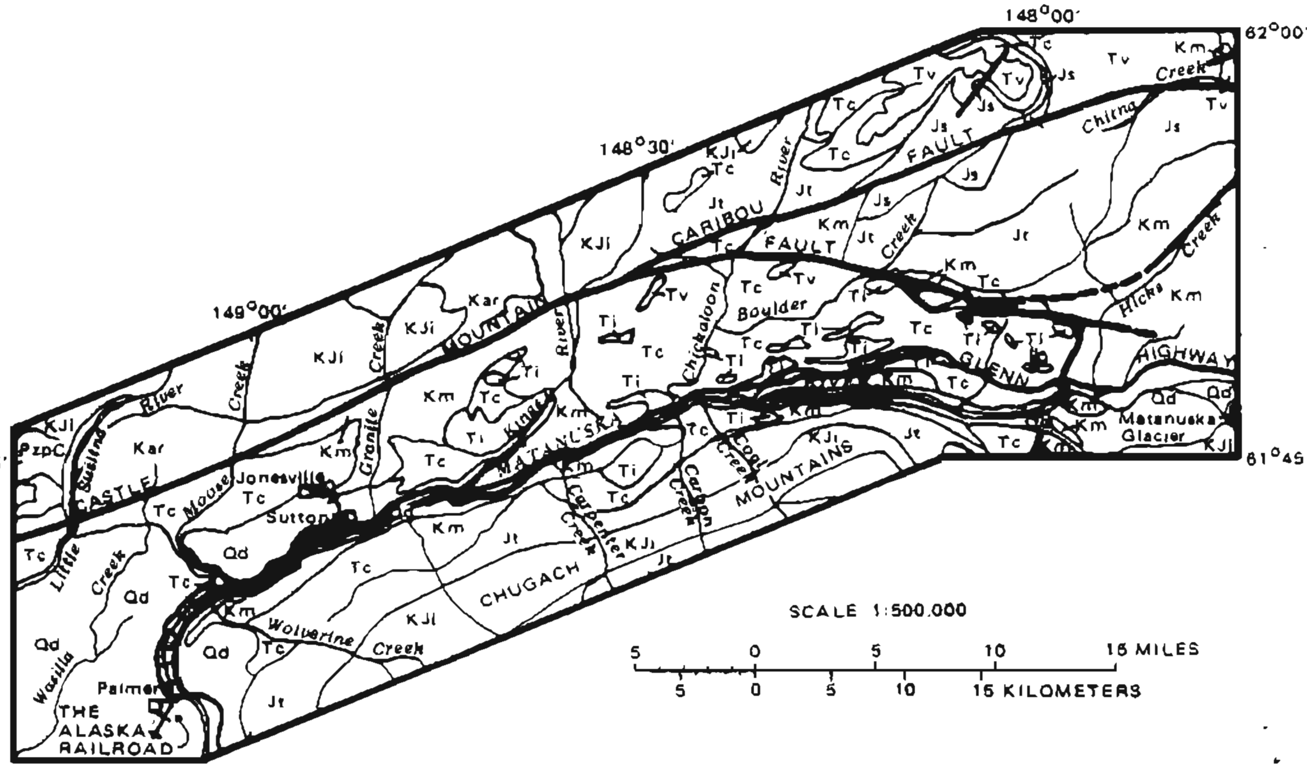

ARCTIC OCEAN
Barrow
Lisburne
Colville
Noatak River
Kobuk
Kobuk R
Arctic Circle
Koyukuk R
Tramway Bar
Porcupine R
Ft Yukon
USSR
USA
Chicago Creek
Nome
Rampart
Yukon River
Nation River
Eagle-Circle
Fairbanks
Nulato
St Lawrence Island
Nenana
Chicken
Tanana R
Poorman
Saint Michael
Little Tonzona
Jarvis Creek
Broad Pass
Windy Middle Forks Flat
Yukon R
Copper River
Little Susitna
Susitna R
Yentna
Matanuska
Farewell
Anchorage
Nunivak-Nelson Islands
Kuskokwim R
Cheeneetnuk River
Beluga
Bering River
Duktoth River
Nunivak Island
Kenai
CANADA (Yukon)
USA (Alaska)
BERING SEA
GULF OF ALASKA
Juneau
Southeast Alaska
Sitka
Ketchikan
Kodiak
Kodiak Island
Chignik
Sitkinak Island
Herendeen Bay
ALEUTIAN ISLANDS
EXPLANATION
Flat
Isolated coal occurrence of unknown extent
Bering River
Coal basin
0 100 200 300 mi
0 100 200 300 400 km

Figure 1



CORRELATION OF MAP UNITS

Qd	Pleistocene and Recent	QUATERNARY
Tv	Oligocene	TERTIARY
Ti	Paleocene, Eocene, and Oligocene	TERTIARY
Tc	Paleocene, Eocene, and Oligocene	TERTIARY
Km	Lower and Upper(?) Cretaceous	CRETACEOUS
Kar	Lower and Upper(?) Cretaceous	CRETACEOUS
KJi	Middle Jurassic to Early Cretaceous	CRETACEOUS / JURASSIC
Js	Middle and Upper Jurassic	JURASSIC
Jt	Lower Jurassic	JURASSIC
PzpC		PRECAMBRIAN OR PALEOZOIC

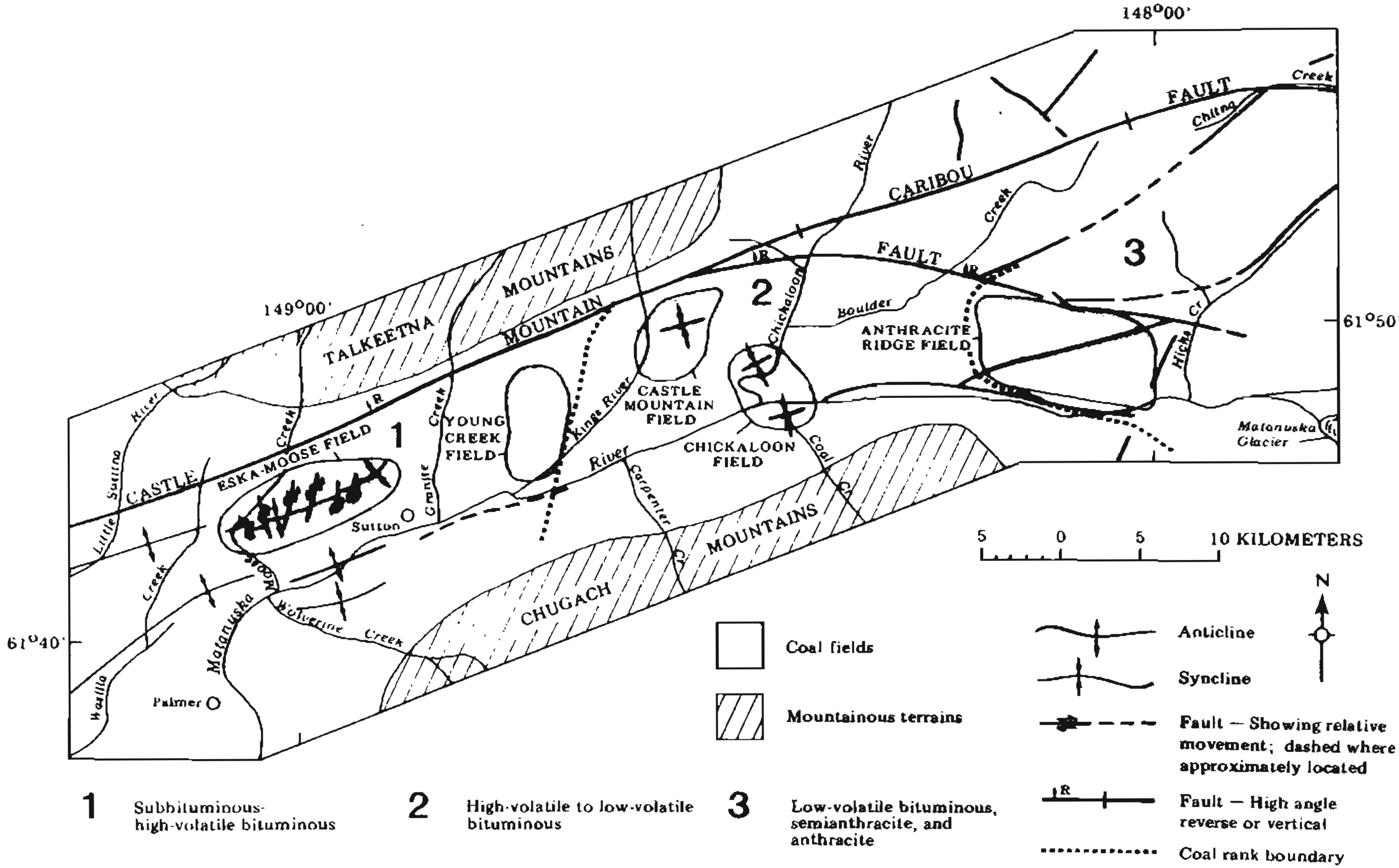
DESCRIPTION OF MAP UNITS

Qd	Surficial deposits
Tv	Volcanic rocks — Mainly basaltic lava flows
Ti	Hypabyssal intrusive rocks
Tc	Continental clastic sedimentary rocks — Includes Chickaloon, Wishbone, and Tsadaka Formations
Km	Matanuska Formation — Marine clastic sedimentary rocks
Kar	Arkose Ridge Formation — Nonmarine arkose, conglomerate, and siltstone
KJi	Plutonic intrusive rocks — Mainly quartz diorite and granodiorite
Js	Marine clastic sedimentary rocks — Consists of Tuxedni, Chinitna, and Naknek Formation
Jt	Talkeetna Formation — Dominantly marine, intermediate volcanic and sedimentary rocks
PzpC	Muscovite schist

Contacts

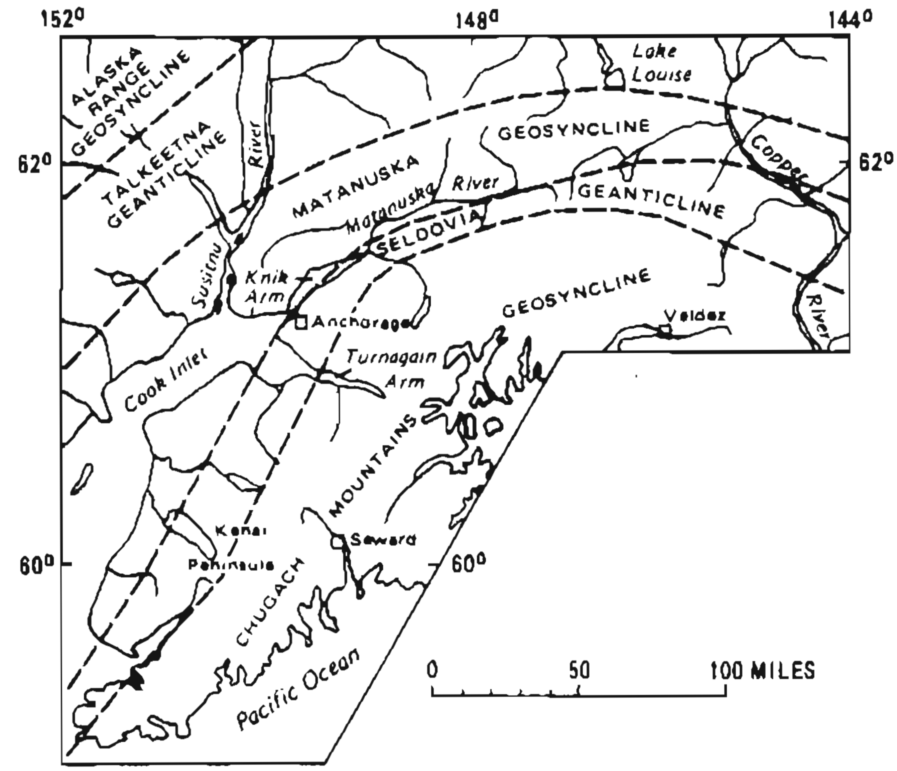
Major faults — Dashed where inferred.

Figure 2



148°00'
149°00'
61°50'
61°40'
CASTLE
MOUNTAIN
CARIBOU
FAULT
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
ESKA-MOOSE FIELD
YOUNG CREEK FIELD
CASTLE MOUNTAIN FIELD
CHICKALOON FIELD
ANTHRACITE RIDGE FIELD
1
2
3
Sutton
Palmer
Matanuska Glacier
5 0 5 10 KILOMETERS
N
Coal fields
Mountainous terrains
Anticline
Syncline
Fault — Showing relative movement; dashed where approximately located
Fault — High angle reverse or vertical
Coal rank boundary
1 Subbituminous-high-volatile bituminous
2 High-volatile to low-volatile bituminous
3 Low-volatile bituminous, semianthracite, and anthracite

Figure 3



152°
148°
144°
62°
62°
60°
60°
ALASKA RANGE GEOSYNCLINE
TALKEETNA GEANTICLINE
Lake Louise
GEOSYNCLINE
MATANUSKA
Matanuska River
GEANTICLINE
SELDOVIA
Copper River
Susitnu River
Knik Arm
Anchorage
GEOSYNCLINE
Valdez
Cook Inlet
Turnagain Arm
MOUNTAINS
CHUGACH
Kenai Peninsula
Seward
Pacific Ocean
0
50
100 MILES

Figure 4

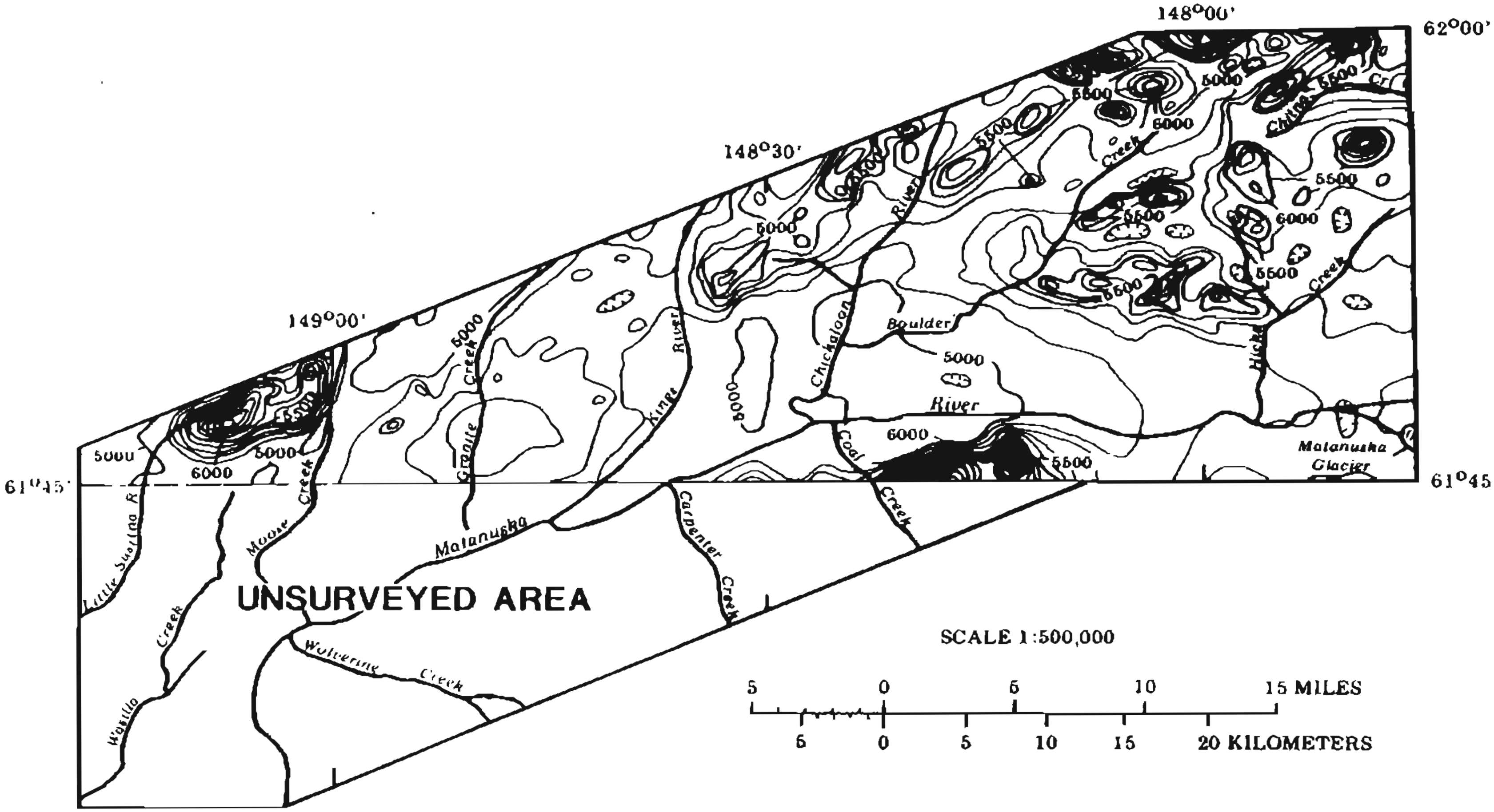
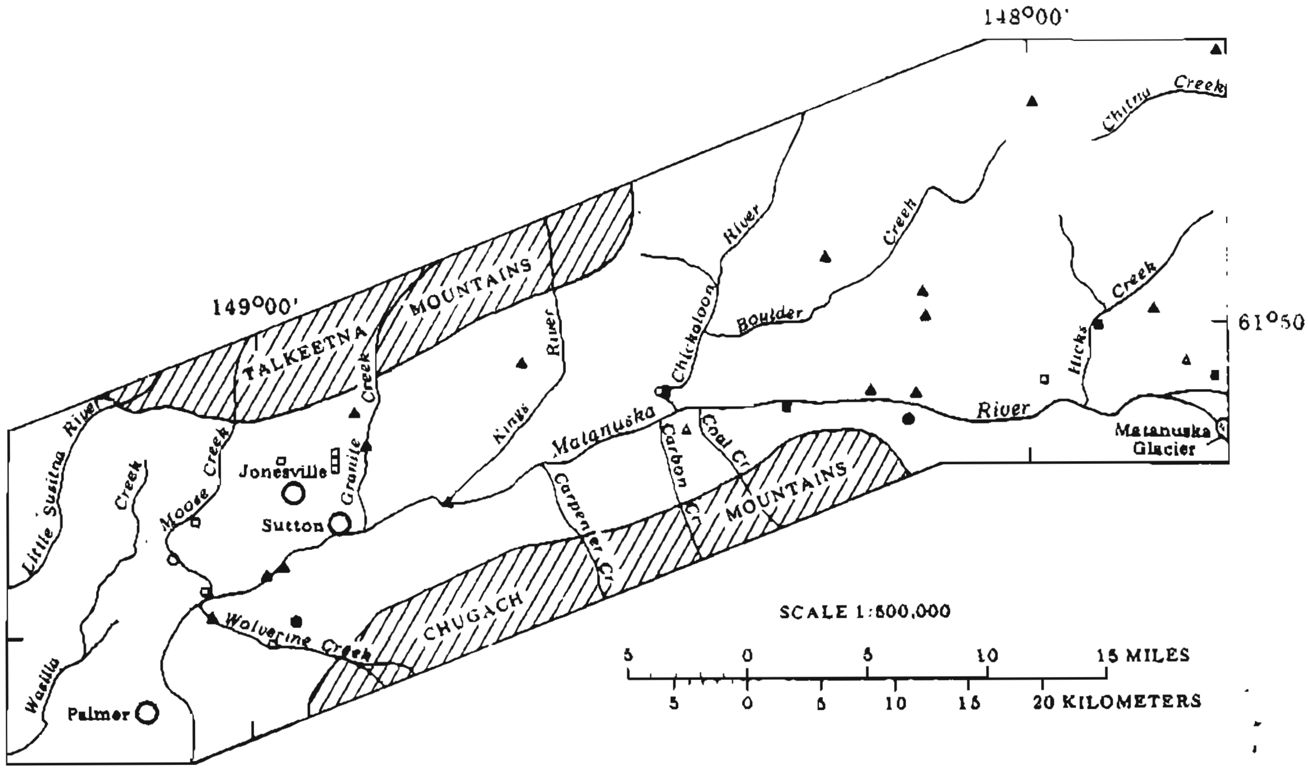

148°00'
62°00'
148°30'
149°00'
61°45'
61°45'
UNSURVEYED AREA
Matanuska Glacier
Matanuska
Chickaloon River
Boulder
River
Coal Creek
Carpenter Creek
Kings River
Granite Creek
Moose Creek
Little Susitna R.
Wasilla Creek
Wolverine Creek
Hicks
5000
5500
6000
SCALE 1:500,000
5 0 5 10 15 MILES
5 0 5 10 15 20 KILOMETERS

Figure 5



EXPLANATION

GENERAL CHARACTERISTICS OF CHICKALOON FORMATION FLORA

Description of megafossil floras:
Predominantly ferns, fan palms, cycads, conifers and various broad-leaf genera

Dominant genera:
Dennstaedtia americana, Onoclea hesperia, Trochodendroides serrulata, "Planera" microphylla, Carya antiquora, Quercophyllum groenlandicus, Dicotylophyllum flexuosa, Anemia elongata, and Hymenophyllum confusum

Inferred climate:
Subtropical to warm-temperate

FOSSIL — BEARING LOCALITIES

TERTIARY
- ○ Plant fossils · Miocene — Tsadaka Fm.
- ■ Mollusk fossil · Paleocene — Chickaloon Fm.
- ○ Plant fossils · Paleocene — Chickaloon Fm.

CRETACEOUS
- ● Mollusk fossils of Albian age — Matanuska Fm.
- ● Mollusk fossils of Campanian age — Matanuska Fm.
- ▲ Mollusk fossils of late Campanian and Maestrichtian age — Matanuska Fm.
- △ Mollusk fossils questionably of late Campanian and Maestrichtian age — Matanuska Fm.

Figure 6

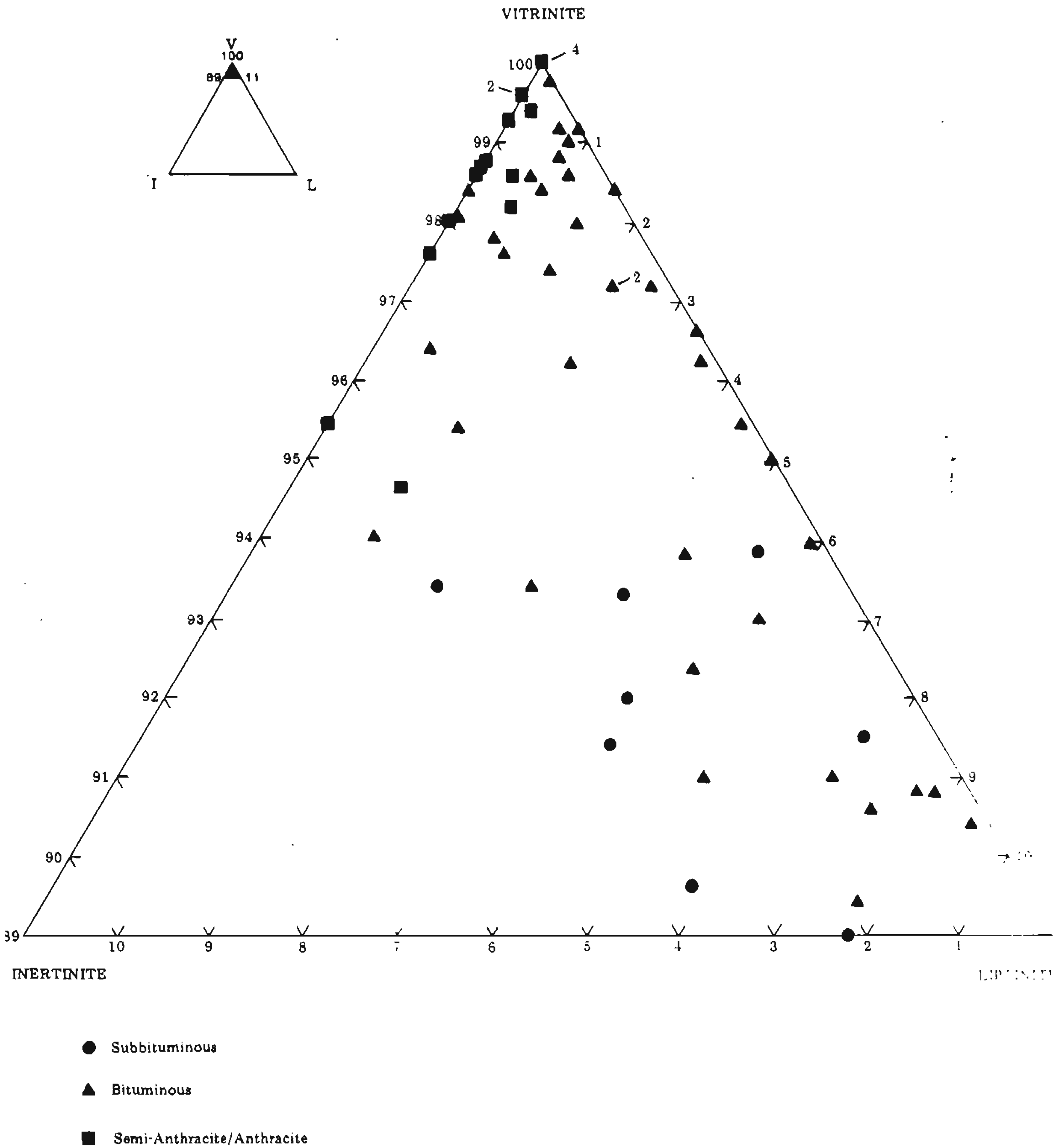

VITRINITE
INERTINITE
V
I
L
Subbituminous
Bituminous
Semi-Anthracite/Anthracite

Figure 7

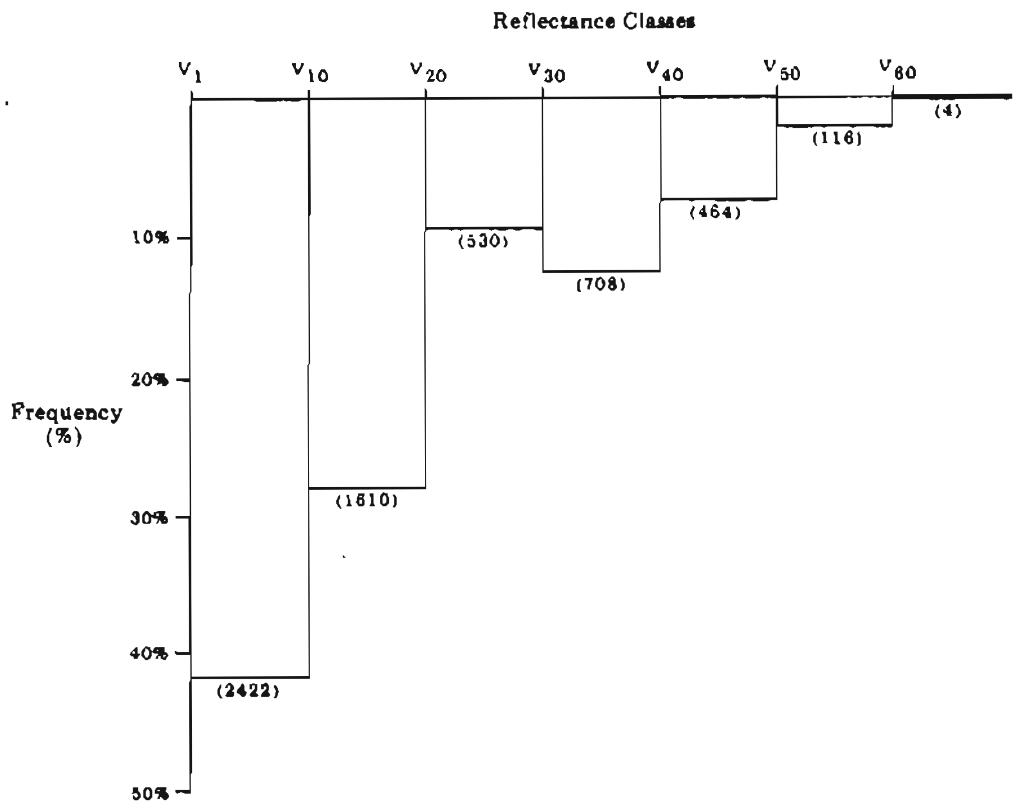

Reflectance Classes
V1
V10
V20
V30
V40
V50
V60
Frequency (%)
10%
20%
30%
40%
50%
(2422)
(1610)
(530)
(708)
(464)
(116)
(4)

Figure 8

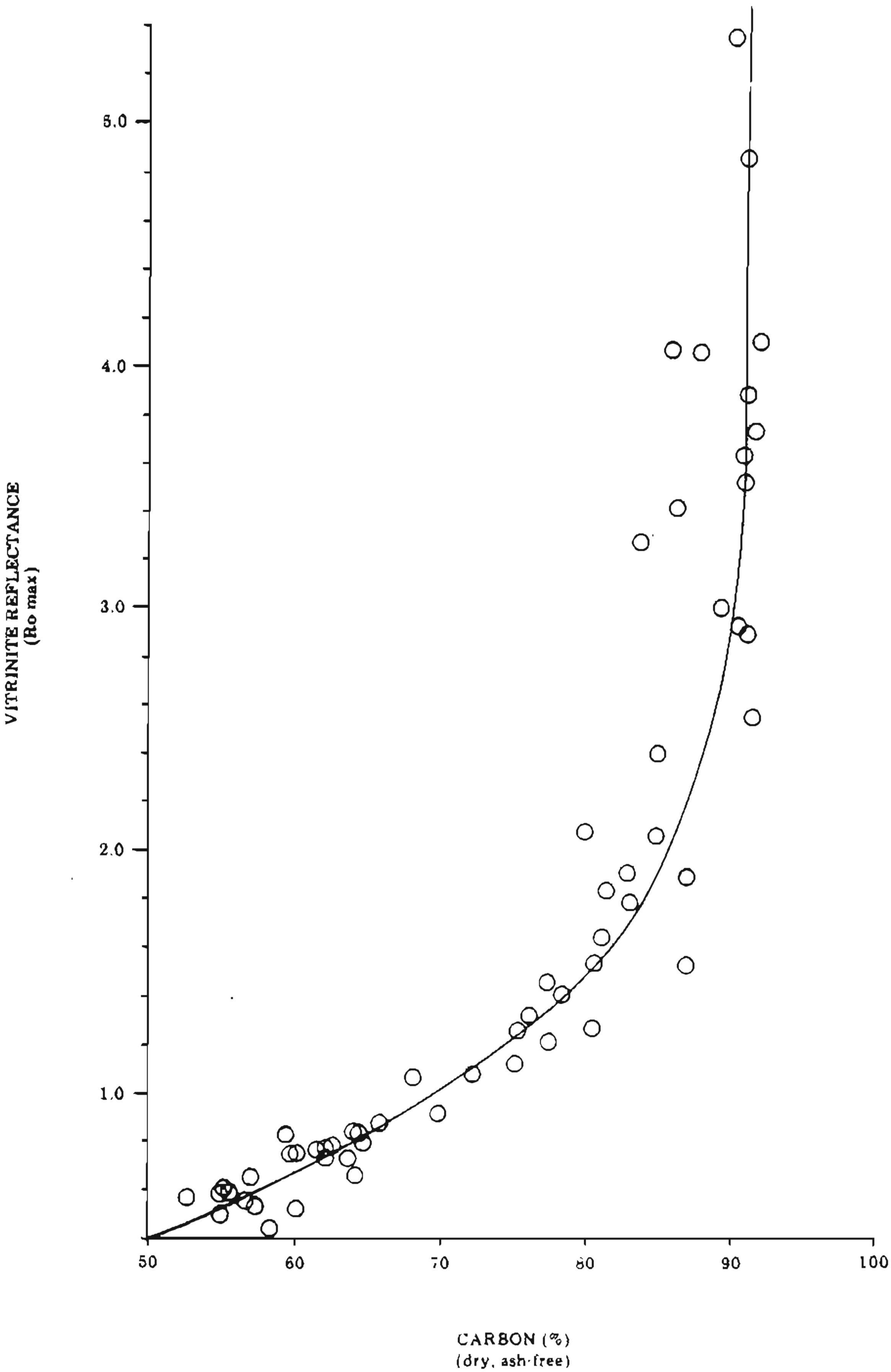

VITRINITE REFLECTANCE
(Ro max)
5.0
4.0
3.0
2.0
1.0
50
60
70
80
90
100
CARBON (%)
(dry, ash-free)

Figure 9

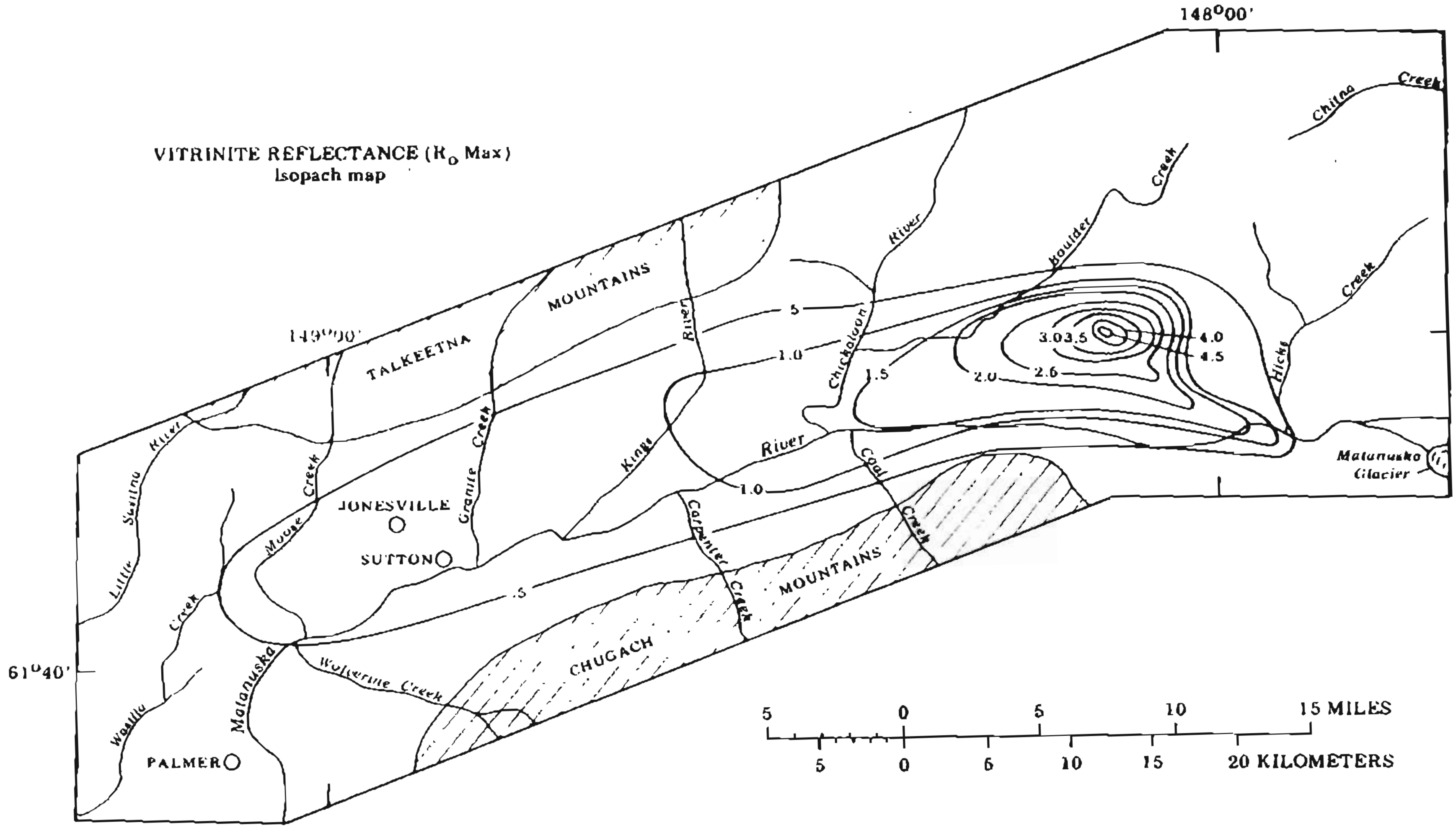

VITRINITE REFLECTANCE (R_o Max)
Isopach map
148°00'
61°50'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Matanuska Glacier
Chitna Creek
Creek
Boulder
River
Chickaloon
River
Hicks
Creek
Kings
River
Granite Creek
Moose Creek
Little Susitna River
Creek
Wasilla
Matanuska
Wolverine Creek
Carpenter Creek
Coal Creek
.5
1.0
1.5
2.0
2.6
3.0
3.5
4.0
4.5
5
0
5
10
15 MILES
5
0
5
10
15
20 KILOMETERS

Figure 10

Figure 11

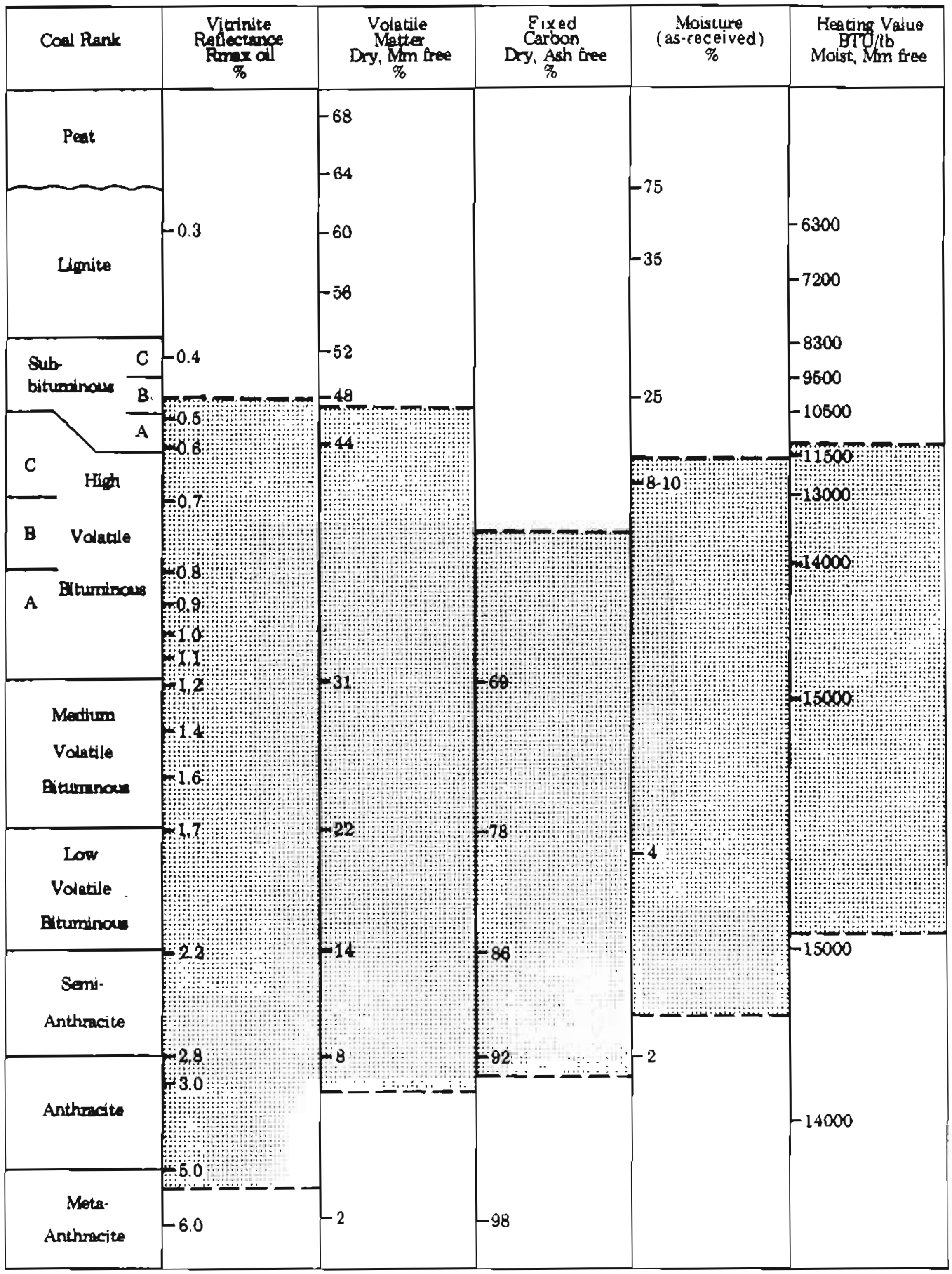

Coal Rank
Vitrinite Reflectance Rmax oil %
Volatile Matter Dry, Mm free %
Fixed Carbon Dry, Ash free %
Moisture (as-received) %
Heating Value BTU/lb Moist, Mm free
Peat
Lignite
Sub-bituminous
C
B
A
C
High
B
Volatile
A
Bituminous
Medium Volatile Bituminous
Low Volatile Bituminous
Semi-Anthracite
Anthracite
Meta-Anthracite
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.4
1.6
1.7
2.2
2.8
3.0
5.0
6.0
68
64
60
56
52
48
44
31
22
14
8
2
69
78
86
92
98
75
35
25
8-10
4
2
6300
7200
8300
9500
10500
11500
13000
14000
15000
15000
14000

Figure 12

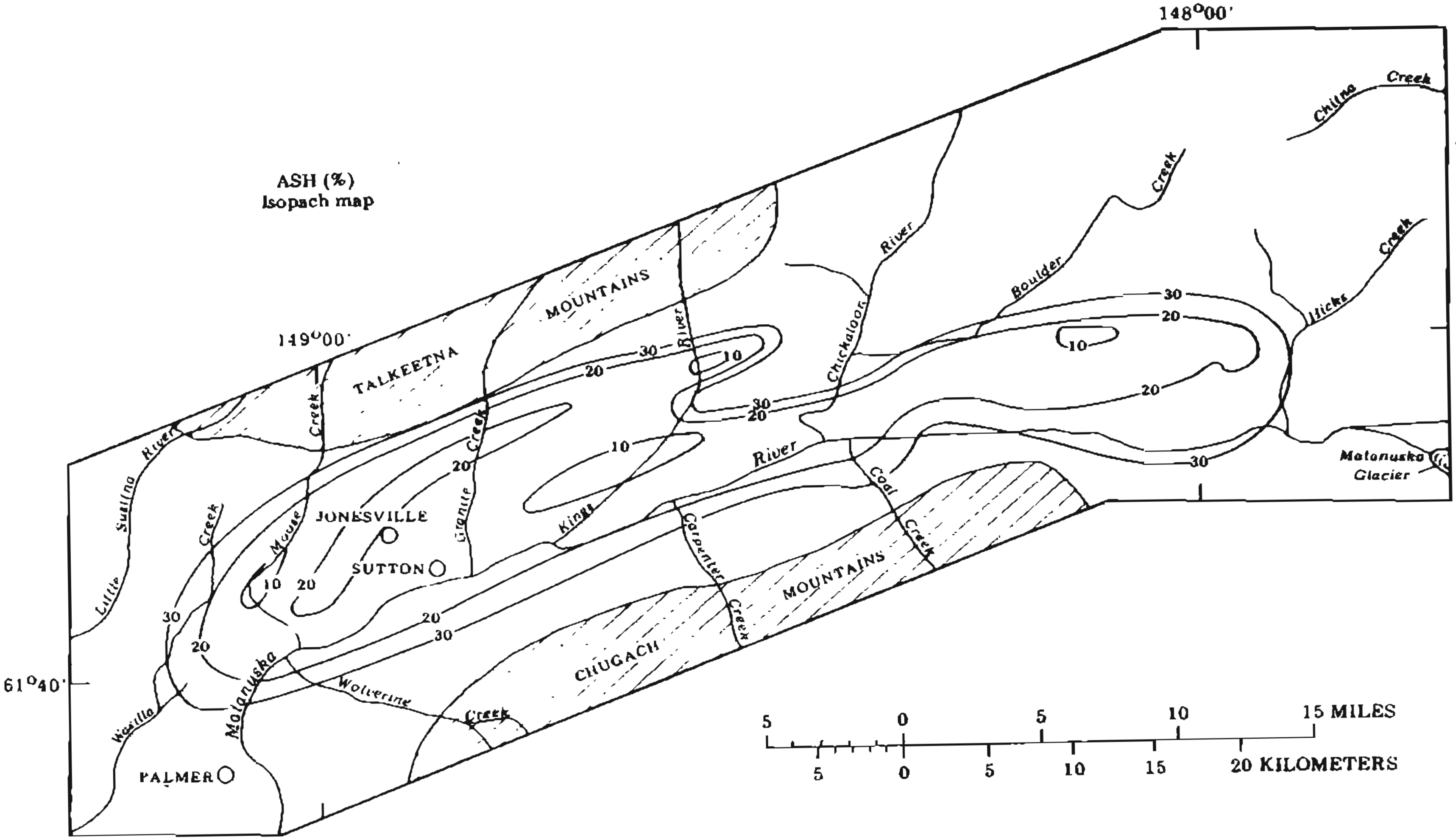

ASH (%)
Isopach map
148°00'
149°00'
61°50'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Chickaloon River
Boulder Creek
Hicks Creek
Chitna Creek
Matanuska Glacier
Matanuska River
Kings River
Coal Creek
Carpenter Creek
Wolverine Creek
Granite Creek
Moose Creek
Little Susitna River
Wasilla
5 0 5 10 15 MILES
5 0 5 10 15 20 KILOMETERS

Figure 13. - . '

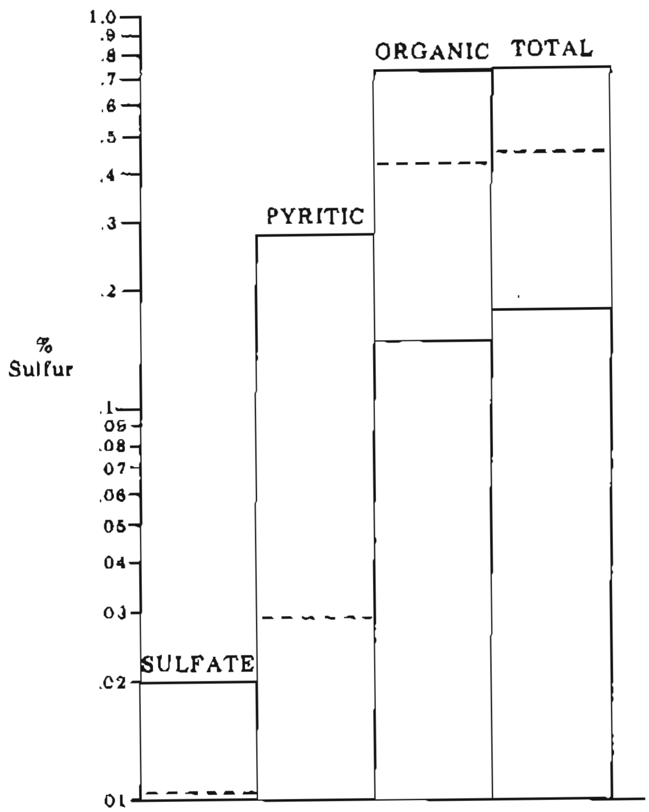

1.0
.9
.8
.7
.6
.5
.4
.3
.2
%
Sulfur
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
SULFATE
PYRITIC
ORGANIC
TOTAL

Figure 14

Raw Coal

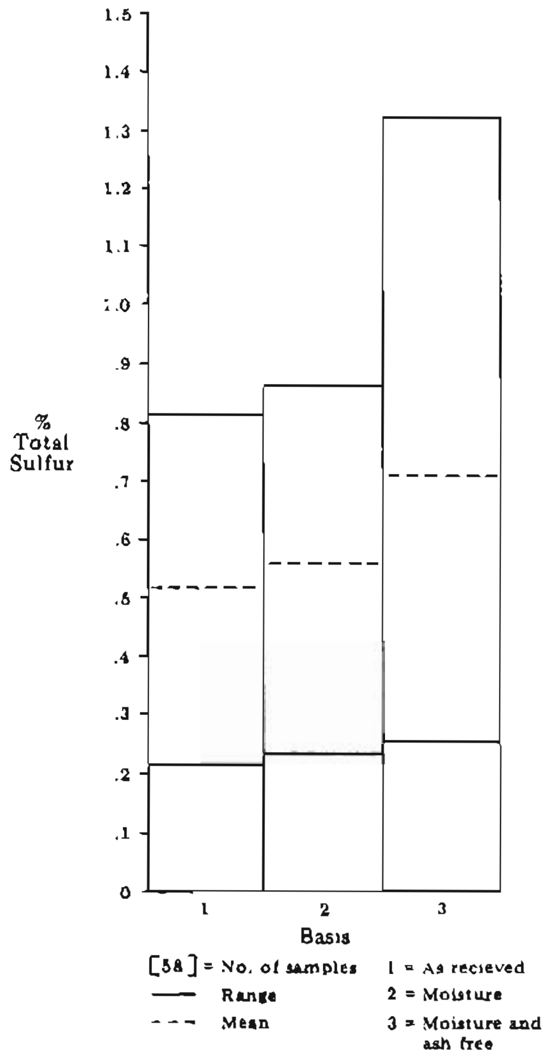


Figure 15

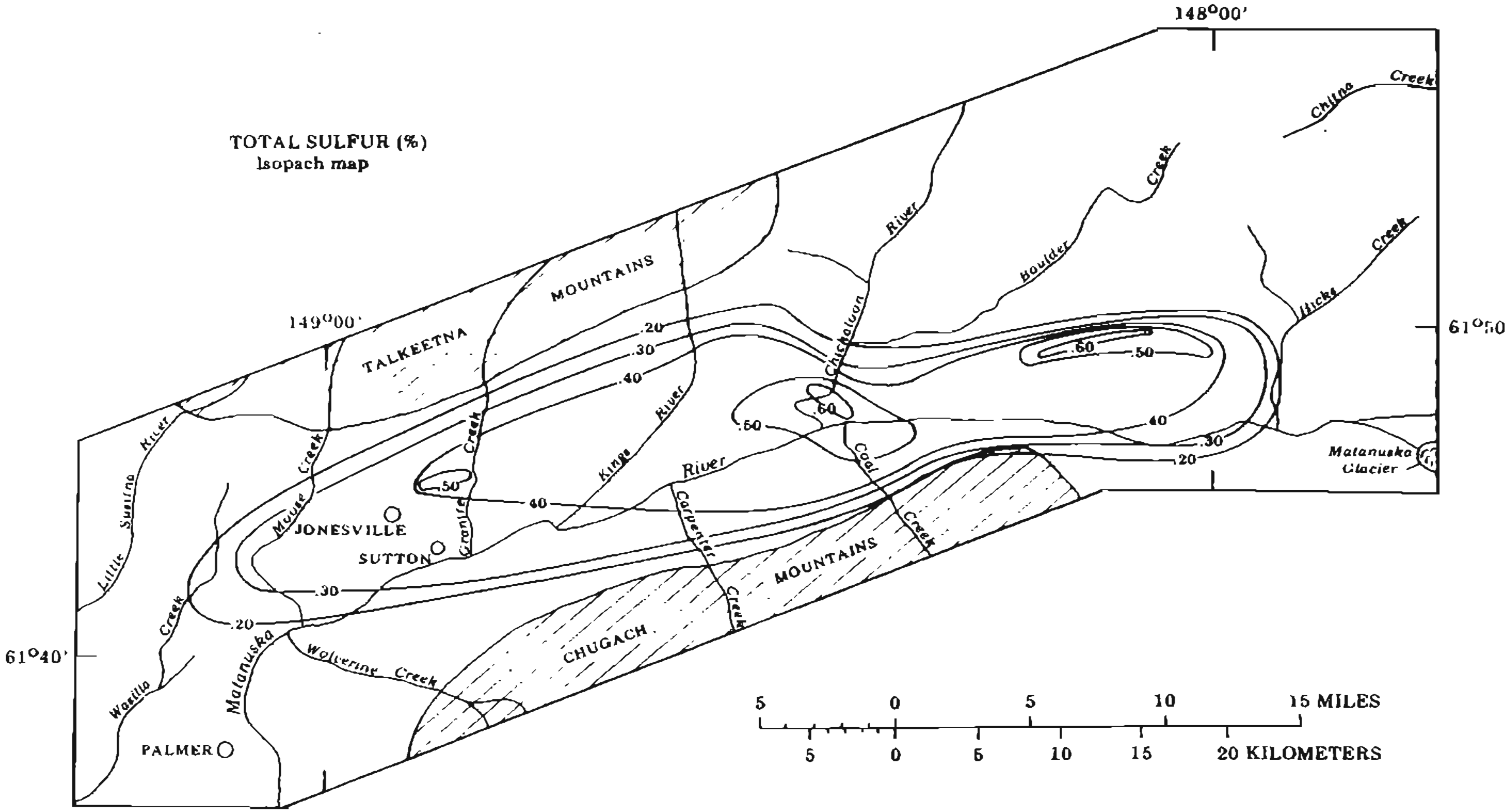

TOTAL SULFUR (%)
Isopach map
148°00'
149°00'
61°50'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Matanuska Glacier
Chitina Creek
Hicks Creek
Boulder Creek
Chickaloon River
Kings River
Coal Creek
Carpenter Creek
Granite Creek
Moose Creek
Little Susitna River
Wasilla Creek
Matanuska River
Wolverine Creek
.20
.30
.40
.50
.60
5 0 5 10 15 MILES
5 0 5 10 15 20 KILOMETERS

Figure 16

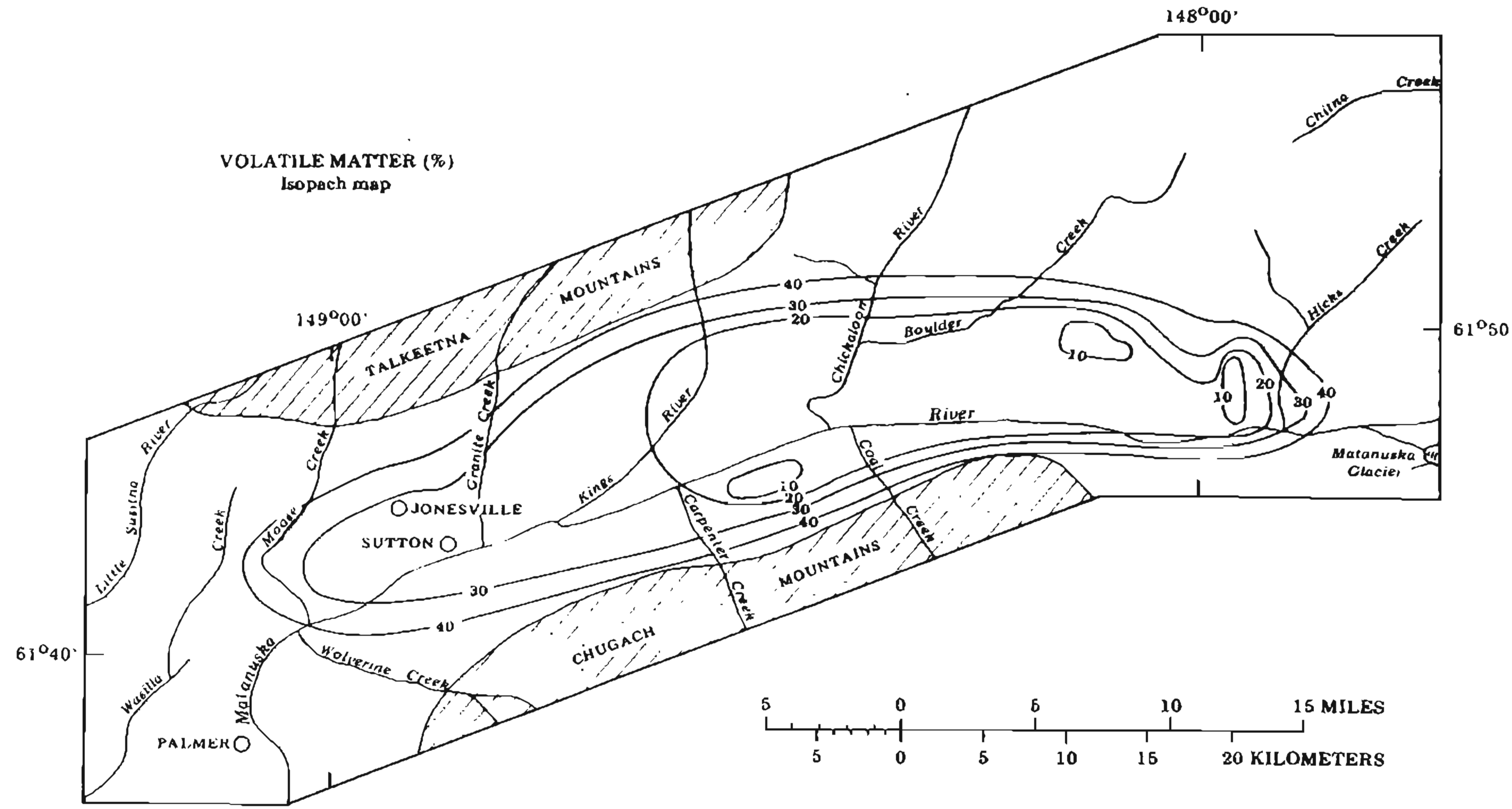

VOLATILE MATTER (%)
Isopach map
148°00'
149°00'
61°50'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Little Susitna River
Wasilla Creek
Matanuska
Moose Creek
Granite Creek
Kings River
Wolverine Creek
Carpenter Creek
Coal Creek
Chickaloon River
Boulder Creek
River
Hicks Creek
Chitna Creek
Matanuska Glacier
10
20
30
40
5 0 5 10 15 MILES
5 0 5 10 15 20 KILOMETERS

Figure 17

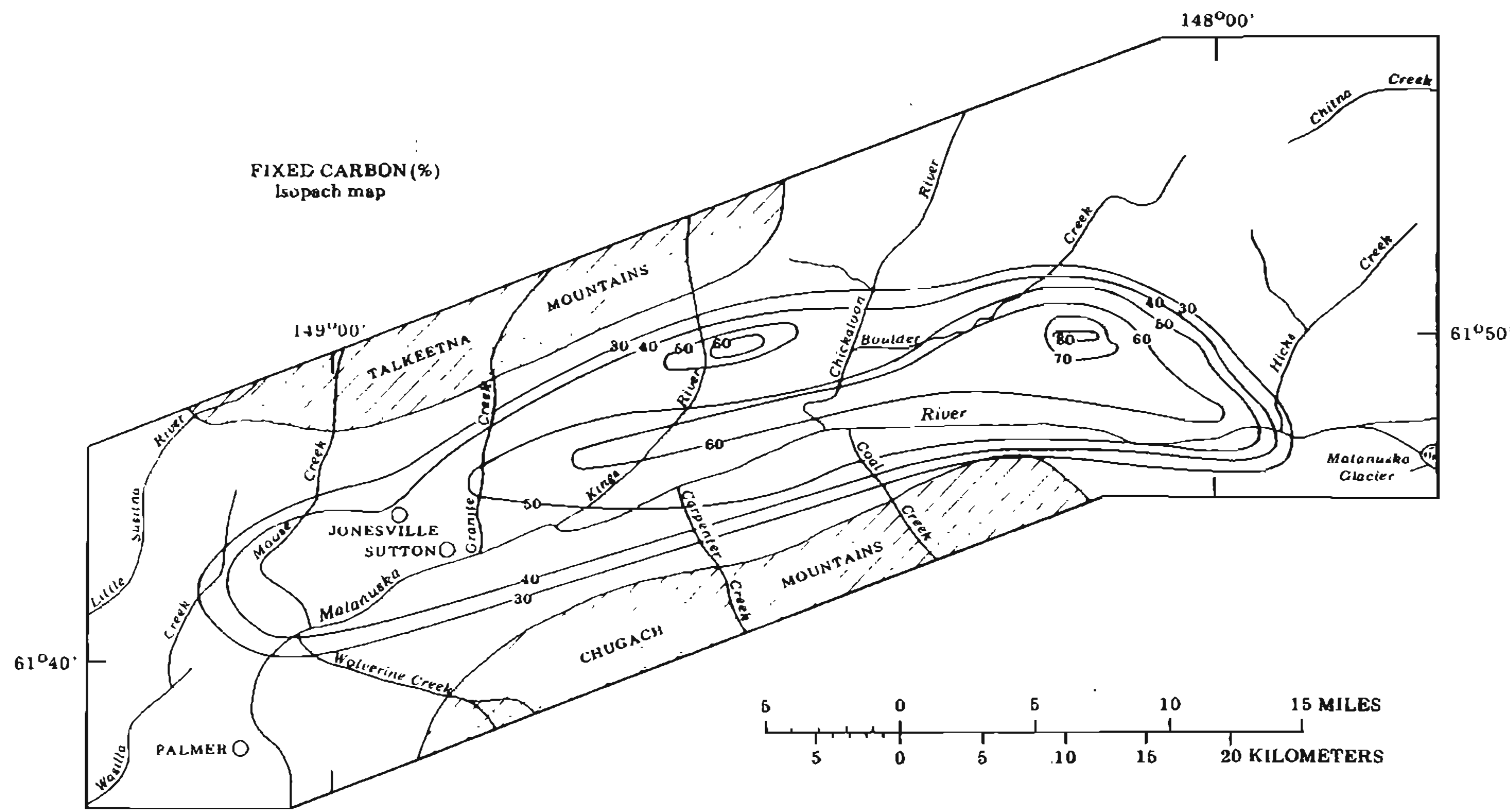

FIXED CARBON (%)
Isopach map
148°00'
149°00'
61°50'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Matanuska
River
Chickaloon
Boulder
Kings
River
Granite
Creek
Coal
Creek
Carpenter
Creek
Wolverine Creek
Moose
Creek
Little
Susitna
River
Wasilla
Chitna
Creek
Hicks
Creek
Matanuska
Glacier
30
40
50
60
70
80
5
0
5
10
15 MILES
5
0
5
10
15
20 KILOMETERS

Figure 13

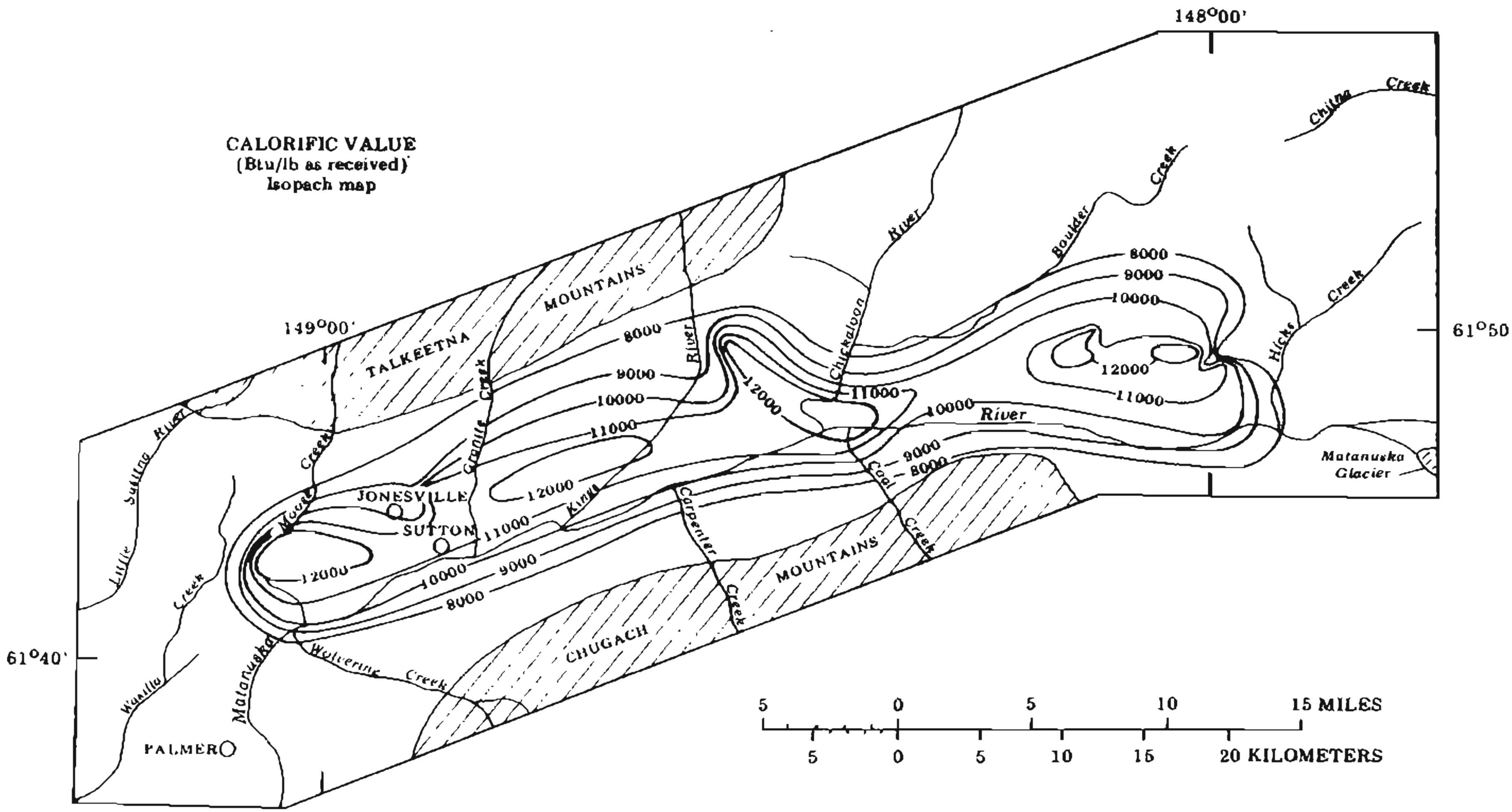
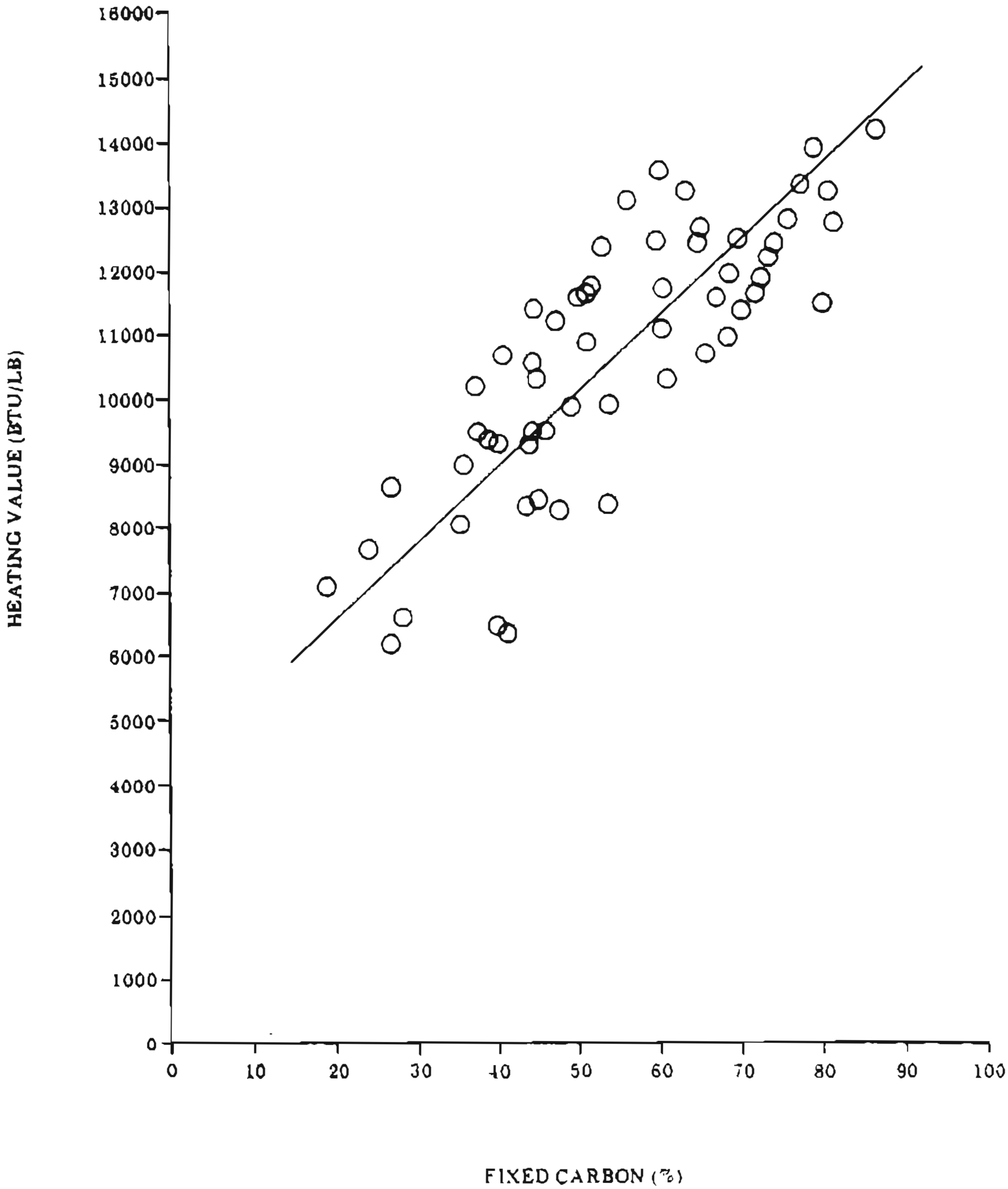
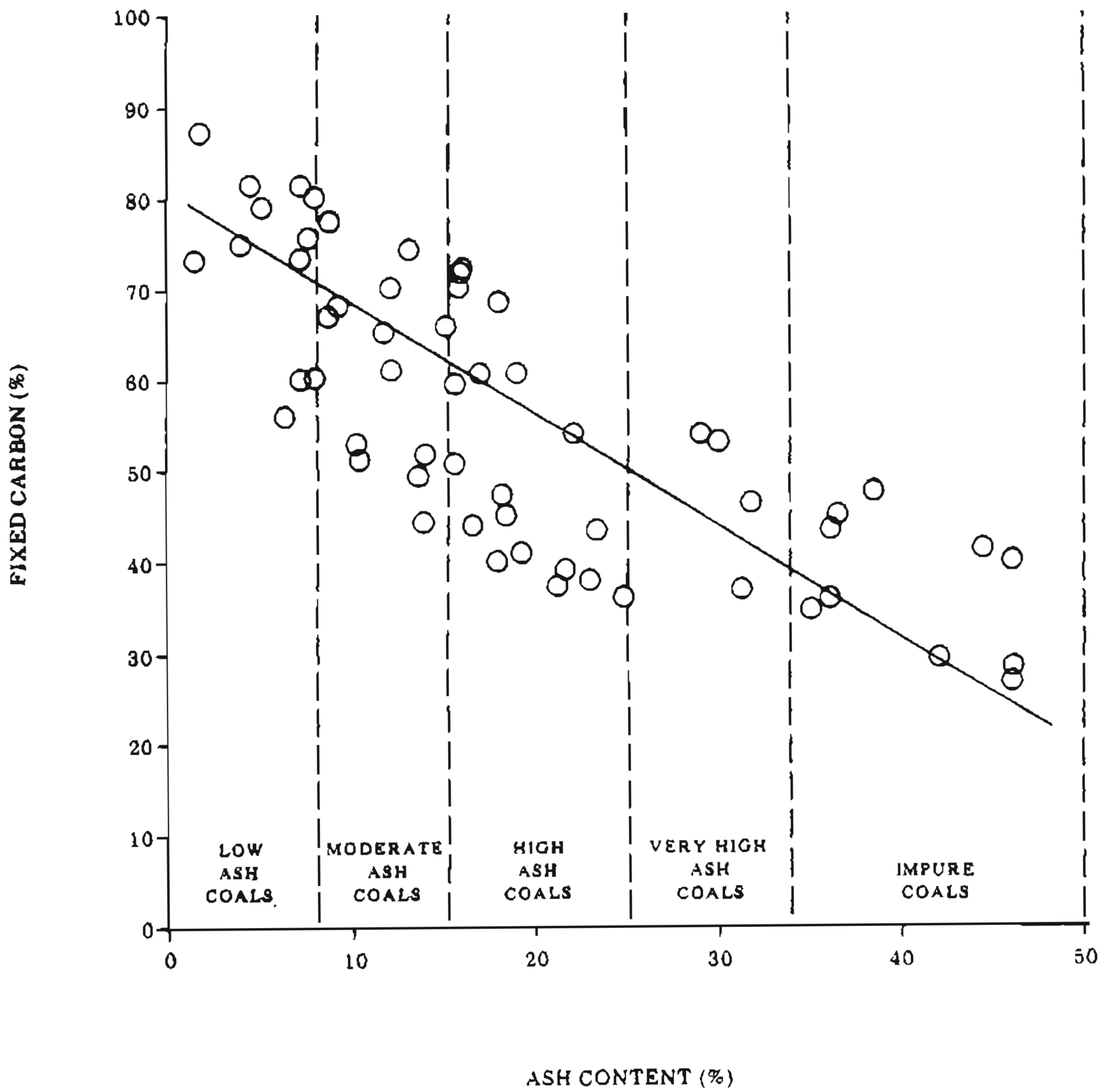

CALORIFIC VALUE
(Btu/lb as received)
Isopach map
148°00'
61°50'
149°00'
61°40'
TALKEETNA
MOUNTAINS
CHUGACH
MOUNTAINS
JONESVILLE
SUTTON
PALMER
Matanuska Glacier
Chickaloon
River
Boulder Creek
Hicks Creek
Chitna Creek
Coal Creek
Carpenter Creek
Granite Creek
Kings
Moose Creek
Wolverine Creek
Wasilla Creek
Little Susitna River
Matanuska
8000
9000
10000
11000
12000
5 0 5 10 15 MILES
5 0 5 10 15 20 KILOMETERS

Figure 19



16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
HEATING VALUE (BTU/LB)
0
10
20
30
40
50
60
70
80
90
100
FIXED CARBON (%)

Figure 20



FIXED CARBON (%)
100
90
80
70
60
50
40
30
20
10
0
LOW ASH COALS
MODERATE ASH COALS
HIGH ASH COALS
VERY HIGH ASH COALS
IMPURE COALS
0
10
20
30
40
50
ASH CONTENT (%)

Figure 21

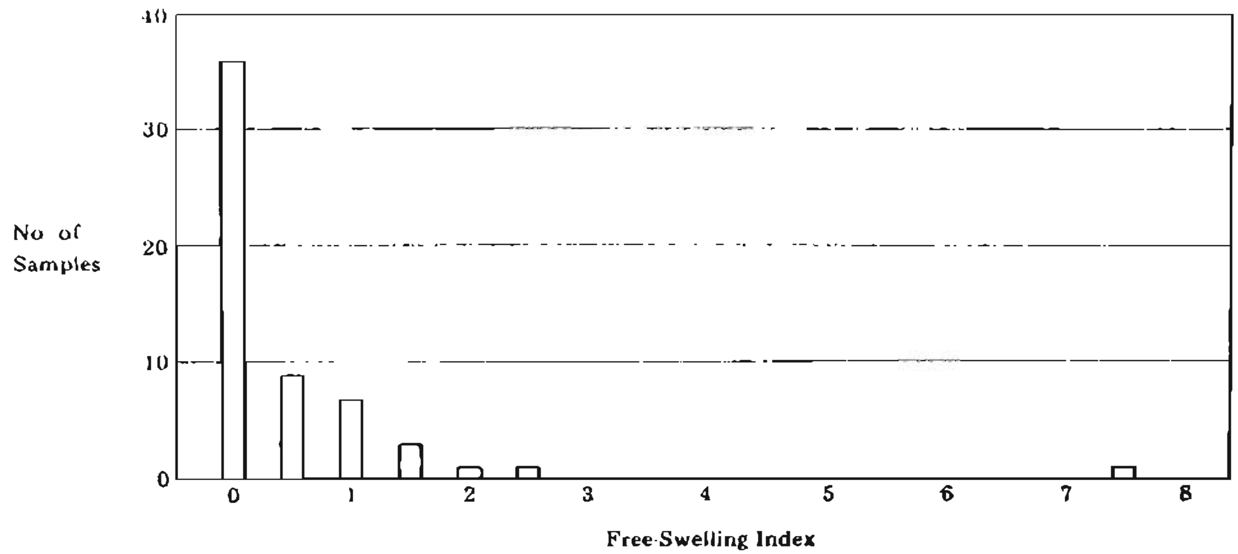


Figure 22

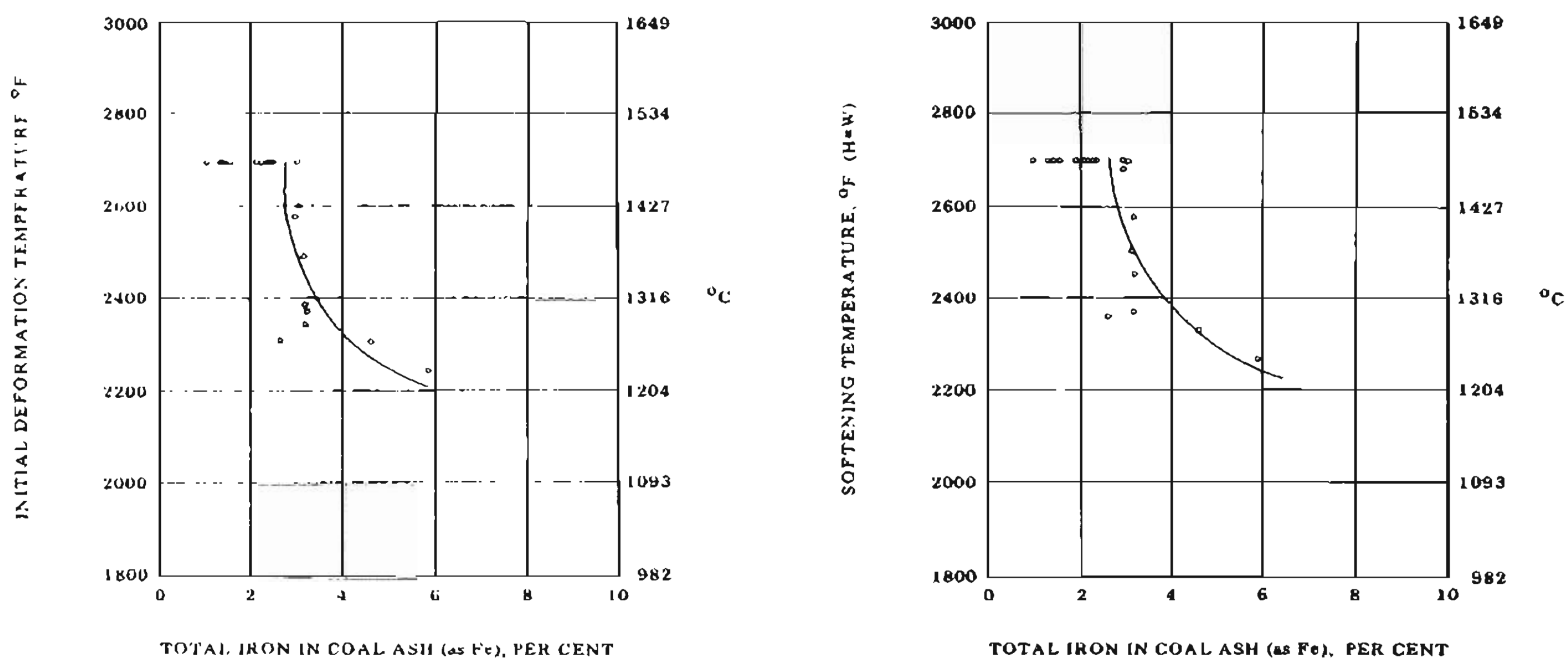
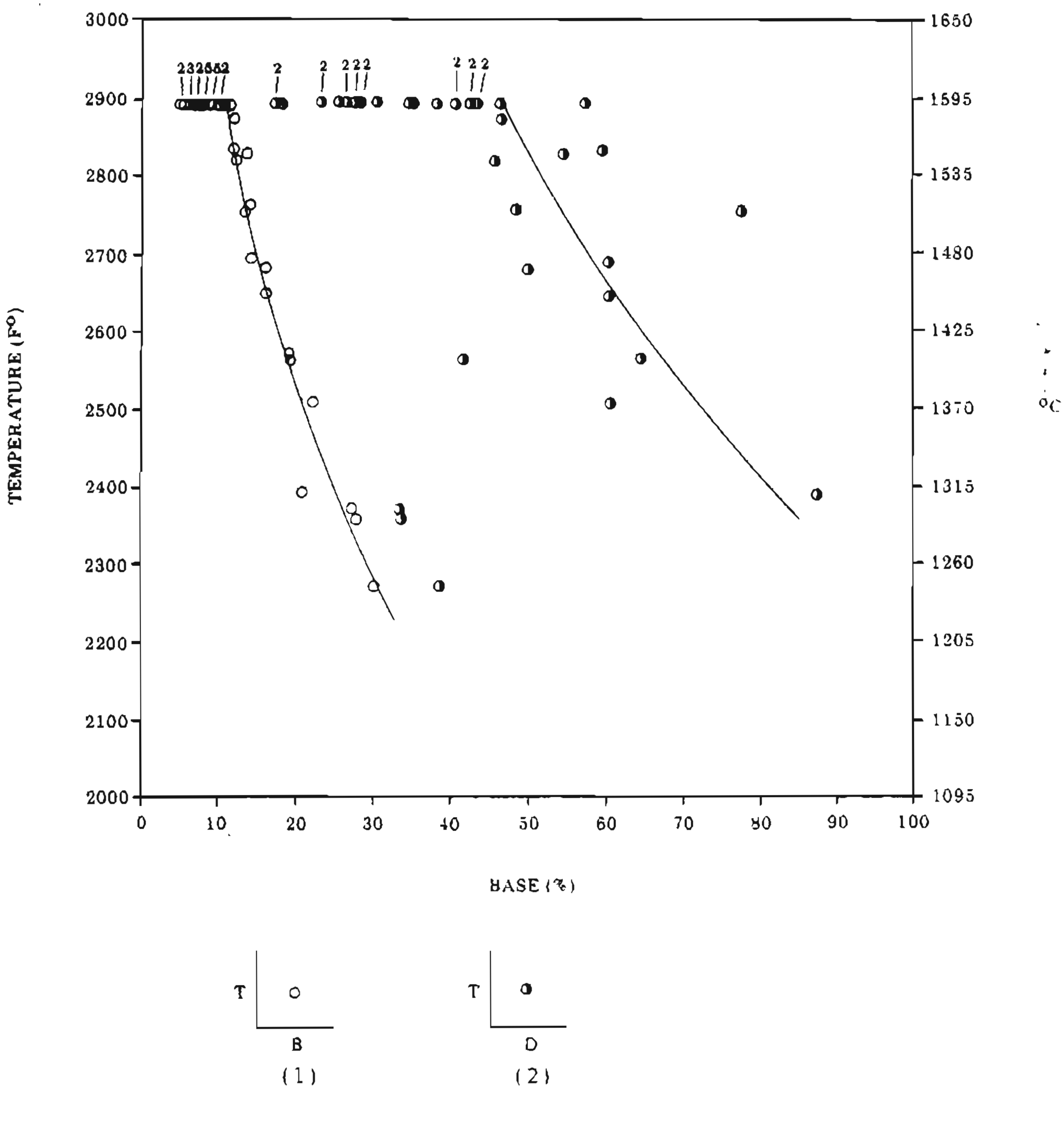
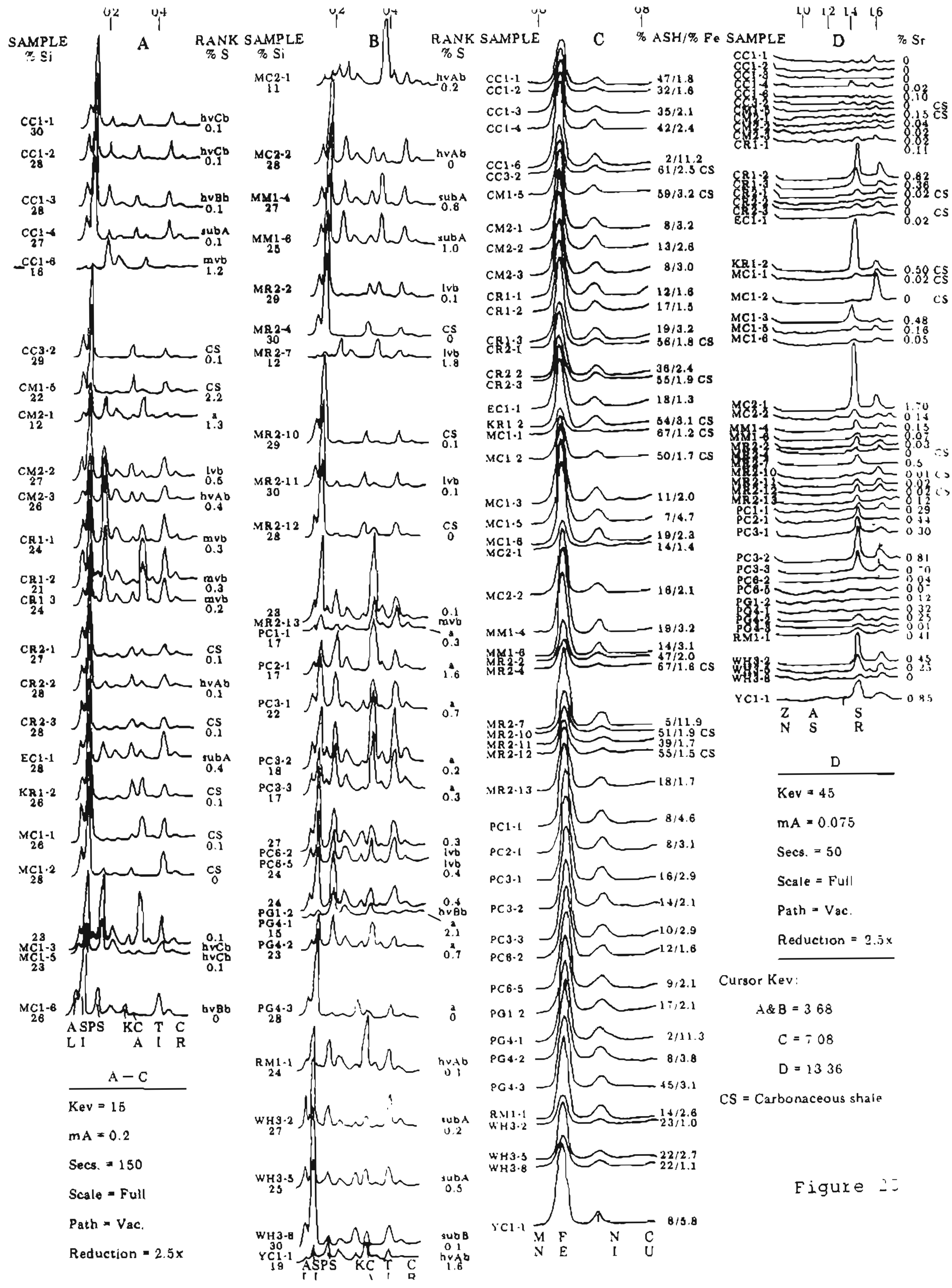

INITIAL DEFORMATION TEMPERATURE °F
3000
2800
2600
2400
2200
2000
1800
1649
1534
1427
1316
1204
1093
982
°C
0
2
4
6
8
10
TOTAL IRON IN COAL ASH (as Fe), PER CENT
SOFTENING TEMPERATURE, °F (H=W)
3000
2800
2600
2400
2200
2000
1800
1649
1534
1427
1316
1204
1093
982
°C
0
2
4
6
8
10
TOTAL IRON IN COAL ASH (as Fe), PER CENT

Figure 23



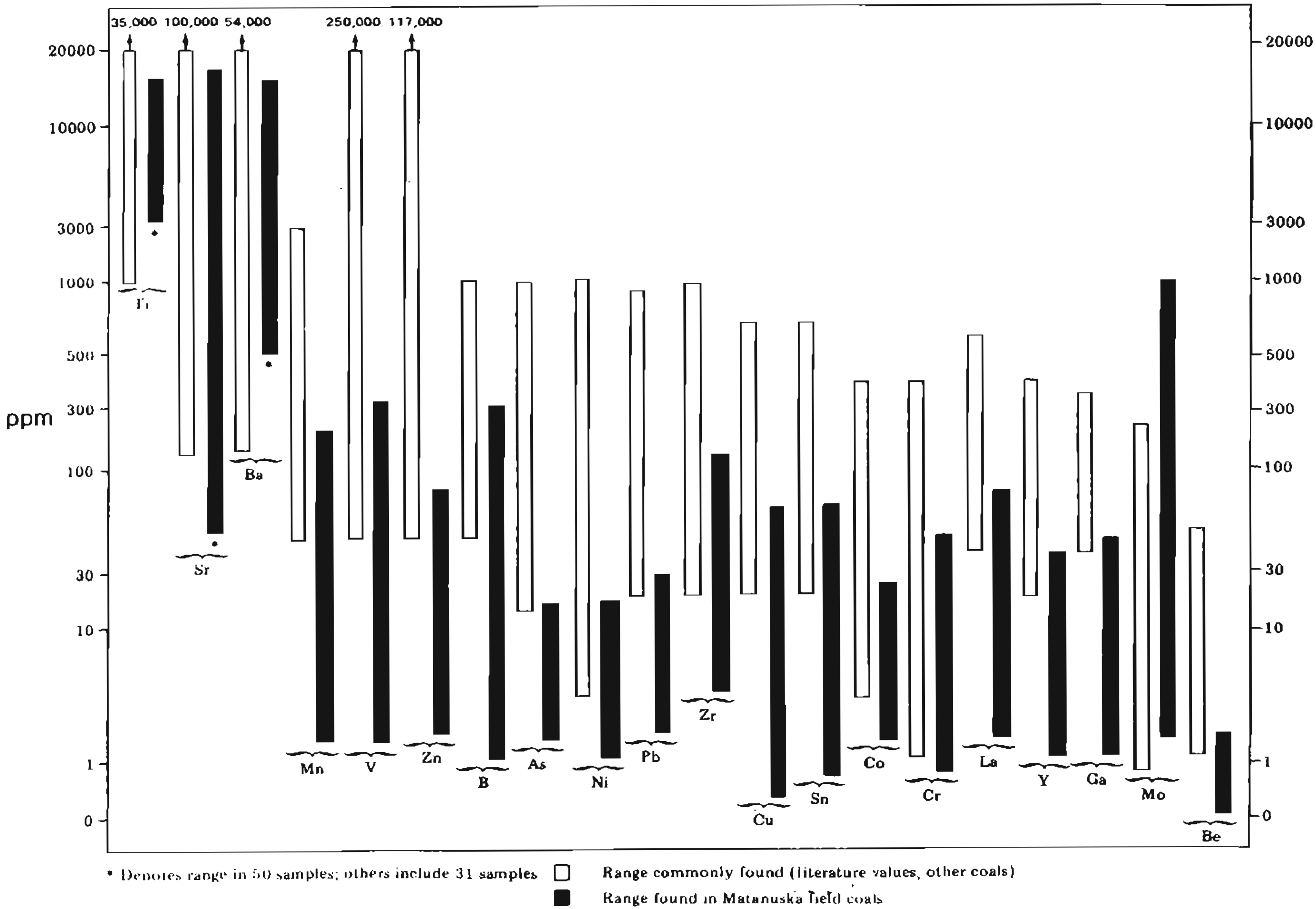
TEMPERATURE (F°)
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1650
1595
1535
1480
1425
1370
1315
1260
1205
1150
1095
°C
0
10
20
30
40
50
60
70
80
90
100
BASE (%)
T
B
(1)
T
D
(2)

Figure 24



SAMPLE % Si
A
RANK SAMPLE % S % Si
B
RANK SAMPLE % S
C
% ASH/% Fe SAMPLE
D
% Sr
A S P S K C T C
L I A I R
M F N C
N E I U
Z A S
N S R
A – C
Kev = 15
mA = 0.2
Secs. = 150
Scale = Full
Path = Vac.
Reduction = 2.5x
D
Kev = 45
mA = 0.075
Secs. = 50
Scale = Full
Path = Vac.
Reduction = 2.5x
Cursor Kev:
A&B = 3.68
C = 7.08
D = 13.36
CS = Carbonaceous shale

Figure 2


35,000
100,000
54,000
250,000
117,000
ppm
20000
10000
3000
1000
500
300
100
30
10
1
0
Ti
Sr
Ba
Mn
V
Zn
B
As
Ni
Pb
Zr
Cu
Sn
Co
Cr
La
Y
Ga
Mo
Be
* Denotes range in 50 samples; others include 31 samples
Range commonly found (literature values, other coals)
Range found in Matanuska field coals

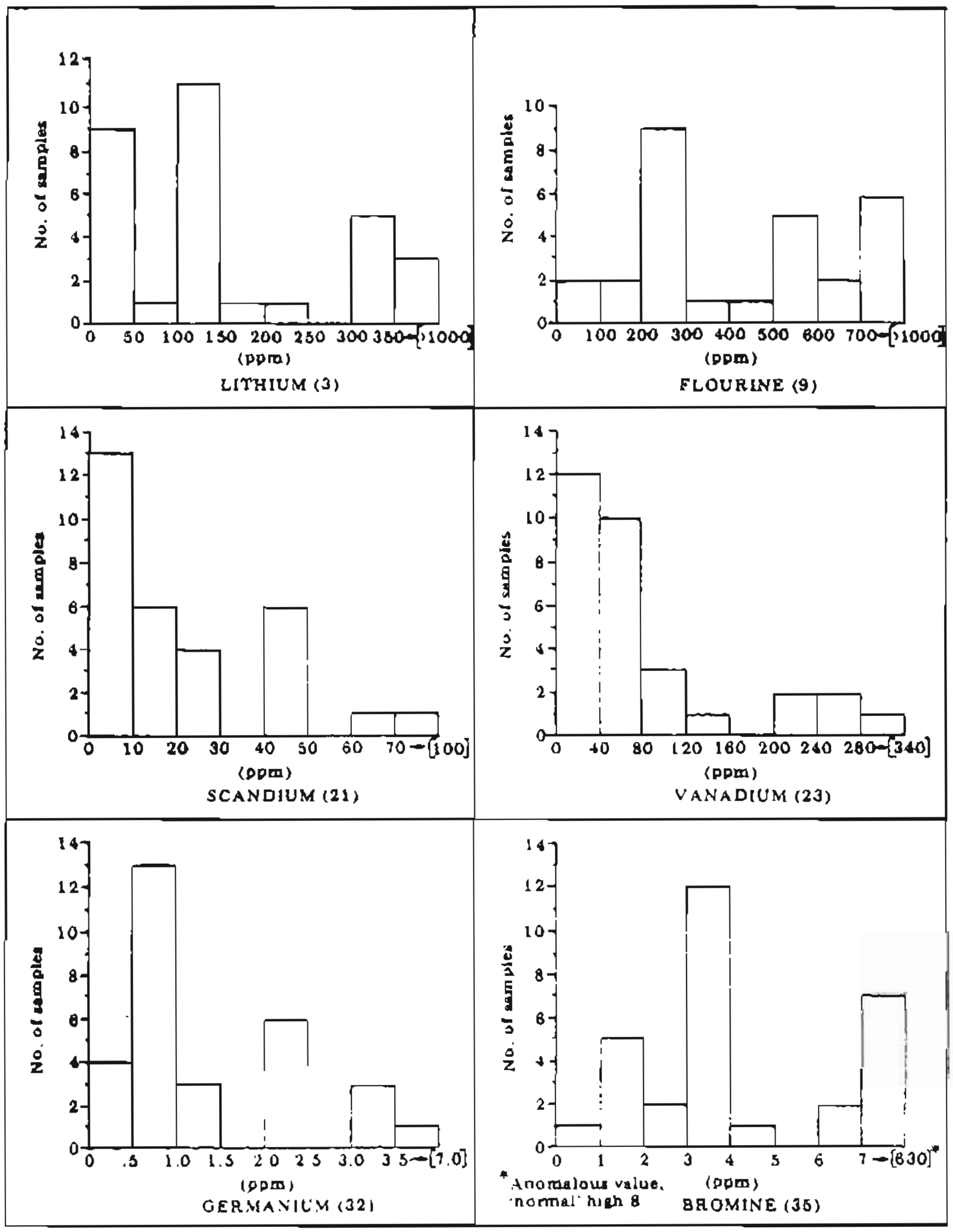

No. of samples
(ppm)
LITHIUM (3)
FLOURINE (9)
SCANDIUM (21)
VANADIUM (23)
GERMANIUM (32)
*Anomalous value, 'normal' high 8
BROMINE (35)

Figure 27

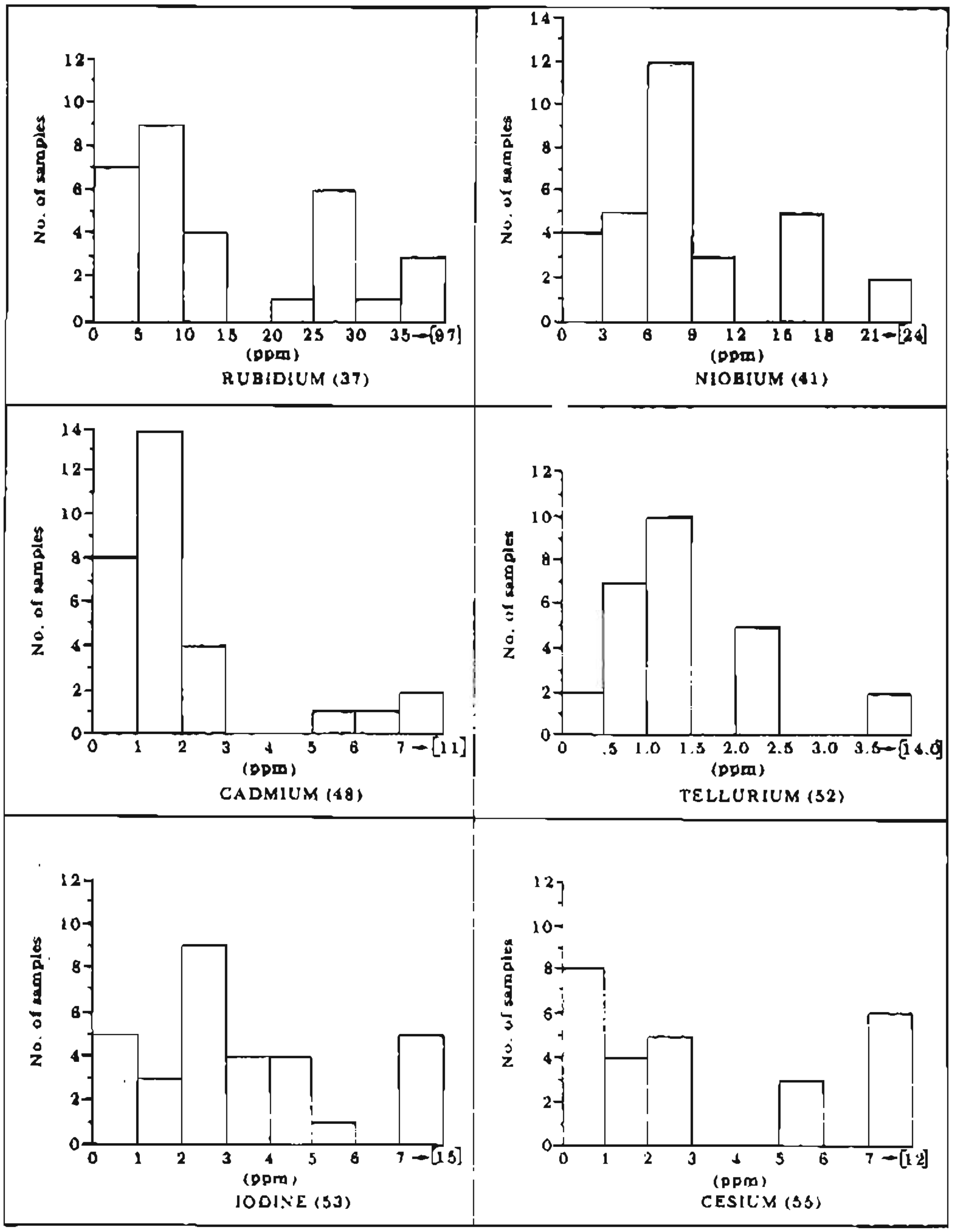

No. of samples
(ppm)
RUBIDIUM (37)
NIOBIUM (41)
CADMIUM (48)
TELLURIUM (52)
IODINE (53)
CESIUM (55)
[97]
[24]
[11]
[14.0]
[15]
[12]

Figure 28

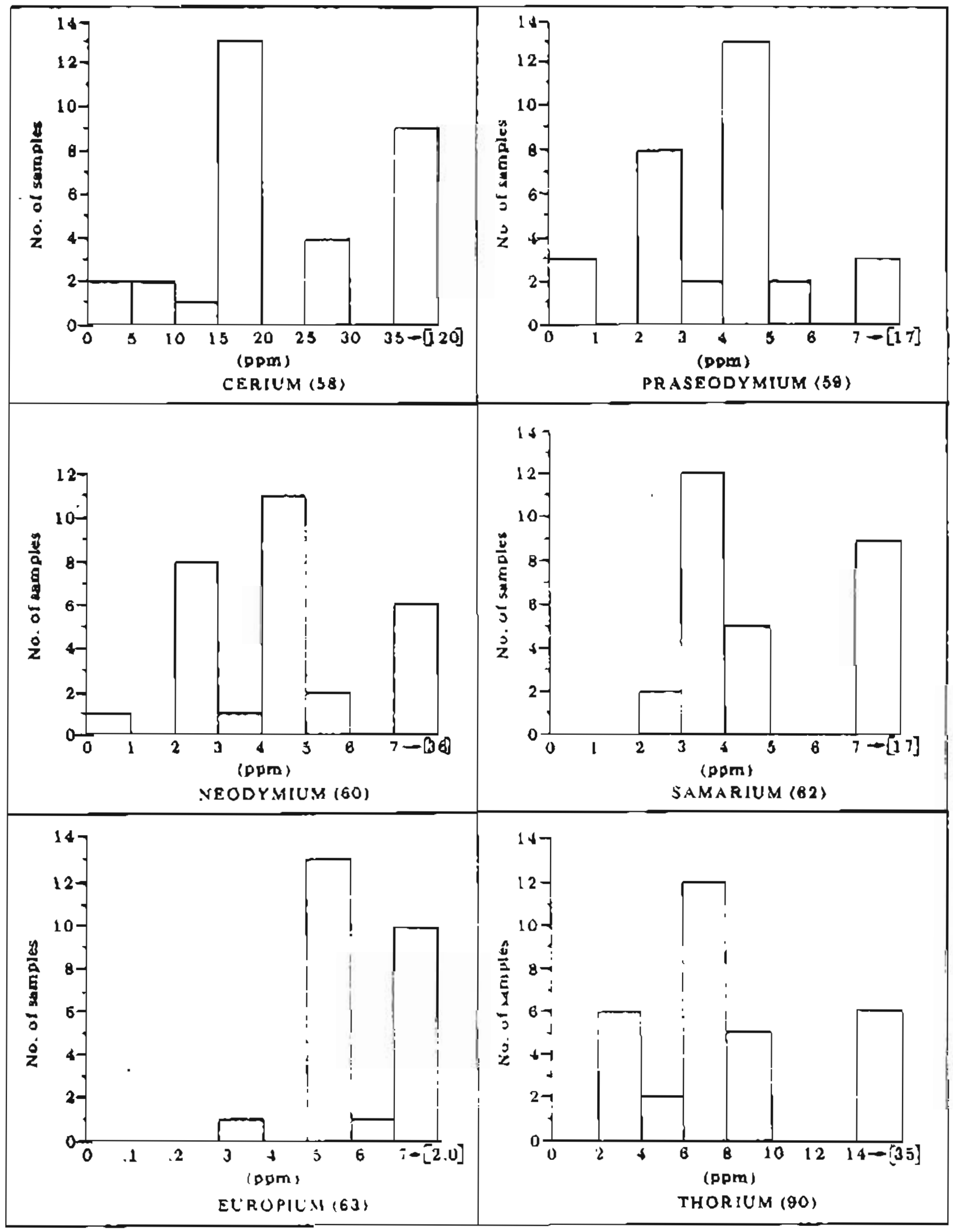
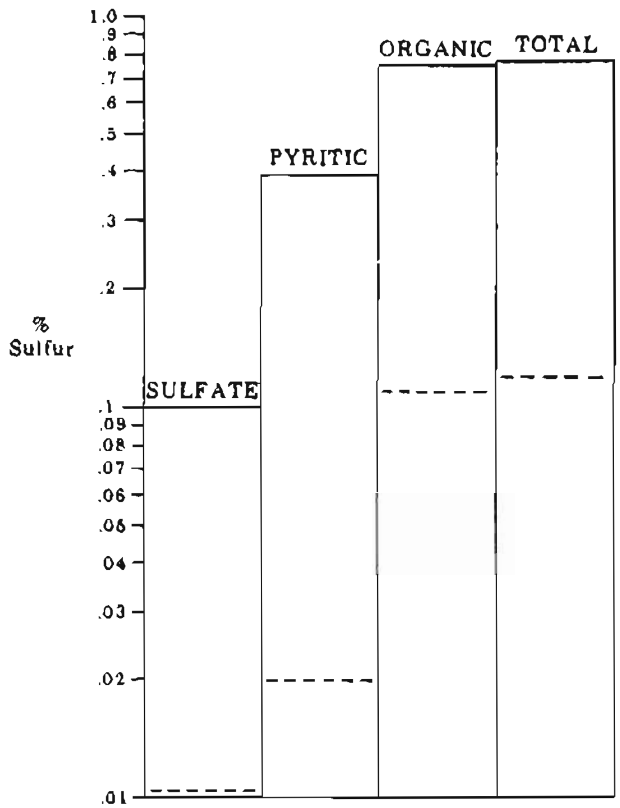
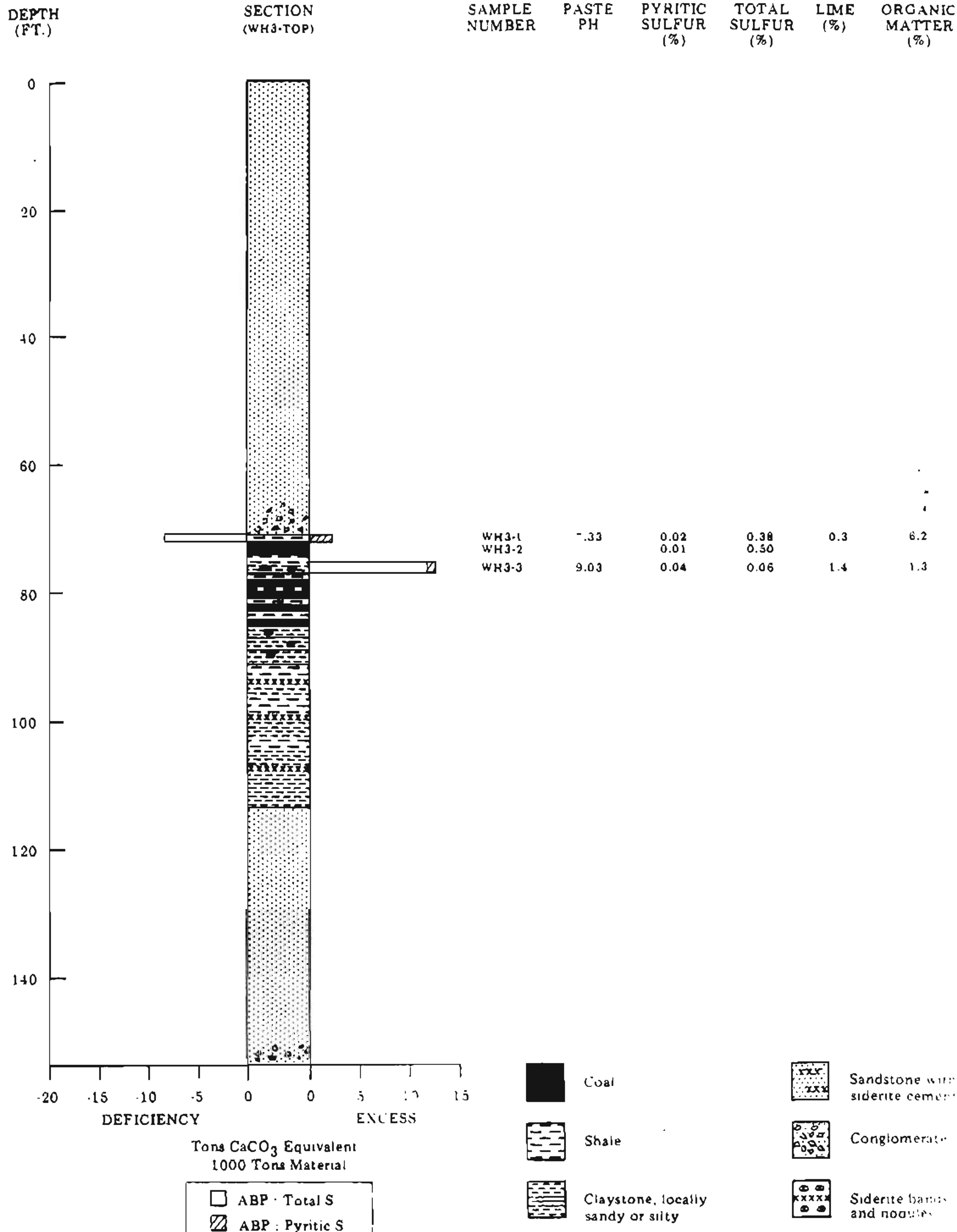

No. of samples
(ppm)
CERIUM (58)
PRASEODYMIUM (59)
NEODYMIUM (60)
SAMARIUM (62)
EUROPIUM (63)
THORIUM (90)

Figure 29



1.0
.9
.8
.7
.6
.5
.4
.3
.2
%
Sulfur
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
SULFATE
PYRITIC
ORGANIC
TOTAL

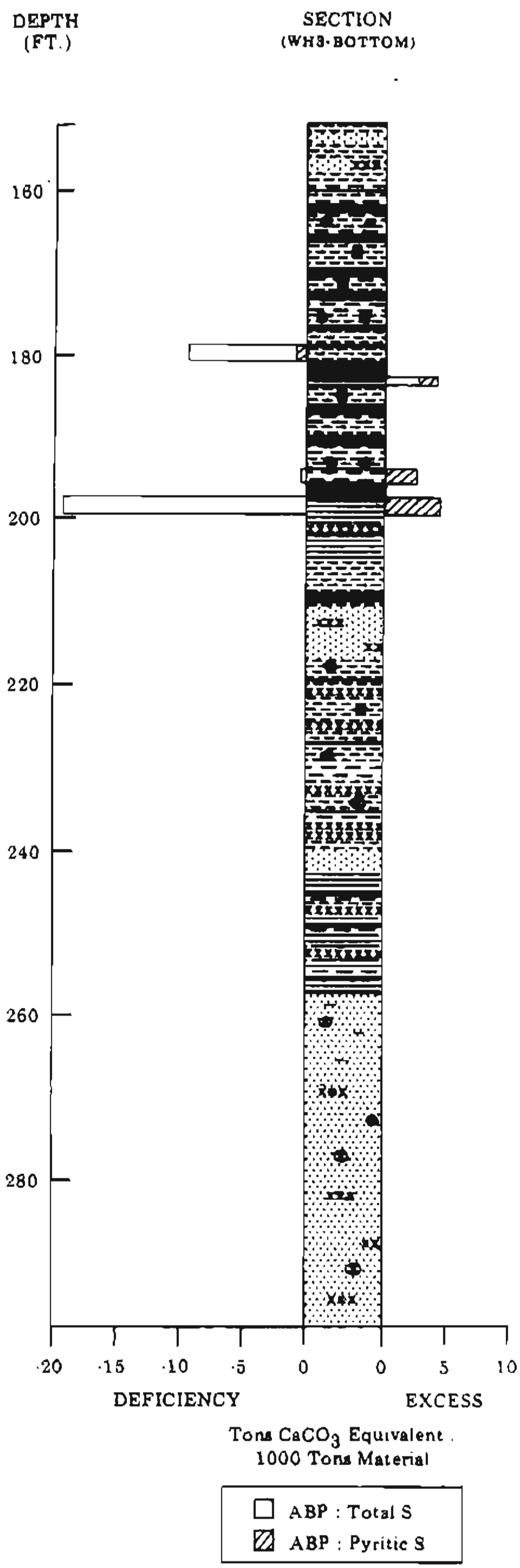
Figure 30



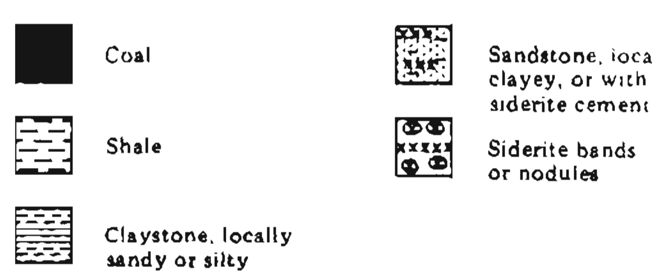
SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
WH3-1	7.33	0.02	0.38	0.3	6.2
WH3-2		0.01	0.50		
WH3-3	9.03	0.04	0.06	1.4	1.3

(A)

Figure 31



SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
WH3-4	8.11	0.03	0.13	<0.1	2.6
WH3-5		0.01	0.34		
WH3-6	8.38	<0.01	0.04	0.4	1.2
WH3-7	8.08	0.01	0.10	0.3	7.5
WH3-8		0.01	0.25		
WH3-9	8.66	0.02	0.78	0.5	3.7



(B)

Figure 31

Table 1. Stratigraphic sequence of rocks in the Wishbone Hill district. Modified from Barnes and Payne, 1956 and Alaska Geological Society, 1964.

Age	Formation	Character	Thickness (ft)
Quaternary		Alluvium, terrace gravels, and moraine deposits.	0-150+
	Unconformity Tsadaka formation	Coarse conglomerate, sandstone, siltstone.	700+
Tertiary	Unconformity Wishbone formation	Medium- to fine-grained conglomerate, sandstone, and minor claystone.	2,000
	Chickaloon formation	Interbedded claystone, siltstone, sandstone, and coal.	5,000+
Upper and Middle Cretaceous	Unconformity Matanuska formation	Shale and sandstone	4,000+
Middle(?) and Lower Cretaceous(?)	Arkose Ridge formation	Arkose, conglomerate, and shale.	2,000+

Table 2. Summary of chief lithologic characteristics and depositional environments of Tertiary and Cretaceous sedimentary rock formations of Matanuska Valley. Compiled from Clardy, 1978.

Formation	Age	Thickness	Lithology	Stratigraphic relationship	Depositional environment
Tsadaka Formation	Oligocene; time equivalent of lowest beds of Kenai Group	Over 150 m in Tsadaka Canyon	Crudely stratified, massive conglomerate; marginal conglomeratic facies of Kenai Group	Overlies Wishbone and Chickaloon formations with a distinct angular unconformity in lower Matanuska Valley	Sheet-flood debris deposited on alluvial fans
Wishbone Formation	Eocene	550-600 m	Well lithified conglomerates, sandstones, and siltstone	Overlies Chickaloon Formation unconformably in Matanuska Valley	Fluvial environment; alluvial fans and associated braided streams, perhaps meandering stream deposits in part
Chickaloon Formation	Paleocene	At least 1,500 m thick in Matanuska Valley	Well indurated claystones, siltstones, sandstones, conglomerates, coal	Conformable with overlying Wishbone Formation south of Willow Creek in southwestern Talkeetna Mountains	Fluvial braided to meandering stream environment in lower part, and fluvial meandering to paludal environment in upper part
Arkose Ridge Formation	Paleocene	Unknown	Coarse-grained clastics---arkosic conglomerates, minor shales	Nonconformably overlies plutonic rocks along south flank of Talkeetna Mountains and overlies Talkeetna Formation to northeast	Local source, fanglomerate deposit
Matanuska Formation	Early to late Cretaceous (Albian to Maestrichtian)	Over 1,200 m thick at type section in Matanuska Valley	Siltstones, sandstones, and cobble conglomerates	Underlies Tertiary rocks with local disconformity	Marine; sublittoral to outer bathyal or abyssal deposition by density currents or submarine slumps

Table 3. Summary of coal petrologic data for 38 bituminous coal samples from the Matanuska Valley.

Maceral	Range	Mean
Vitrinite	57-97	80
Pseudovitrinite	0.0-0.2	0.0
Gelinite	0.0-1.0	0.1
Phlobaphinite	0.0-0.2	0.0
Pseudophlobnphinite	0.0-3.6	0.3
Vitrodetrinite	2-42	15
Total vitrinite	89-100	96
Fusinite	0.0-1.8	0.2
Semifusinite	0.0-2.0	0.2
Sclerotinite	0.0-1.2	0.3
Macrinite	0.0-0.4	0.3
Inertodetrinite	0.0-3.2	0.3
Total inertinite	0.0-4.8	1.1
Cutinite	0.0-2.2	0.1
Sporinite	0.0-0.2	0.0
Resinite	0.0-4.4	0.9
Suberinite	0.0-5.8	0.7
Alginite	0.0-0.2	0.0
Liptodetrinite	0.0-7.2	1.6
Exsudatinite	0.0-0.3	0.1
Total liptinite	0.0-9.4	3.0

Table 4. Summary of coal petrologic data for 17 semi-anthracite and anthracite coal samples from the Matanuska Valley.

Maceral	Range	Mean
Vitrinite	52-98	82
Pseudovitrinite	0.0-7.8	0.7
Gelinite	0.0-0.0	0.0
Phlobaphinite	0.0-0.0	0.0
Pseudophlobaphinite	0.0-0.0	0.0
Vitrodetrinite	2-34	10
Total vitrinite	66-100	94
Fusinite	0.0-2.6	0.3
Semifusinite	0.0-1.6	0.1
Sclerotinite	0.0-1.4	0.3
Macrinite	0.0-1.0	0.1
Inertodetrinite	0.0-1.6	0.3
Total inertinite	0.0-4.2	1.2
Cutinite	0.0-0.0	0.0
Sporinite	0.0-0.0	0.0
Resinite	0.0-0.8	0.1
Suberinite	0.0-0.0	0.0
Alginite	0.0-0.0	0.0
Liptodetrinite	0.0-0.4	0.0
Total liptinite	0.0-1.2	0.1

Table 5. Petrology of Matanuska Valley subbituminous coals.

Maceral group/ maceral	Sample (volume %, mineral-matter-free basis)							
	CC1-4	EC1-1	MM1-4	MM1-6	RM1-2	WH3-2	WH3-5	WH3-8
Ulminite/vitrinite	68.2	80.0	76.8	78.7	78.2	75.6	76.0	79.4
Pseudovitrinite	0.0	0.0	0.0	0.7	0.0	0.0	0.1	0.0
Gelinite	0.0	0.5	1.0	0.5	0.4	2.2	0.0	2.2
Phlobaphinite	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0
Pseudophlobaphinite	0.0	0.2	0.0	0.0	0.4	0.2	0.0	0.0
Humodetrinite	25.2	10.8	13.6	13.2	9.8	11.4	15.9	12.2
Total huminite	93.4	91.5	91.4	93.3	89.0	89.6	92.0	93.8
Fusinite	0.2	0.0	0.6	0.4	0.0	0.4	0.2	0.0
Semifusinite	0.4	0.0	0.2	0.0	0.8	0.4	0.7	0.0
Sclerotinite	1.4	0.1	0.6	0.3	0.6	1.4	0.6	0.2
Macrinite	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.2
Inertodetrinite	2.0	0.5	2.0	1.6	0.8	1.4	1.6	0.4
Total inertinite	4.4	0.8	3.6	2.5	2.2	3.6	3.1	0.8
Cutinite	0.2	0.0	0.0	0.9	0.6	0.4	1.4	0.2
Sporinite	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.2
Resinite	1.2	5.2	4.2	0.7	5.4	4.6	1.0	3.2
Suberinite	0.0	0.0	0.0	0.4	0.2	0.0	0.1	0.2
Alginite	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Liptodetrinite	0.8	2.5	0.8	1.0	2.6	1.8	1.9	1.6
Total liptinite	2.2	7.7	5.0	4.2	8.8	6.8	4.9	5.4

Table 6. Average ash, sulfur content, and calorific value for coal samples from various mines in the Matanuska Valley. Compiled from various sources.

Mine	No. of samples	Ash % (as received)	Sulfur % (as received)	Btu/lb (as received)
Matanuska Center	3	15	0.5	11,200
Rawson	3	8	0.4	11,900
Buffalo	10	13	0.3	11,800
Baxter	4	7	0.3	12,600
Premier	10	8	0.4	12,600
Doherty	2	20	0.5	10,600
Evan Jones	15	18	0.4	11,000
Knob Creek	2	9	0.4	10,200
Eska	36	14	0.4	11,700
Chickaloon	2	8	0.6	13,900
Coal Creek	1	10	0.4	13,600

Table 7. Comparison of Matanuska Valley, Bering River, and Pennsylvania anthracites.

	Matanuska coal field, Alaska[1]	Bering River coal field, Alaska[2]	Pennsylvania[3]
Moisture	6.3	7.3	3.7
Volatile matter	7.6	6.4	5.4
Fixed carbon	74.7	77.0	80.7
Ash	11.4	9.2	10.2
Sulfur	0.5	1.2	0.7
Btu	12,070	12,350	12,980
Fuel ratio	10.1	12.2	15.0

[1]Mean of 11 samples analyzed during this study.
[2]U.S. Bureau of Mines, 1946, p. 62-67; mean of 10 samples.
[3]Average of three samples from Slatjck, 1980; Cady, 1978; and Babcock and Wilcox, 1972.

Table 8. Summary of proximate and ultimate analysis data for Matanuska Valley coal samples.

Statistic	Basis*	Moisture	Volatile matter	Fixed carbon	Ash	Heating value	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
Range	1	3-15	6-34	27-87	2-47	6,300-14,300	2.4-5.6	40-76	0.9-1.7	7-21	0.3-0.7
	2	- -	6-37	29-90	2-49	6,600-14,800	1.9-5.3	42-79	1.0-1.9	3-13	0.3-0.7
	3	- -	8-47	53-92	- -	13,000-15,700	3.0-6.3	76-91	1.6-2.3	3-15	0.5-0.9
Mean	1	6	18	56	20	10,700	4.1	59	1.3	11	0.5
	2	- -	20	60	21	11,700	3.7	63	1.4	7	0.5
	3	- -	25	75	- -	14,300	4.9	83	1.9	9	0.7

*1 - As received; 2 - Moisture-free; 3 - Moisture and ash free.

Table 9. Typical limits of major-oxide ash composition of Matanuska Valley coals compared to other coals. Ranges in other coals from McClung and Geer, 1979.

Constituent	Matanuska Valley	United States	England	West Germany
Acidic oxides:				
Silica (SiO_2)	23-63	20-60	25-50	25-45
Alumina (Al_2O_3)	25-38	10-35	20-40	15-21
Titania (TiO_2)	0.9-2.3	0.5-2.5	0-3	- -
Basic oxides:				
Ferric oxide (Fe_2O_3)	1-17	5-35	0-30	20-45
Calcium oxide (CaO)	0.3-19	1-20	1-10	2-4
Magnesia (MgO)	0.4-2.6	0.3-4	0.5-5	0.5-1
Alkalies (Na_2O+K_2O)	0.5-3.5	1-4	1-6	- -
Other oxides:				
Sulfur trioxide (SO_3)	0.1-4.4	0.1-12	1-12	4-10
Phosphorous pentaoxide (P_2O_5)	0.02-8.0	0.7-5.5	0-3	- -

Table 10. Mean composition of major oxides in all Matanuska Valley raw-coal-ash samples, composition by rank and relationship with rank (weight percent, ignited basis).

Oxide	Mean weight % all ranks	Mean weight % subbituminous	Mean weight % bituminous	Mean weight % anthracite	Relationship with rank
SiO_2	50.46	57	51	43	Decreases
Al_2O_3	29.90	29	30	29.5	Constant
Fe_2O_3	4.50	3.04	4.41	5.88	Increases
CaO	4.10	2.12	3.80	6.51	Increases
P_2O_5	3.75	0.76	2.80	3.20	Increases
K_2O	1.53	1.85	1.53	1.26	Decreases
MgO	1.50	1.17	1.28	2.40	Increases
TiO_2	1.48	1.57	1.43	1.58	Constant
SO_3	1.21	0.97	1.01	1.97	Increases
Na_2O	0.74	0.66	0.58	1.29	Unclear
BaO	0.35	0.17	0.32	0.58	Increases
SrO	0.30	0.16	0.29	0.42	Increases
Mn_3O_4	0.03	0.021	0.032	0.038	Increases
Undetermined	1.34	1.47	1.06	2.08	Unclear

Table 11. Ash fusion temperatures (°F) for representative coals compared to Matanuska Valley coals.

	Pittsburgh W.V.	Illinois No. 6	Wyoming subbituminous[1]	Texas lignite[1]	Matanuska Valley subbituminous(1)	Matanuska Valley bituminous(2)	Matanuska Valley anthracite(3)
Initial deformation:	2030	2000	1990	1975	2490	2280	2340
Softening:	2175	2160	2180	2130	2510	2315	2380
Hemispherical:	2225	2180	2250	2150	2530	2390	2440
Fluid:	2370	2320	2290	2240	2555	2500	2490

[1]Source: Babcock & Wilcox Company, 1972.
( ) = no. of samples. Total Matanuska Valley samples = 6.

Table 12. Comparison of arithmetic mean, minimum, and maximum values for certain trace-element contents in Matanuska Valley coals with Illinois basin, eastern United States, and western United States coals [in ppm; 1=arithmetic mean; 2=minimum value; 3=maximum value; and 4=number of samples].

Element	Illinois Basin*				Appalachian coal fields*				Western United States*				Matanuska Valley			
	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)	1	2	3	(4)
Fluorine (F)	67	29	140	(113)	89	50	150	(23)	62	19	140	(29)	374	51	710	(24)
Scandium (Sc)	2.7	1.2	7.7	(56)	5.1	1.6	9.3	(14)	1.8	0.50	4.5	(22)	23	0.5	100	(31)
Vanadium (V)	32	11	90	(113)	18	14	73	(23)	14	4.8	43	(29)	80	7	340	(31)
Germanium (Ge)	6.9	1.0	41	(113)	1.6	0.10	6.0	(23)	0.91	0.10	3.0	(29)	1.4	0.3	7	(29)
Bromine (Br)	15	0.6	52	(113)	12	0.71	26	(23)	4.7	0.50	25	(29)	27	0.7	630	(30)
Rubidium (Rb)	19	2.0	46	(56)	22	9.0	63	(14)	4.6	0.30	29	(22)	19	1	97	(31)
Cadmium (Cd)	2.2	0.1	65	(93)	0.24	0.10	0.60	(23)	0.18	0.10	0.60	(29)	1.9	0.4	11	(29)
Iodine (I)	1.7	0.24	14	(56)	1.7	0.33	4.9	(14)	0.52	0.20	1.0	(22)	3.7	0.4	15	(30)
Cesium (Cs)	1.4	0.5	3.6	(56)	2.0	0.40	6.2	(14)	0.42	0.02	3.8	(22)	4.0	0.2	12	(25)
Cerium (Ce)	14	4.4	46	(56)	25	11	42	(14)	11	2.8	30	(22)	29	2	120	(31)
Samarium (Sm)	1.2	0.4	3.8	(56)	2.6	0.87	4.3	(14)	0.61	0.22	1.4	(21)	4.8	2	17	(28)
Europium (Eu)	0.26	0.1	0.87	(56)	0.52	0.16	0.92	(14)	0.20	0.07	0.80	(22)	0.70	0.3	2	(24)
Thorium (Th)	2.1	0.73	5.3	(56)	4.5	1.8	9.0	(14)	2.3	0.62	5.7	(22)	8.8	3	35	(26)

*From Gluskoter and others, 1977.

Table 13. Estimates of potentially minable coal resources of the Matanuska coal field (in millions of short tons to projected depth of 150 m and in beds over 0.75-m thick; from Merritt and Belowich, 1984).

Field	High assurance	Moderate assurance	Low assurance
Eska-Moose	32.5	45	60
Young Creek	2.5	5	8
Castle Mountain	6.5	10	25
Chickaloon	20.5	30	40
Anthracite Ridge	4.5	10	20
Other (scattered)	14.5	20	30
Total	81	120	183

Table 14. Coal groups (series) of the Chickaloon Formation, Wishbone Hill district. Adapted from Alaska Geological Society, 1964; Conwell and others, 1982.

Group name	Thickness	Equivalent named or numbered beds
Jonesville Coal Group	120 ft, Evan Jones Mine	Beds 1 through 4, Evan Jones Mine (exposed but unnamed on Moose Creek at the Premier Mine, found in drill holes on the south limb and near the axis of the Wishbone Hill syncline) 2-5 ft thick. To west at Moose Creek, group contains much bony coal of lower quality.
Interval	170-220 ft, north side of Wishbone Hill.	
Premier Coal Group	90-100 ft, Moose Creek. 100 to 260 ft, eastern part of district. (The thickness of the group increases rather abruptly from west to east along the north side of Wishbone Hill. This is thought to be the result of differential compaction of the strata which separate the coal beds of the group), one-third of total thickness is coal.	Beds 7, 7A, 7B, and 8, Evan Jones Mine. Chapin, Maitland, David, and Emery beds in the Eska Mine.
Interval	75 ft (average).	
Midway Coal bed	7.5 to 12 ft on Moose Creek including various thicknesses of bone and claystone. Consists of two or three 1½ to 2½ ft benches of coal separated by 2 to 2½ ft of coaly claystone in eastern part of district.	Bed 9, Evan Jones Mine.

Table 14 (Con.)

Group name	Thickness	Equivalent named or numbered beds
Interval	100 ft, Moose Creek, 70-200 ft eastern part of district.	
Eska Coal Group	60-75 ft, Eska Mine.	Bed 10 and adjacent beds, Evan Jones Mine. Eska, Shaw and Martin beds, Eska Mine. These coal beds vary considerably in thickness across Wishbone Hill. The Martin bed consists of one to three benches, each with 1 to 3.5 ft of clean coal. The Shaw bed occurs in two benches 2 to 3.5 ft thick separated by coaly claystone and claystone. In central Wishbone Hill area, the Shaw bed pinches out and grades into coaly claystone. The Eska bed has layers of 0.8 to 5.8 ft thick clean coal with bony coal and claystone partings and interbeds.
Interval	200 ft, Moose Creek.	
Burning Bed Coal Group	125 ft on Moose Creek, 35 ft in eastern part of district (group appears to pinch cut in center of Wishbone Hill, thickest on northeast and southeast ends. Two to eight individual coal beds (none greater than 3 ft thick) are separated by partings and thin beds of bony coal and claystone.	

Table 15. Summary geochemical and physical characteristics of analyzed coal overburden samples from the Matanuska Valley.

Overburden parameter	Range	Mean	Units
Paste pH	4.7-9.0	7.3	pH
Electrical conductivity	0.1-2.2	0.6	umho/cm
Saturation percentage	20-56	36.3	%
Water soluble cations			
Calcium	0.3-9.9	1.1	meq/liter
Magnesium	0.1-7.0	1.7	
Sodium	0.4-24.0	3.5	
Potassium (saturated paste)	1.4-17.2	7.4	mg/l
Sodium adsorption ratio	0.2-36.9	5.8	ratio
Exchangeable sodium percentage	1.0-55.7	12.2	%
Particle size			
Sand	9-85	59.2	%
Silt	9-53	18.8	
Clay	5-49	22.0	
Texture	C, CL, L, LS, SL, SCL, SiCl	- -	- -
Organic matter	0.9-32.0	5.1	%
Extractable nutrients			
Nitrate nitrogen (NO_3-N)	0.5-5.0	2.3	ppm
Phosphorous	<1.0-10.4	<1.6	
Potassium	39-252	128	
Pyritic sulfur	<0.01-0.4	<0.02	%
SO_4 sulfur	<0.01-0.1	<0.01	%
Organic sulfur	<0.01-0.76	0.11	%
Total sulfur	<0.01-0.78	0.12	%
Lime	<0.01-1.5	0.6	%
Acid potential (total sulfur)	-19.4-12.4	1.9	Tons $CaCO_3$ equivalent 1,000 tons
Acid potential (pyritic sulfur)	-0.9-14.4	5.4	do.
Trace elements			
Boron	1.50-5.30	3.05	ppm
Copper	0.24-18.88	3.53	
Molybdenum	<0.10-1.45	<.16	
Lead	0.14-7.04	1.12	
Selenium	<0.01	<0.01	