K-ELK RIVER 68(1)A

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REPORT OF
GEOLOGICAL EXPLORATION
of the
ELK RIVER COAL FIELD
SOUTHEASTERN BRITISH COLUMBIA
1 9 6 8

By

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DEGREES
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This report describes a coal deposit included within the Upper Elk River coal field of southeastern British Columbia, Canada. The description includes regional and local geology, geological exploration done in 1968, coal reserves above approximate water level and, finally, outlines recommendations for future exploratory work.

Stratigraphically, the coal field is in the Kootenay formation of Juro-Cretaceous age. There are at least fourteen minable coal seams ten feet or more in thickness together with a number of lesser seams and splits of major seams. In the local section, which probably exceeds 2100 feet in thickness, the coal seams are primarily medium-volatile bituminous in rank with variable ash contents ranging from "low" to "very high". Practically all show coking characteristics.

The base of the coal measures is defined by a persistent massive sandstone believed to be the reworked beach sands of the retreating Logan Sea in late Portlandian time. Erosional detritus from positive areas to the west were being introduced progressively eastward causing subsidence and differential sedimentation within the Kootenay as it was being emplaced. This sedimentary encroachment and subsidence caused a high degree of variability of dip of bedding, turbidity current deposition, and differential compaction which, in turn, resulted in (among others) scour-and-fill, cross-bedding, lenticularity, distorted bedding, variability of ash content of coal seams, and more or less, affected other coal characteristics.

The coal measures were eventually overlain by a very hard, resistant bed of Elk or lower Blairmore conglomerate which is evidenced by occasional float seen throughout the area. This conglomerate would not be encountered <u>in situ</u> within the deposit so would not become a mining problem.

Structurally, the coal deposit occurs in the Front Ranges sub-province about six miles west of the Lewis thrust. The main body of the coal deposit occurs in two segments of a ridge (Weary Ridge) which is a portion of the east limb of the relatively large Alexander Creek syncline. The deposit has been carried forward several miles as a portion of the Lewis thrust sheet and has also been overridden by the Elk River thrust.

The Kootenay beds (including the coal seams) dip westerly from thirty-five degrees to vertical. The average dip throughout most of the deposit approximates thirty-eight degrees westerly. Topographic slopes downdip generally range from ten to thirty degrees.

One or two large slides and many smaller ones occur within the field. Many of the beds below the large slides have been overridden by other beds, either updip or downdip, by thrusting and/or sliding. Such action has warped the previously distorted bedding and has brought different coal beds into juxtaposition in places thus adding to the difficulties of correlation. Thick alluvial and talus gravels cover large portions of the area and greatly hampered all forms of exploratory work.

The 1968 exploration program began with a two-week photogeologic reconnaissance in the field during June. This was followed by intensive exploratory trenching, drilling and coring, underground bulk-sampling, and surveying ranging from late July through mid-October (excepting for a long-holing project which continued beyond November first). A total of $300,000 was allotted toward this exploratory program for 1968 and a supplemental sum of $50,000 was added in January 1969 to meet continuing expenses. Aerial photographs were an invaluable aid throughout the period. They were used for laying out roads and other engineering features as well as for locating sites for exploratory cuts and for drilling. New photographs were flown regularly for keeping progress records of work done and for adding to the geology as it was developed. Helicopter services were used on occasion. The entire mode of operation is described in great detail in the body of the report.

Results of the intensive exploration program indicates that total reserves of coal-in-place within the study area above the upper river level of 5200 feet are 148 million tons. The overall average overburden to coal ratio is 9.1 cubic yards per ton of coal with ratios for individual "reserve blocks" ranging from 2.6 to 12.8.

Specific recommendations are made for additional exploratory drilling and bulk sampling to be done before actual operative mine planning is begun.

G E O L O G Y

Preamble

The coal deposit included within the study area described in this report is a part of the Elk River coal field. It is a continuation or extension of the structural trough which produced the Crowsnest coal field and which has been producing coking coal for many years. The southern part of the area is bounded by Aldridge Creek, a westerly-flowing tributary of Elk River, the affluent point of which is forty-eight miles north of Sparwood Junction, British Columbia (the nearest railhead). The northern end is within two and one-half miles north of Weary Creek, another westerly-flowing tributary.

In this area the topographic differential is about two thousand feet. Here Elk River ranges between 5,000 and 5,200 feet in elevation above sea level. The top of Weary Ridge is about 7,200 feet. The maximum elevation of the "Little Weary Ridge" coal measures is 6,300 feet. Both Weary and Little Weary Ridges are quite steep on their easterly sides, ranging in places on Weary Ridge up to forty-five degrees and on Little Weary Ridge to about forty degrees. The westerly slopes in only limited spots exceed thirty degrees and generally range downward from twenty degrees.

Both ridges are timber-covered excepting for the steeper, rockier slopes where, in general, only alder and other brush has been capable of establishing itself. Almost all tree-growth has developed since 1936 when a severe forest fire ravaged nearly the entire Elk Valley. Most new evergreen growth is less than thirty feet high and of small diameter, consisting mainly of unmerchantable "jack" pine. A few small spruce have started to become established within recent years. Large diameter deadfall covers the ground rather thickly in a few local areas.

The climate of the general area is described by the Fernie Chamber of Commerce as "a rare stimulating mountain climate with cool nights for refreshing sleep." Frost normally comes every month of the year. Snow showers can occur in the higher elevations also during the midsummer months.

Records of precipitation in the study area are not available; however, such records obtained from Fernie (elevation 3305) and Elko (elevation 3080), the nearest reporting weather stations, indicate that average total precipitation is 41.68 and 19.63 inches respectively. Winter snowfall averages 145.0 and 55.2 inches respectively. In 1965-66 snowfall at Elko exceeded 7 feet and that at Fernie 16 feet. At the elevation of the study area 16 to 20 feet of snow may cover the ground before the season ends. The highest and lowest temperatures ever recorded at these two stations is 97 and minus 40 degrees at Fernie, and 102 and minus 27 degrees at Elko.

The coal lands held in the study area provide a compact mining property, already serviced by electric power and roads, where coal transportation facilities can be built at relatively low cost per mile. These lands all lie within a three-mile radius of a point in Lot 6387. The broad Elk River valley, which is from three-fourths to one mile wide, contains numerous large, flat, well-drained, gravel-filled sites that are considered particularly suitable for most mine-plant applications including townsites, campsites, airstrips, washery and treatment plants, tailings and settling ponds and loading and transportation facilities. The sites may be adjacent to the river on both the east and west sides, but more particularly on the east. River water for domestic or other use is clean and would require but little treatment.

The Kan-Elk power line (130 kv) and service road follows the valley edge on the east side of the Elk River along the base of the minable coal measures across seven lots (seven miles). In addition, numerous access and seismic trails have been completed up Weary and Little Weary Ridges and along Aldridge and Weary Creeks. The main service road from Natal is composed of gravel and is but little affected by wet weather. A new forest road along the west side of the river is presently under construction with completion expected within another year or two.

There is a gradual ascent from the Canadian Pacific Railway junction at Natal (elevation 3400 feet) to the lower part of the property near Aldridge Creek (elevation 5200 feet) about forty-eight miles upriver. The average grade is roughly seven-tenths of one percent. A railroad branch, which has previously been surveyed, could be built at a relatively low per-mile cost with a grade favorable to the load. It would generally be less than one percent and should never exceed one and one-half percent.

General Geology

Stratigraphy

The general stratigraphy of the area is provided in the Table of Formations (Table 1) included herein for convenience. The coal-bearing unit of the Upper Elk River coal fields is the Kootenay formation, considered to be Juro-Cretaceous in age. Pocock (1964) concluded from pore and pollen examinations that the Kootenay at its type section is entirely Jurassic in age; however, he reported that Cretaceous beds are included within it in other areas. Because of the tectonic history of the region, the Kootenay formation in southeastern British Columbia and in adjacent parts of Alberta, Canada, occurs today as a number of disconnected patches.

According to Price (1962), "The Kootenay Formation comprises grey and black carbonaceous sandstones, siltstones, mudstones, and shales with interbeds of coal and quartz-chert pebble conglomerate and conglomeratic sandstone." Its maximum measured thicknesses in the Fernie basin is 3,530 feet on Coal Creek

TABLE OF FORMATIONS*

MODIFIED AFTER DOUGLAS (1950) CRABB (1957) AND PRICE (1958)

AGE	FORMATION	PRINCIPAL LITHOLOGY	THICKNESS
UPPER CRETACEOUS	BELLY RIVER	NON-MARINE SANDSTONE & SHALE	3000 - 4200
	WAPIABI	MARINE GREY SHALE	1000 - 1600
	CARDIUM	MARINE SANDSTONE	30 - 300
	BLACKSTONE	MARINE GREY SHALE & SILTSTONE	450 - 1000
UPPER CRETACEOUS	CROWSNEST	VOLCANIC AGGLOMERATE & TUFF	0 - 1000
LOWER CRETACEOUS	BLAIRMORE	NON-MARINE SANDSTONE, SHALE & CONGLOMERATE	1000 - 2200
	DISCONFORMITY		
LOWER CRETACEOUS -JURASSIC	KOOTENAY	NON-MARINE SANDSTONE, SHALE & COAL	600 - 2400
JURASSIC	FERNIE	MARINE BLACK SHALE	480 - 1500
	DISCONFORMITY		
TRIASSIC	SPRAY RIVER	MARINE LAMINATED SILTSTONE	0 - 1800
PERMO-PENN	ROCKY MOUNTAIN	ORTHOQUARTZITE & ARENACEOUS DOLOMITE	100 - 1000
MISSISSIPPIAN	RUNDLE GROUP		2000
	ETHERINGTON	SILTY DOLOMITE	
	MOUNT HEAD	THIN BEDDED LIMESTONE	
	LIVINGSTONE	MASSIVE CRINOIDAL LIMESTONE	
	BANFF	DARK, ARGILLACEOUS CHERTY LIMESTONE	800
MISSISSIPPIAN ?	EXSHAW	BLACK, FISSILE SHALE	20 - 250
	DISCONFORMITY		
DEVONIAN	PALLISER	CLIFF-FORMING MOTTLED LIMESTONE	900 - 1000
	FAIRHOLME	DARK GREY LIMESTONE, REEFOID DOLOMITE	1600
	DISCONFORMITY		
CAMBRIAN	DOLOMITE UNIT	LIGHT GREY DOLOMITE	280 - 350
	SHALE UNIT	GREEN SHALE & LIMESTONE	215
	QUARTZITE UNIT	LIGHT YELLOWISH GREY QUARTZITE	140
	DISCONFORMITY		
PRECAMBRIAN	KINTLA	RED & GREEN ARGILLITE & QUARTZITE	600 - 1600
	SHEPPARD	DOLOMITE, QUARTZITE, SILTSTONE	150
	PURCELL LAVA	AMYGDALOIDAL ANDESITE	320
	SIYEH	GREY DOLOMITE	1150
	GRINNELL	RED ARGILLITE	350
	APPEKUNNY	GREEN ARGILLITE	1700
	ALTYN	GREY ARGILLACEOUS LIMESTONE	1500
	WATERTON	BANDED LIMESTONE & DOLOMITE	300+

Table 1

*After Dahlstrom, et al. ,1962

near the town of Fernie (Price, 1962) and 3,600 feet near Michel (MacKay, 1934). Price earlier (1962) reported 4,000 feet of Kootenay at an unspecified location elsewhere in the basin, however. Apparently its thickest recorded section is some distance northward at Mount Minnes where 6,150 feet of strata was described as possibly correlative with the Kootenay (Ziegler and Pocock, 1960).

A fourfold division of the Kootenay formation was proposed by Norris (1959) at its type section on Grassy Mountain in Alberta where it is 413 feet thick. Named in the ascending order these members include the Moose Mountain, Adanac, Hillcrest and Mutz. No attempt has been made to identify the members present in the area of this study; however, it is presumed that the basal Kootenay sandstone may be equivalent to the Moose Mountain member. Pocock (1964) points out that lithologic evidence indicates the type section members are probably of local significance only.

In the study area the Kootenay, Elk, Blairmore and Crowsnest rocks represent all that remain of the nonmarine deposition between the retreat of the Logan Sea in the late Portlandian and the advance of the Blackstone Sea in the Cenomanian. (See Correlation of Lowe Cretaceous Formations, Table 2). These rocks, in order, contain deposits of littoral marine, lowland, inland flood-plain and volcanic origin.

Norris (1964) states that

> "Through the Late Jurassic and Early Cretaceous continental conditions advanced eastward, encroaching on the Logan Sea through the introduction of erosional detritus from positive areas to the west. The local basement gradually subsided in response to the load so that differential sedimentation took place during the progressive eastward advancement of the strand from Fernie area to the western Alberta Plains. The off-shore bottom of the Logan Sea was receiving considerably less sediment than the aggradational areas of the flood-plains and lowlands to the west.

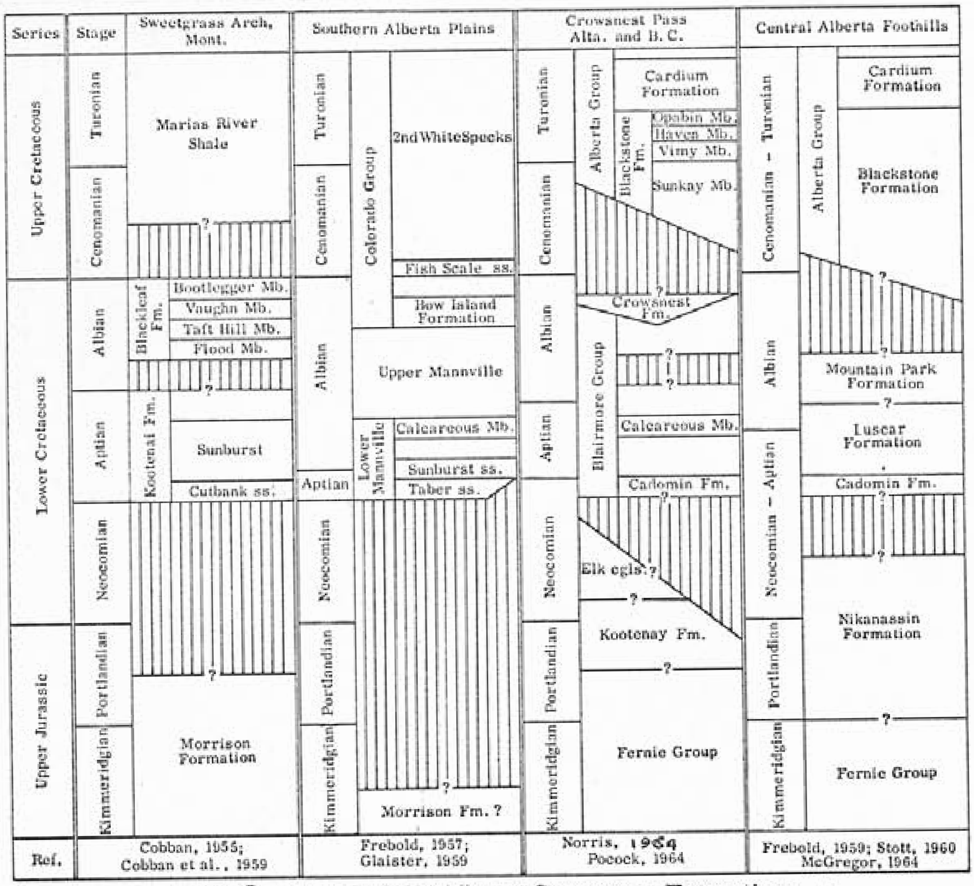


Table 2—Correlation of Lowe Cretaceous Formations. *

* After Norris, 1964

> "The basal sandstone (Moose Mountain Member) of the Kootenay Formation is a marine sandstone of retrogression . . . (and) . . . the commonly sharp upper contact of the Moose Mountain Member is indicative of subaerial gradation planes developed across beach and littoral bottom planes as the sand from adjacent land areas was swept into the sea and reworked by the waves and offshore currents."

"The Passage Beds", i.e., the Fernie group beds immediately below the Kootenay sandstone, represent the horizon of the sand-mud transition in the offshore zone which migrated seaward at essentially constant level as the sand beaches were built into the sea.

Norris believes that the westward and vertical progression from shale to sandstone to coal to coarse clastics from any point near the top of the Fernie group suggests that the nonmarine succession was one and the same succession of retrogression. He points out that coal is almost invariably found resting on or lying within a few feet of the top of the Moose Mountain member.

The introduction of coarse clastics with chert and quartzite pebble-conglomerates in the Kootenay, Elk and lower Blairmore probably results from a differential uplift still farther west in Neocomian and Aptian time. Paleozoic and Precambrian sedimentary and low-rank metamorphic rocks west of the Rocky Mountain Trench near the present Purcell and Selkirk Mountains may have been the source of supply.

Norris is of the opinion that the disconformity at the base of the Cadomin and Dalhousie in the foothills and mountains of southwestern Alberta is indicative of a regional pause in the subsidence of the margin of the sedimentary basin in conjunction with the uplift farther west. Chert and quartzite pebbles derived from the Elk member and from the source area were then spread eastward over the Kootenay. The eastward termination of the Elk and thinning of the Kootenay was likely caused by erosional truncation and differential sedimentation.

In the immediate study area there are at least fourteen minable coal seams in the Kootenay formation. A number of lesser seams and splits of major seams occur throughout the local section which, according to Dowling (1915), is ". . . upwards of 1800 feet" in thickness. Our measurements indicate that the local section probably exceeds 2100 feet. There appears to be little difference in the rank of the coals from the base of the section to the stratigraphically higher beds in the study area. Most of the seams fall into the category of medium volatile bituminous and practically all show coking characteristics. Ash contents vary from "low" to "very high". The coals are, in certain specific locations, very friable -- probably because of localized folding and/or faulting.

Correlation of seams within the study area is difficult because of lensing and splitting of seams, probable scour-and-fill conditions, and because of the division of the field into two distinct units separated by a zone of structural complications. Pore and pollen studies, additional drilling and logging, and analytical comparisons of samples from various parts of the study area could all help in either confirming or invalidating the seam correlations proposed herein which are, nevertheless, believed to be reasonably accurate.

Structural Geology

As can be seen in B. R. MacKay's map, used herein with additions (Fig. 1), the general structural trough containing the coal fields of the Kootenay formation are divided into three main basins which have been superimposed thereon. They are (1) the Flathead River coal fields in the south, (2) the Crowsnest coal fields (Fernie Basin) in the middle, and (3) the Upper Elk River coal fields in the north. Actual mining operations are presently confined to the Fernie basin--- a pear-shaped synclinal basin which corresponds roughly to the outcrop pattern of the Kootenay formation.

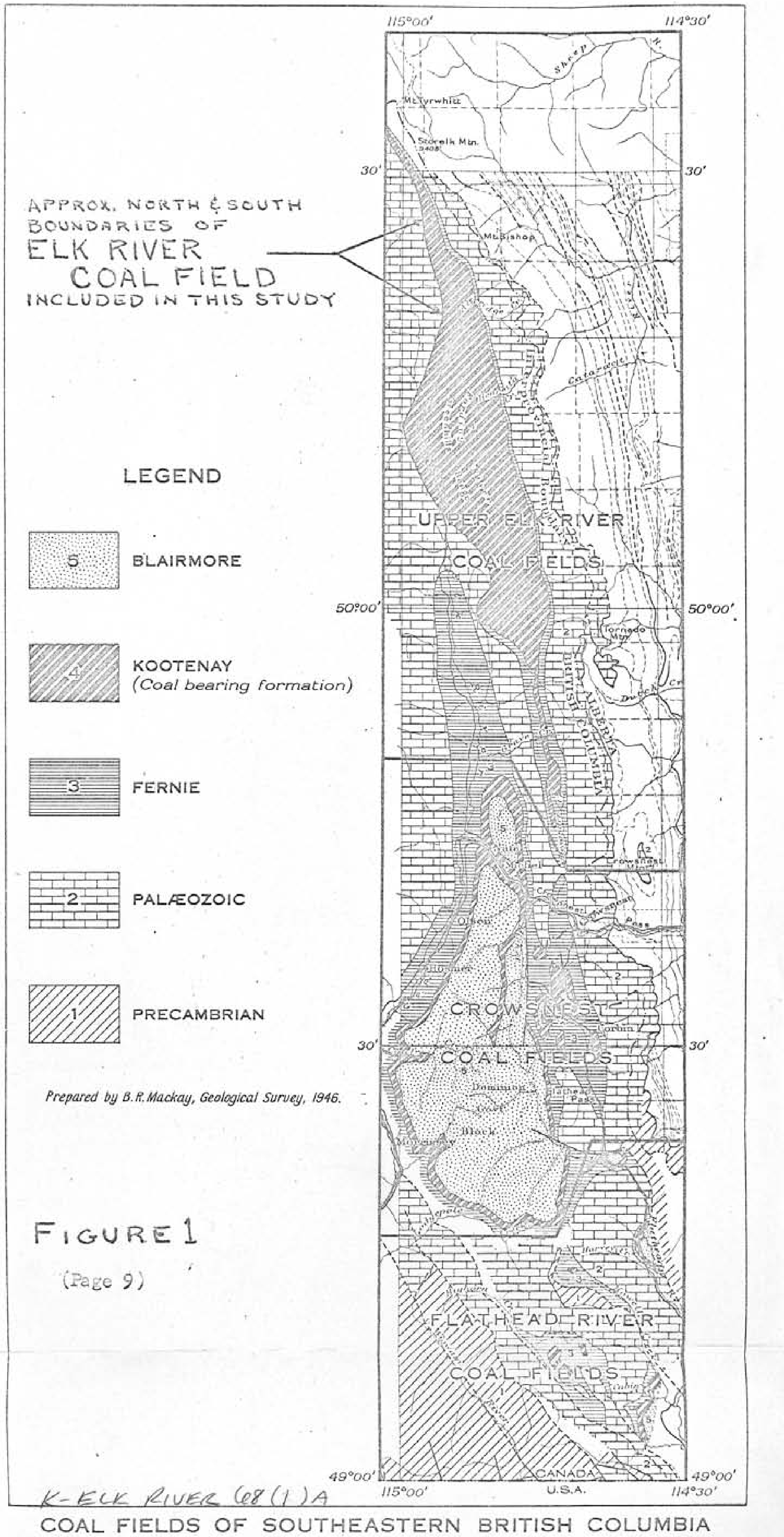


FIGURE 1

(Page 9)

K-ELK RIVER (68(1)A

COAL FIELDS OF SOUTHEASTERN BRITISH COLUMBIA

SCALE OF MILES

10 0 10 20 30

North of the Fernie basin in the general area of interest the geology of the Upper Elk River coal fields appears to be fairly straightforward. The mountains have a general northerly alignment which corresponds to the axes of narrow parallel fault blocks and major thrust folds related to the Lewis and associated thrust faults described later. In plan, the coal-bearing Kootenay beds form a long, narrow, somewhat lenticular strip, trending slightly to the west of north. They are limited on the west by the upraised rocks of the west limb of the northward extension of the structural trough.

All around the Fernie basin the incompetent beds of the Fernie group commonly exhibit pronounced disharmony between the pattern of folding evident in the upper part of the Paleozoic succession and that evident in the overlying beds of the Kootenay formation and Blairmore group. Presumably, also, this same disharmony extends into the Upper Elk River coal fields. Price (1962) has pointed out that

> "This disharmony reflects differential tectonic thickening within the incompetent Fernie interval and indicates that there has been some, if not considerable, independent movement between Kootenay and younger rocks on the one hand and the competent Paleozoic succession on the other."

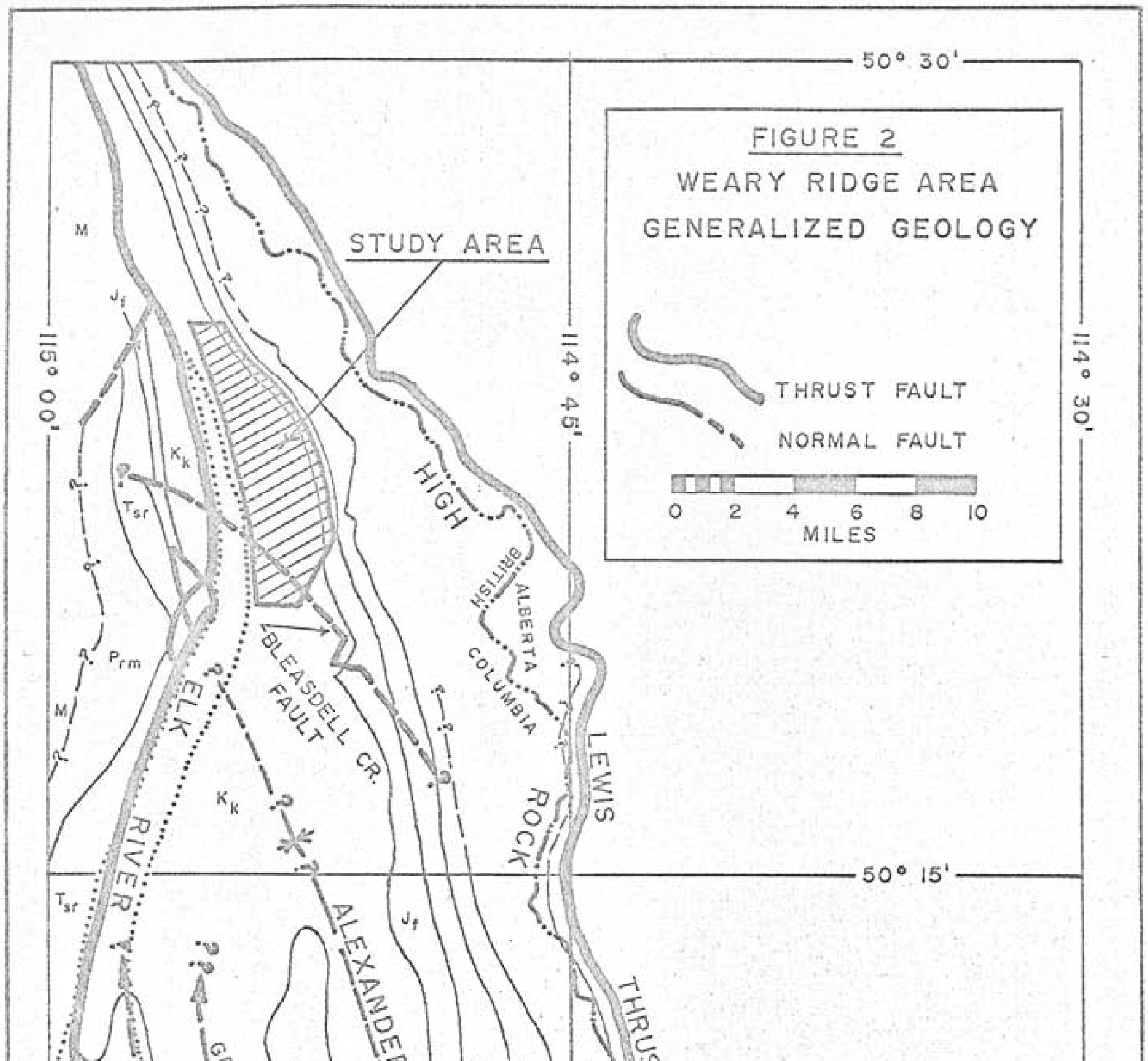
The general area (Fig. 2) is readily divisible into four structural and topographic units, as follows:

(1) The High Rock range, which marks the British Columbia-Alberta boundary, is the leading edge of the Lewis thrust sheet. It is composed mainly of upper Paleozoic limestones that are in a homoclinal structure.

(2) The Alexander Creek syncline, which contains lower Mesozoic rocks.

(3) A somewhat complicated doubly-plunging anticlinal feature between the Alexander Creek syncline and the Fording River fault which exposes Paleozoic rocks of the Lewis thrust plate.

(4) The mountains immediately west of the Elk River which are formed of folded Paleozoic and Mesozoic rocks believed to be overthrust on the Mesozoic rocks of the Elk Valley.



K-ELK-RIVER 68(1)A.

- The Lewis Thrust -

The Lewis is an outstanding example of a folded thrust plate. The Erickson Ridge anticline and the Alexander Creek syncline is the major fold pair in the general area. The absolute minimum displacement of the Lewis thrust in the general area is eight miles at the north side and twelve miles at the south (Dahlstrom, et al, 1962). In the Elk River coal field study area the minimum movement must have been at least eight miles.

- The Elk River Thrust -

This thrust, termed herein the "Elk River thrust," may have a displacement nearly equal to that of the Lewis in the vicinity of the study area. It has had considerable influence in defining the Elk River valley throughout the general area. On the assumption that the block of Kootenay rocks on the west side of Elk River were thrust eastward from a position near the projected anticlinal axis of the Fording Mountain anticline, the displacement would approximate five miles. In the Cadorna Creek area, immediately northwest of the study area, Mississippian rocks are thrust even farther eastward so that stratigraphically higher rocks are missing between Mississippian and Kootenay. These higher rocks were either overridden or, if thrust forward, have since been eroded away.

- The Fording River Fault -

On the east side of this fault there is a normal succession from Rundel to Kootenay. The Kootenay-Fernie contact can be traced northward around the north-plunging end of the Erickson Ridge structure and back to a normal succession from Kootenay to Rocky Mountain on the east flank of Fording Mountain. As Dahlstrom, et al, (1964) state, "This unbroken contact indicates that the upper plate above the Erickson Ridge thrust . . . is the same as the upper plate in Fording Mountain . . . therefore, . . . the relative movement in the Fording

River fault is west side down." The unbroken Kootenay-Fernie contact also indicates that the displacement on the normal FordingRiver fault decreases northward from a maximum near Fording Mountain to zero on the north-plunging end of the Erickson Ridge structure.

- The Bleasdell Creek Fault -

This is an inferred fault probably extending fifteen miles or more southeasterly. The inference for its existence is based partially on photogeological evidence which includes the apparent displacement of the Kootenay sandstone where the fault cuts through it. In addition a distinct, though localized, change in strike of strata in an area half-way between Weary and Aldridge Creeks north of the fault is notable. Also, there is an apparent displacement of the coal beds cut in Drill Hole 12 (south of fault) as compared with those cut in Drill Hole 1A (north of the fault). Correlation of coal seams in Hole 13 with those in the rest of the field is considered questionable. On the east side of Elk River the fault probably approaches a bedding-plane thrust. There seems to be relatively little normal displacement compared with the planar displacement which is thought to be much greater. The relative movement is north side eastward. The Bleasdell fault probably results from the more advanced thrusting of the Mississippian rocks eastward in the vicinity of Cadorna Creek.

Geology of Study Area

The Elk River coal field study area is a low, timber- and brush-covered, stream-divided ridge, located on the east side of the Elk River valley, between Elk River and the British Columbia-Alberta border. It is in the Front Ranges sub-province about six miles west of the Lewis thrust and lies just east of the Elk River thrust.

Coal is said to have been discovered in this part of the country long before the turn of the century. Its reported existence is alluded to in the Report of Progress of the Geological Survey for 1880-82 and 1882-84. The general coal-bearing area was approximately defined and examined in a preliminary way by Dr. G. M. Dawson in 1883 and was again visited, after some prospecting had been done, by Dr. A. R. C. Selwyn in 1891. Dowling (1915) reports that prospectors working between the Weary and Aldridge Creek valleys in 1905 ". . . uncovered about 22 seams on the eastern slope of a ridge . . . (Weary Ridge)." in 1906, F. A. Wilkinson described and reported favorably on many of the individual coal beds by measurement, detailed bedding characteristics, analytical results, weathering characteristics, and structural dip.

By 1909 there were at least three major coal syndicates with holdings in the general area. These included Canadian Pacific Railway Company, Imperial Coal Company and Northern Coal & Coke Company. The latter company started cross-cutting the measures on Weary Ridge with an adit in 1909. In this same year W. F. Robertson, British Columbia Minister of Mines, (Dowling, 1915) described the local coal measures as well as limited regional structural and stratigraphic geology. In 1911, Mr. J. W. Furness, mining engineer, did likewise but, in addition, took many samples of the various seams and had them analyzed. In 1913, Messrs. John and C. H. Geddes, English mining engineers, had the properties examined by their Mr. Cotton and, in 1914, wrote a very favorable report which described the coal beds and the geology of the area. Percival Muschamp, another English mining engineer, wrote a similar report in 1920 in which he also described the cross-cut adit as being driven into Weary Ridge a distance of 650 feet. This was its length when opened in 1968 and it is probable that little work was done on it after 1917. The geological work done by Mr. Walter Gardner was probably accomplished during this same period of time, i.e., 1909 to 1917.

Except for a brief geological description by B. R. MacKay in 1947, little interest was shown in the area from 1920 until 1952 when Mr. S. Ward, geologist for West Canadian Collieries, was placed in charge of considerable prospecting work and coal seam sampling for that company. Carmichael and Lane made their preliminary investigation in June, 1968, and The North American Coal Corporation began its major exploration program that summer, the results of which are described in this report.

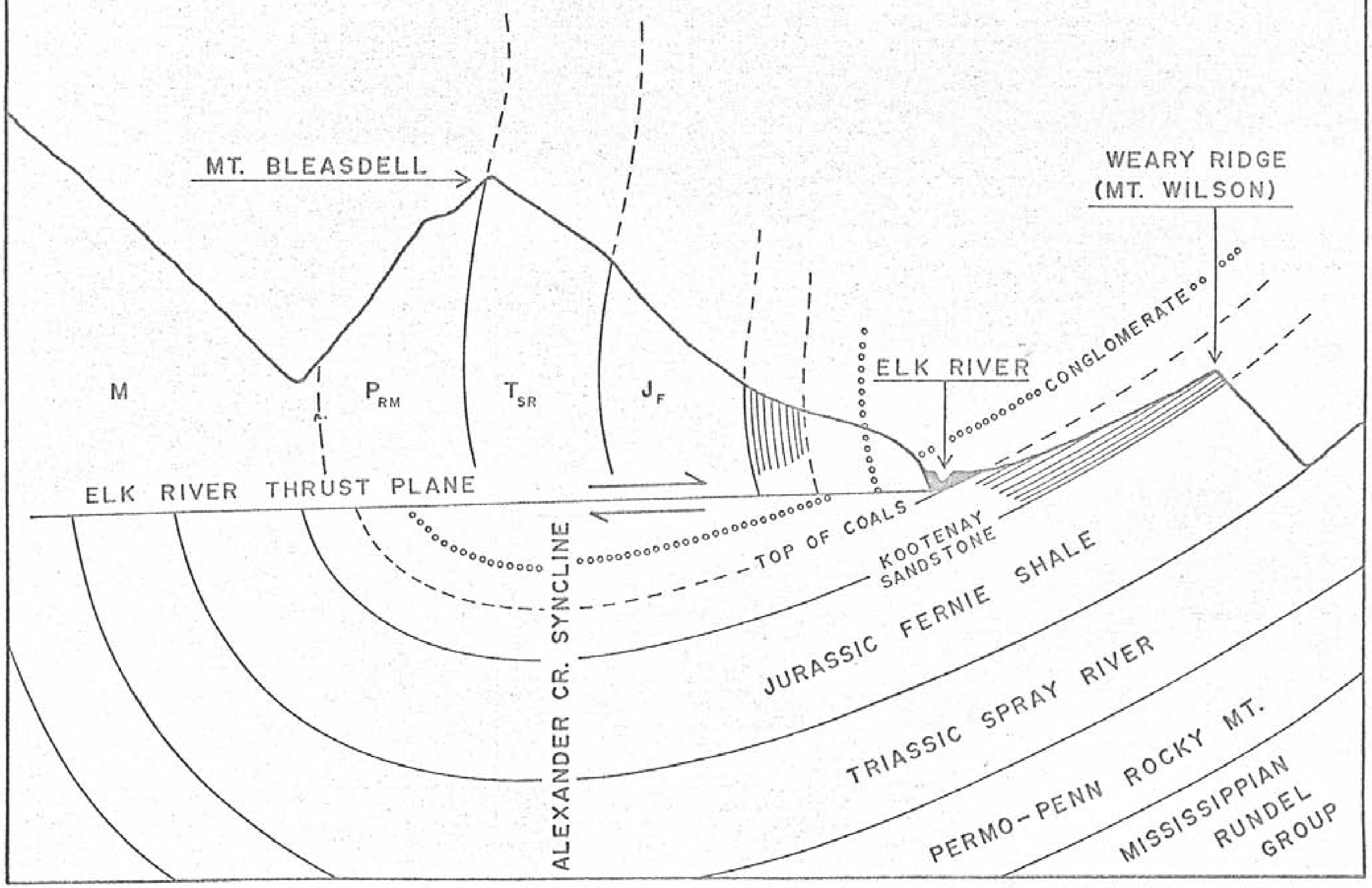
The ridge included in the study area has been divided by Weary Creek into two segments. Both segments, the largest of which is known as Weary Ridge or Wilson Mountain, and the smallest, herein called "Little Weary Ridge", are assumed to be remnants of the east limb of the Alexander Creek syncline, the axis of which lies downdip to the west beneath overthrust Paleozoic and Mesozoic rocks (Fig. 3). The latter include coal-bearing Kootenay rocks of the west limb of the Alexander Creek syncline and, presumably, stratigraphically lower Mesozoic rocks (Figs. 2 & 3).

The base of the coal measures is defined by a persistent massive sandstone which crops out at the east side of Weary Ridge and also to the northwest and southeast thereof. One minor coal seam (Bed A or No. 1) occurs between the two massive competent members of the sandstone in places and, as well be explained later, this incompetent bed has acted somewhat as a lubricant for one member to slide over the other at the north end of Weary Ridge. This slide, together with another possible large one and several much smaller ones in the area, resulted in the covering of previously strippable coal to some considerable depth. The resulting rock debris also causes difficult drilling in these locations.

The coal measures have been overlain by a very hard, resistant bed of Elk and/or lower Blairmore conglomerate, occasional float of which has been seen throughout the study area. At least fourteen coal seams of more than ten feet in thickness occur here. Walter Gardner noted at least twenty-five coal seams

K - ELK RIVER 68(1)A

FIGURE 3 - SIMPLIFIED STRUCTURE DIAGRAM OF WEARY RIDGE AREA



more than three feet thick on Weary Ridge; D. B. Dowling reported twenty-one seams; F. A. Wilkinson counted nineteen; J. W. Furness noted twenty-two "commercial" seams and S. Ward exposed fourteen seams ranging from five to twenty-seven feet thick. In this report the various coal seams have been assigned identifying letters or numerals, alphabetically or numerically consecutive and stratigraphically upward from Bed A (No. 1) in the basal Kootenay sandstone. (See Correlation Chart, Plate I). No gas was encountered in the sampling entries driven on the various coal beds during this study; however, gaseous conditions must be anticipated because flammable gas continued to surface with the artesian water flow from Drill Hole No. 5.

The Kootenay beds dip westerly from thirty-five degrees near the mouth of Aldridge Creek and along Weary Creek to vertical in specific local cases (Plates II & III). The average dip throughout most of the deposit approximates thirty-eight degrees except where structural complications have affected it. The average strike is about north ten degrees west excepting, again, in local areas of structural complications. Surface slopes downdip of the beds ranges from ten to thirty degrees generally excepting for flatter slopes along stream valleys.

The relatively recent rock slide mentioned previously, which occurred on the north end of Weary Ridge, appears to have developed by downdip slip of the entire Kootenay sandstone mass for some hundred yards or so. The bottom member continued downward, partially lubricated by the thin incompetent coal seam between the two, and piled up to a considerable depth (100 to 300 feet ?) over the previous ground surface. This slide may have resulted from a weakening of the strata by thrusting action or it may have been because erosion along the base of Weary Ridge weakened and destroyed downdip support. In any event, much evidence exists to indicate either (or both) an easterly thrust and a relatively massive westerly rock slide (and certainly the latter). Many of the beds below the slide have been overridden by other beds; either updip or downdip, sometimes bringing different coal seams into juxtaposition.

Particularly noticeable about one-half mile south of Weary Creek is the bending of the visible Kootenay strata westward from approximately north fifteen to twenty degrees west to north five and less degrees west within the next one-half mile. In a gully about four thousand feet south of Weary Creek the coal seams have been forced into a vertical position as a result of either (1) the thrust containing these beds having met resistance in this area or (2) the strata having been "rammed" downdip by the visible slide or by another much earlier slide which may have occurred adjacent to the north . The evidences for the latter have since been largely eroded away. How deeply the effects of these phenomena extend below the surface is not known; however, in the cross-sections the seams have been extended downward at the more severe dip until they intersect the normal dip projections of their correlatives upward from the west (Plate III).

At another location about half-way between Aldridge and Weary Creeks the strata bend rather abruptly again from an approximate north strike to one of north thirty-six degrees west, thence returning to the normal north ten degrees west a short distance farther south. This abrupt bending bounds the south side of the structurally complicated area described in the preceding paragraph. The bending may, also, be partially related to the relatively greater southeastward thrusting of the rocks lying between this area and the Bleasdell Creek fault.

Although the resultant mining problems to be encountered may be expected to be similar (except at depth) under either interpretation of the local structure, it is more probable that thrusting action, rather than downdip sliding action, has the more greatly affected it. The Elk River thrust probably exerted its greatest force on Weary Ridge rocks in a southeasterly direction from the more forward thrusting of the Mississippian rocks immediately south of Cadorna Creek. This could well have been the direct cause of the Bleasdell Creek fault, as well as another suspected small fault just north of Weary Creek. The warping of Kootenay strata west of the slide area may have been due to the thrust having met relatively more resistance to forward movement in this area. Such warping would naturally weaken the structural strength of the rocks making them more susceptible to sliding. It would also affect the strata to a greater depth than would be expected to result from ramming by a slide block. In the latter case the effects would be relatively shallow, perhaps not more than one or two hundred feet. Slide effects have, however, been superimposed on the older structure in this immediate area.

The coal seams noted on Bleasdell Creek (or, more specifically, on its short tributary, Coal Creek) stand nearly vertical and strike north twenty-five degrees west where measured. Little field work was done on these seams and, because the beds are cut by the sharp Coal Creek gully at nearly right angles and are well exposed, it is assumed that the geologic section measured by Mr. Ward is quite accurage. (See Fig. 4). The overthrust Kootenay formation, of which these beds are a portion, extends in a northerly direction along the west side of Elk River a distance of about nine miles and lies almost directly across from the study area. It is likely that this block of Kootenay is coal-bearing throughout its length; however, drilling will be required to prove or disprove this assumption.

Mr. Matt Walton, consulting geologist (1968), has summed up his interpretation of structure from studying the complete core from Core Hole C, by stating that ". . . there is some indication of flattening of the dip in the lower part of the hole, consistent with the existence of a major syncline to the west." He points out that one of the striking features of the bedding . . . is the high degree of variability. Dips varying by ten or twenty degrees can be measured within a few feet or even a few inches. This means that the attitude of small scale laminations or other structures related to stratification in the

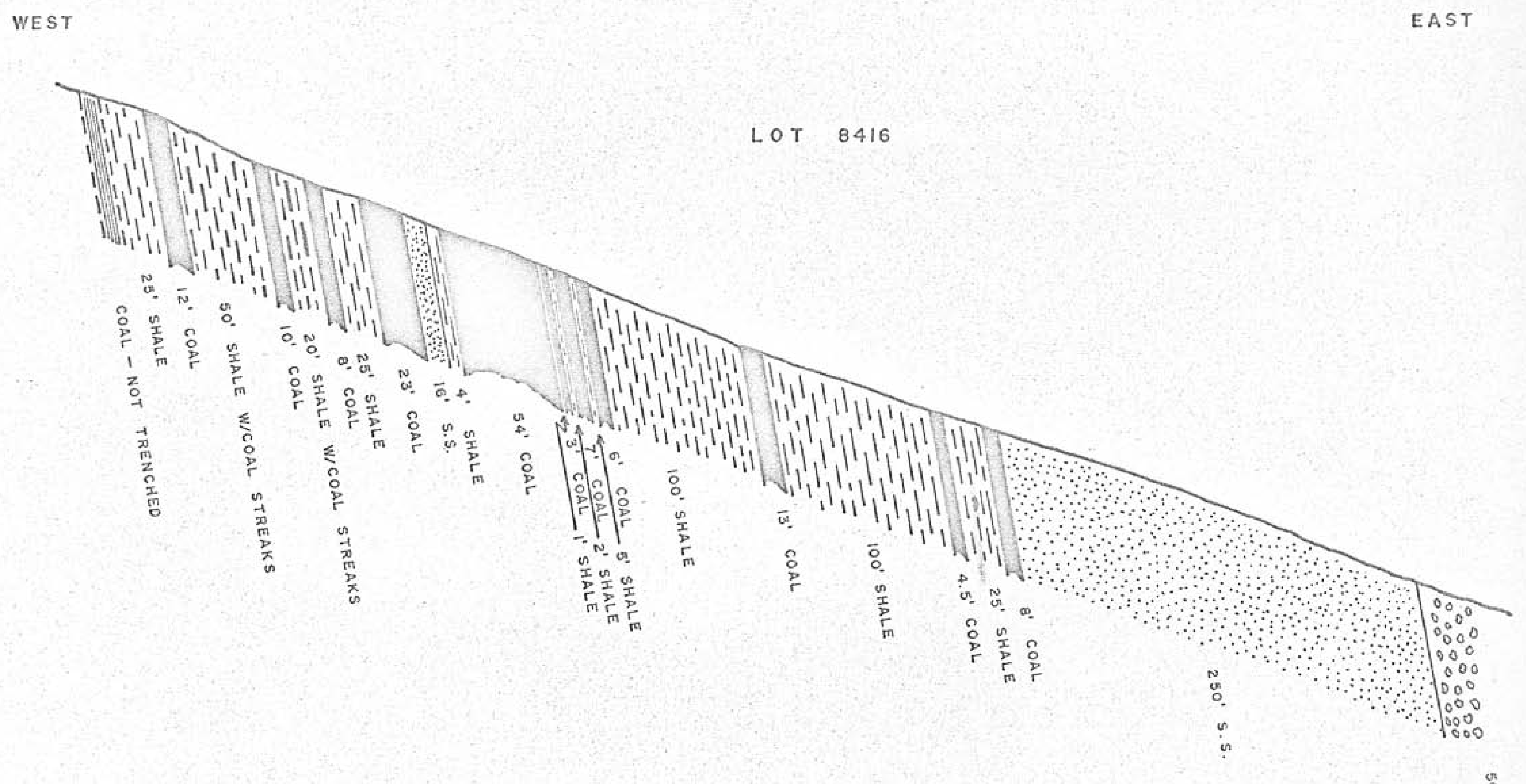


FIGURE 4

SECTION ON COAL CREEK
BRANCH OF BLEASDELL CREEK

K-ELK RIVER 68(1)A. SCALE 1" = 100' (AFTER S. WARD) drill cores cannot be accepted uncritically as representing the horizontal surface of sedimentary deposition at the time the beds were deposited. On the other hand, he says, there is abundant evidence that the process of sedimentation taking place when these beds were laid down resulted in considerable variation in primary dips over relatively small distances. Throughout the core there is abundant evidence that clastic sediments were being brought into the basin by turbidity currents. Turbidity current deposition produces such features as channel scour-and-fill, high- and low-angle cross-bedding, intra-formational unconformity, contorted and deformed bedding, lenticularity, and lateral discontinuity. Immediately after deposition, silty and argillaceous sediments deposited in this irregular way tend to undergo varying degrees of differential compaction, resulting in further variations in the attitude of bedding and distortion of bedding. These features can occur on scales ranging from a fraction of an inch to many feet.

For the reasons above stated, dips measured from cores must be used with considerable caution insofar as projection for overall attitude of the formation is concerned. The most reliable dips are likely to be reflected in the attitudes of coal layers or sharp clean carbonaceous partings -- but even these show evidence that either the surface on which the carbonaceous layers were deposited was undulating or that there has been a significant amount of intra-formational deformation during differential compaction.

Mr. Walton noted that, in general, there is more evidence of a large influence on primary dip by turbidity current deposition in the upper strata than there is in the lower. This fact, together with the many other findings from the core analysis, seem to confirm Mr. Norris' description of the geologic history of the area presented earlier in this section, at least insofar as the deposition of the coal beds are concerned.

E X P L O R A T I O N, 1 9 6 8

Preamble

The Elk River coal field was first examined on the ground by NACCO's Virgil Carmichael and Scurry's David Lane during the first half of June, 1968, using aerial photographs as geologic aids. This preliminary examination antedated by a few days preparatory photogeologic interpretation and a review of all available records and analyses developed by earlier workers in the area.

The second half of June was devoted to office work which culminated in a joint preliminary report summarizing the writers' findings and comparing them with results obtained by earlier workers. This report contained a general cultural map, a general geology map, and a topographic map of the field. The latter map also contained tentative coal seam correlations, limited geology, and proposed locations for bulldozer cuts and sampling entries. Cross-sections were developed from the topographic map which resulted in a preliminary estimate of 15 million tons of strippable coal (at an overburden:coal ratio of 5:1) and a total minable reserve of 87 million tons of coal (based on a recovery rate of 40 percent), much of which appeared to have coking qualities. Furthermore, the report outlined and recommended for immediate acceptance and initiation a proposed full-scale exploration and sampling program and provided an attached work-flow sheet as a guide; asked for funds totaling $175,000 to cover the costs of the program; and recommended that certain other noncontrolled coal-bearing lots be obtained with dispatch.

The preliminary report was completed about mid-July and was presented immediately to NACCO for consideration by its Board of Directors. Approval for up to $300,000 for exploration funds was granted by the Board on July 17, 1968, and final expenditures approximated the entire grant. In addition, the Board approved the formation of a subsidiary company (to be owned jointly and equally by NACCO and Scurry) to handle the development and marketing of the coal reserves of the field.

Modus Operandi

In order to properly evaluate the major coal seams in the deposit as to quantity and quality of reserves available, it was proposed in the preliminary report to make a minimum of 14 bulldozer cuts on as many different coal seams at the top of Weary Ridge and to drive at least seven entries on various coal seams for bulk sampling. It was recommended that the cuts should transect Weary Ridge on each of the major seams to a depth of 25-30 feet which, it was believed, would be sufficient to provide samples of unweathered coal and measurable thicknesses of seams and intervals between. It was also recommended that the entries on the coal seams should be driven underground on strike far enough to provide from 30 to 50 feet of overlying material -- a depth believed to be sufficient to obtain bulk samples below the weathered zone.

In the preliminary report it was pointed out that the first work to be completed should be the cuts on top of Weary Ridge. It was suggested that the entire exploration program be critically reevaluated as soon as these seams were exposed, spot sampled, and analyzed. If it was found that the seams did not hold up in thickness and quality a decision might well be made at that time as to whether or not the project should be continued.

On the assumption that the requested exploration funds would be granted, Spartan Air Services, Limited, Calgary, Alberta and Ottawa, Ontario, was contacted in early July and was asked to air-photograph the entire Elk River coal field immediately so that a more suitable scale of photos would be available for engineering and geological planning. Spartan was notified that a topographic map at a scale of 1 inch to 1000 feet with 20-foot contour intervals would be essential to our work soon after exploration approval; therefore, the photographs were to be such that the topography could be developed as rapidly as possible from them. The area was flown by mid-July and Spartan gave assurance that the required topographic map could be provided by approximately mid-September if definitely requested.

Prior to exploration approval, contact was made with Nodwell Brothers, Ltd., trailer manufacturers in Calgary, Alberta, about supplying a mobile camp for our exploration requirements. Nodwell was alerted that a camp might be needed and was advised as to the probable number of men to be cared for. This project was particularly valuable to Nodwell because the company ordinarily supplies camps for winter seismic work, thus creating an excess of camping units in stock during the summer.

Several firms with bulldozers for hire were contacted during this period and a firm commitment was made with W. A. Cook & Sons, Ltd., Pincher Creek, Alberta, to supply labor and D-8 Caterpillar equipment for road construction, trenching, and exposing coal seams if, and when, funds became available. Big Indian Drilling Co., Ltd., Calgary, Alberta, was contacted as to availability for drilling and coring the coal beds. Several other drilling companies were also contacted; however, Big Indian was the only company that had a drill-rig available so late in the season and who was willing to hold it on standby for a few days to await our decision.

On July 22 arrangements were completed with Big Indian Drilling Co. to rebuild a drill rig for this particular job and to move it in as rapidly as possible. Spartan was told to complete the topographic map. Nodwell was asked to start delivery of a kitchen, wash-house, power plant, and sleeping units immediately. Three four-wheel drive vehicles were rented for management personnel. Two D-8 Caterpillar tractors were being "walked" in to the project. Foothills Catering, Ltd., Calgary, Alberta, contracted to provide camp services and meals. NACCO's assistant geological engineer, Mr. Dwosh, reported to the project with Mr. Lane.

The priority importance of access roads situated over the property was recognized immediately, particularly because the drill-rig was expected to be moved in within a relatively short time if results of preliminary analyses of coals exposed on Weary Ridge appeared favorable. Roads were tentatively laid out on the aerial photographs and the task of driving the first road southeasterly to the ridge top in Lot 6384 was well underway by July 23. On this same day the No. 9 Seam on Weary Creek was exposed with the second 'dozer. By the end of the week, i.e., July 27, most of the camp had been delivered and set up, including the power-house, kitchen, wash-house, and several sleeping units; two large coal seams had been exposed; and the access road had reached the top of Weary Ridge near its south end in Lot 6384. Here the first switch-back was built preparatory to following the ridge top northward where it was proposed to cross-cut each sizeable coal seam up to a depth of 30 feet. In addition, arrangements had been consummated with Shepherd Enterprises, Ltd., Rossland, British Columbia, to provide (1) a large D-8 Caterpillar tractor with ripper for exposing coal seams; (2) a mining crew for sampling-entry work on a trial basis; and (3) a wheel tractor with combination back-hoe and front-end loader attachments, together with an operator, to attend to general camp maintenance and to aid in sampling-entry work. A third new, hydraulically-operated Caterpillar tractor with ripper had been arranged for with W. A. Cook, making a total of four track-tractors available (or soon to be) for the project. NACCO's Lignite Division Engineer, Mr. Kanthack, arrived on the project to aid in management.

The first progress report, dated August 7, 1968, pointed out that (1) over three miles of access road on Weary Ridge had been completed; (2) coal seams P and Q on Weary Ridge had been exposed to a depth of 20 feet; (3) coal seam P, later named No. 9 and correlated with G, had been exposed on both sides of Weary Creek (as had two smaller seams) and entry work had begun on the former; (4) coal seam S?, later correlated with Q, had been well exposed just south of the old cross-cut portal, as had another coal seam later correlated with Seam I and No. 10, directly up the drainage to the east where folding and faulting had been noticed; (5) coal grab-samples had been taken from several openings and forwarded to Warnock-Hersey International, Ltd., Vancouver, B.C., for analyses to determine if coking qualities were present, at least in some areas, before contracting for a drill rig; and (6) topographic mapping had been ordered.

By the time the second progress report was written on August 16, 1968, coal seams F and F' through U had been exposed and their thicknesses along the ridge top had been estimated. Utilizing a planned bulk-sampling technique described later, the entry on No. 9 seam on the north side of Weary Creek had been advanced forty feet, more or less, and a new entry was begun with a second mining crew on the S_1? seam, later correlated with Q, about half-way between Aldridge and Weary Creeks. An incomplete geologic section of the coal measures along the south side of Weary Creek had been opened by bulldozer, exposing numerous coal seams. The old cross-cut portal, between Weary and Aldridge Creeks, had been successfully opened and the 650-foot cross-cut appeared to be standing. McElhanney Associates, professional land surveyors from Vancouver, B.C., had been asked to come in and survey certain lot lines so that the timber along them could be cut and thus photographed from the air. An additional access road had been built to the top of Weary Ridge near the north end of the coal measures exposed on that ridge. By this time it was found that the roads to the top of Weary Ridge were almost invaluable for many reasons, not the least of which was their provision of access to the only point in the area from where radio-telephone communication was feasible.

The bulk-sampling technique, as planned for each coal seam to be sampled, consisted of: (1) starting an entry on the footwall of the seam; (2) driving the entry along strike until an 8 or 9 coke button was attained at our camp laboratory from face samples; (3) upon attaining such a button, turning at right angles and cross-cutting the entire seam from footwall to hanging wall; (4) cleaning the cross-cut opening thoroughly; (5) marking with spray paint a channel to be cut from footwall to hanging wall; (6) cutting the channel with an air-powered chipping hammer along its entire length for a consistent depth sufficient to provide a minimum of ten barrels of coal; (7) thoroughly mixing the sample by shoveling back and forth into different piles at least four times; (8) shoveling the final coal pile into steel drums except for putting every fifth shovelful into another smaller pile; (9) sealing the drums of coal with rubber seals and shipping immediately to Commercial Testing and Engineering Laboratories, Charleston, West Virginia; and (10) bagging in plastic two portions of the smaller pile and shipping one portion to Warnock-Hersey International, Vancouver, B.C., and the other portion to H. L. Washburn, The North American Coal Corporation, Cleveland, Ohio.

As of August 25, 1968, (1) almost all coal seams on Weary Ridge had been exposed to depths of 20 to 30 feet; (2) an access road to the top of "Little Weary Ridge" was nearing completion; (3) the entry on No. 9 coal seam had been completed and bulk sampling was to begin on the 26th; (4) the entry on the S? [Q] seam between Aldridge and Weary Creeks was nearing completion and a sampling entry was started on the No. 8 seam on the south side of Weary Creek; (5) a complete geologic section had been exposed by bulldozer and ripper along the south side of Weary Creek and consecutive numbers had been assigned to seams numbered 1 through 9 there; (6) No. 10 seam had been exposed by the building of the road up Little Weary Ridge; (7) the first drill hole was being "punched" near the south end of Weary Ridge about half-way up; (8) analytical reports were being received indicating that some of the coal seams, at least, contained coals of coking quality; (9) two 'dozers' services were discontinued by August 23rd; and (10) surveys of the exposed coal seams atop Weary Ridge had been started by Messrs. Dwosh and Kanthack. By this time, too, a basic decision had been made to concentrate bulk sampling work along the Weary Creek exposures and direct more exploratory work toward Little Weary Ridge because of its simpler structure, thicker coal seams, and relatively smaller size. Total expenditures accumulated and contracted for by this time approximated $100,000.

By September 15, 1968, total expenditures accumulated and contracted for (including a minimum contract with Canadian Longyear, Limited, Vancouver, B. C., for core drilling) were estimated to be nearly $190,000. Two of NACCO's surveyors from the Company's Ohio Division had arrived on September 13th and a survey of all new roads and coal exposures along the top of Weary Ridge and Little Weary Ridge was begun with completion expected within three weeks' time. Seams Q (S_1) and No. 9 bed, by this time had been bulk-sampled and the samples were enroute to Commercial Testing and Engineering Laboratories, Charleston, West Virginia, for complete analytical and washability testing. The 650-foot cross-cut adit was found to be open to the face and standing well; however, its length was now reduced to 630 feet because the first 20 feet had been removed by a 'dozer. McElhanney Associates had begun the legal survey of strategic property lines and had agreed to work closely with Messrs. Kanthack and Dwosh on the local surveys so that all surveys would eventually be "tied" together.

Coring results by Big Indian Drilling Co., Ltd. had, by this time, proven to be most unsatisfactory and that company was requested to do nothing but drill holes, log them to the best of their ability, and collect chip samples. The inability of this company to recover core was a considerable disappointment because the company representative had provided strong assurances that they had made good recovery doing similar work for Kaiser Coal near Natal, B.C. In addition, Mr. Lane had received assurances from Canadian Pacific Oil & Gas that Big Indian's work for them on similar ground had been quite satisfactory. However, because of the inavailability of drills at this particular time of year, it was decided to keep the rig working for correlation purposes even though satisfactory cores could not be recovered. It was believed that if all holes were later logged with a gamma ray-neutron logging device the data obtained by the drillers and the logging device together would be of considerable value. This proved to be the case when the first four holes were thus logged on September 13th by ROKE Oil Enterprises, Ltd., Calgary, Alberta.

After proof of Big Indian's inability to core these coals a desperate effort was made to obtain the services of another drilling company for core drilling. The best that could be done was to contract with Canadian Longyear, Limited, Vancouver, B.C., to move in a wire-line rig and crew from the Canadian Pacific Oil & Gas coal drilling and coring project on Fording River, approximately 15 air miles southeasterly, as soon as they completed their work there (estimated to be about October 1st). This, of course, drastically limited the core-drilling season. Furthermore, Longyear required a guaranteed minimum of 3000 feet of drilling and coring before accepting the job. However, because it was essential to obtain coal cores or samples at depth to project quality and volume of coal seams with any satisfactory degree of certainty and because Longyear's reputation for good core recovery with high speed drilling techniques was of the best, the decision was made to begin the project as soon as men and equipment because available with the dubious hopes that the work could be completed by October 20th.

On September 25th, in order to start earlier on the contract, Longyear began moving in a drill and crew from Smithers, B.C., and by the 28th had begun core-drilling. By October 8th, a complete 1000-foot geologic section had been cored in two holes (Core Holes A and B) which extended from 100 feet above the No. 10 seam to the basal Kootenay sandstone. A third hole (Core Hole C) had been started three-fourths of a mile south of Weary Creek. Recovery was proving to be extremely satisfactory, being nearly 100 percent of both rock and coal. Coal cores were being separated from the rock cores and reboxed with plastic sheeting surrounding them. Arrangements were made to send the coal cores to Paul Weir Company, Chicago, Illinois, with a request to provide a detailed description of each coal seam and the results of proximate analyses, Btu and coking tests, and any other analytical work believed to be of importance. The rock cores were being forwarded to Mr. Matt Walton, geological consultant for Al Johnson Construction Company, Denver, Colorado, for complete petrographic analyses, stress and strain analyses, and sedimentation and structural interpretation.

On September 26th the third (and largest) Caterpillar tractor was moved off the job. Thus only the smallest remained for drill site clearing, moving drills, and for general duty. By this time, too, Big Indian was having fair success drilling since they were no longer required to core. Mr. Kanthack and the Ohio Division surveyors completed their work by October 3rd and McElhanney Associates were having considerable difficulty locating original lot corners in the area. The corners seemed to have been destroyed during the intense forest fire that passed through the area in 1936.

On October 6th and 7th the first large snowfall of the season occurred and snow continued to accumulate on Weary Ridge and surrounding areas (particularly above 6000 feet elevation) until the project closed for the season. By October 8th, four more coal seams (Nos. 2, 4, 8 and 10) had been entered, bulk-sampled, and the samples shipped to Charleston, West Virginia. Entries were being driven on Nos. 3 and 7 seams in preparation for sampling. Under a contract with Shepherd Enterprises a cross-cut diamond drill had been installed at the face of the newly opened cross-cut adit and more than 100 feet of core had been extracted. Water pressure problems (ultimately reaching 260 p.s.i.) became noticeable almost immediately in this long-hole which was lined up with the adit and was being drilled horizontally. The long-hole was being drilled with the expectation of providing information for advancing the cross-cut adit in the same direction some time in the future if this should be desired. By this time McElhanney Associates were finding major discrepancies in retracing the original lot surveys in the area and were having an expert come in to go over the problem with them. Because of the rapid accumulation of snow and, consequently, the additional hardships of trying to find old corners, McElhanney was asked to discontinue their work for the season on October 12th.

One crew of miners completed sampling coal seam No. 3 and an additional portion of Seam Q (S_1) by October 11th and were released from the job. Big Indian completed their last drill hole (No. 13) on October 12th and moved their drill out on October 15th. ROKE Oil Enterprises was called in to log the rest of the Big Indian drill holes and to try to log at least one of the Longyear core holes for a comparative check. ROKE successfully logged and checked the only open Longyear core hole (Core Hole B) and all remaining Big Indian drill holes between October 13th and 15th during which time more than 6 inches of new snowfall occurred. Longyear completed Core Hole C on October 12th and moved to Core Hole D on the 13th. On October 16th the last crew of miners completed sampling seam No. 7 and moved out of camp; Nodwell moved the first camp unit out; and Longyear moved to their last core hole (Core Hole E). By October 21st seven camp units had been moved out, Shepherd had moved most of his equipment off the job, and Longyear had completed Core Hole E. The camp was practically closed on October 22nd except for the long-hole crew working in the cross-cut adit. Graphic logs of all drill holes are shown in Plate IV and graphic logs of the coal seams exposed along the ridge top of Weary Ridge are shown in Plate IV-A.

Three camp units were retained at the site by Shepherd Enterprises, whose long-hole crew stayed on the job until November 14th. By this time they had completed 1001 feet of coring beyond the cross-cut adit face which was an additional 630 feet beyond the present portal.

Mapping and Field Checking

The base map of the area of interest (Plate II) was developed from aerial photographs. It was both flown and mapped by Spartan. Topographic mapping was at a scale of 1" = 1000' with 20-foot contour intervals and was based entirely on control obtained from the existing 1:50,000 National Topographic Series Map 82J/7W. The basic vertical information was obtained by identifying spot heights at countour crossings on the more prominent rivers and streams. This information was then used to control a photogrammetric bridge using the Wild A_7 Stereoplotter. Maximum error in topography, according to Spartan, is less than one-half contour interval (10 feet). Our own leveling work, however, indicates that Spartan's maximum error was nearer 30 or 40 feet. This amount of error is considered reasonable for this type of reconnaissance mapping. A discrepancy also occurs in orientation.

McElhanney Associates were contracted to try to define certain strategic lot lines in the area of interest. On September 11, 1968, that company began running field traverses (Plate V) and searches for missing lot corners. Within the subject area these traverses were to serve the further function as a system of control for the concurrent geological investigations. McElhanney's attempts to find precise field evidence of original monuments and boundaries were unsuccessful up to their demobilization date of October 13th when several inches of snow on the ground made further searches impractical. That company now recommends additional field search and searches of various company files before presenting their request to the B. C. Provincial Surveyor-General for aid in establishing pertinent lot corners and lines.

A total of more than one month's time was spent developing "tight" survey control throughout the area of interest by two engineers from NACCO's Lignite Division office in North Dakota and two surveyors from the Ohio Division office (Plate VI). Wooden hubs and iron pins were installed along the newly constructed roads to the top of Weary Ridge and Little Weary Ridge and survey ties were run to all drill holes, ridge cuts, and to McElhanney's survey stations. Understandably, such tight control cannot be made to fit precisely that developed by Spartan because Spartan's work was based on a relatively small-scale map without the aid of ground control.

As geology and culture was developed it was, with the aid of a pocket stereoscope, mapped on two scales of aerial photographs supplied by Spartan. Such photographs were taken several times during the exploration season to provide relatively continuing evidence of work completed and to aid in more accurately locating exposed coal seams. Geology was continually revised directly on the photographs by examining the relationships between the coal outcrop traces as determined on the photographs and the evidences of outcrop traces on the ground. There is no obvious and continuous expression of the coal zones, i.e., no "black band" contours the hillsides labeling the existence of a coal seam. However, studies of the photos indicate that several characteristic topographic features are related to the presence of coal. No one feature or combination of features is continuous over the entire area; nevertheless, the outcrop trace of the coal horizon may generally be "roughed in" on the photos over most of the area in preparation for field checking with bulldozer and drill. It is essential, too, that all marking on stereo-pairs be consistently done only on alternating photos to insure the retention of photo legibility.

The contributions of aerial photographs to this type of program are at least three-fold. First, they save much time in the initial reconnaissance of a coal deposit, which may spread over many square miles, often containing but few roads and trails. Second, the photos provide an inviolable representation of the land. Third, despite the difficulties experienced in carrying their precise outcrop traces from place to place, the coal beds can be "seen" on the photos in those areas not covered by alluvium, talus, land slides or other debris. Their subtle expression is recorded as an inherent part of the landscape. No conventional map could contain this type of information and the advantages are obvious. The advance information derived from the photos becomes the key to intelligent planning of the drilling program which, in turn, is the key to the final and correct interpretation of outcrop and stripping limits on the photos and the calculation and evaluation of coal reserves.

Drilling is included as one of the steps in the field checking although it also serves other purposes; e.g., (1) accurate measurement of coal seam thickness; (2) recovery of samples for visual inspection and analysis; (3) determination of the character of overburden and interbedded rock; (4) stratigraphic correlation, and (5) as an aid in the interpretation of geologic structure. It is mandatory, of course, for the development of valid quantitative information and for interpreting geologic structure and stratigraphic correlation. Each new bit of information thus gained makes further appraisal of the geology possible.

The drilling program was laid out on the basis of information derived from photogeological mapping. It was closely supervised and revisions were made as to location and depth of holes as it progressed. On this particular project the drilling program was severely limited because of insufficient time and poor availability of equipment. Although a sufficient amount of drilling and coring was done (in conjunction with bulldozer work) to provide a reasonable interpretation of the geology and coal reserves, it is essential that considerably more drilling be done in the future to provide assurance of quantity and quality of such reserves before the actual mining program is attempted.

Using various topographic features for planimetric control, all geologic and cultural information developed on the aerial photographs was transferred to the base map (Plate II) by means of a photo-sketchmaster, a device which is basically little more than an elaborate camera lucida with adjustments for reducing photo distortion. Other office procedures consisted of the following steps developed in the order presented:

(1) Location of geologic cross-sections on the photos and on the base map by inspection.

(2) Estimation of elevation of top of coal on the various beds with the aid of cross-section interpretations and information developed on the photos by field measurement.

(3) Inking of the information placed on the base map and cross-sections, followed by planimetering the end areas of the various cross-sections to determine the total coal and total rock above water level and the basal sandstone member.

(4) Calculation of tonnage of reserves of coal and yardage of rock for each set of cross-sections by using a commonly accepted factor of 23 cubic feet of coal per ton.

C O A L R E S E R V E S

In the study area total reserves of coal-in-place above the 5200-foot contour (water level) are estimated at more than 148 million tons. Of this total, 87 million tons are on lands controlled by NACCO-Scurry, and the remaining 61 million tons are on lands controlled by Cominco. The overall average ratio is 9.1 cubic yards of rock per ton of coal. The ratios for individual "reserve blocks," however, vary from a low of 2.6 to a high of 12.8. (See Table 3, Elk River Study Area Coal Reserves by Ownership).

Because of the nature of the terrain, the relatively limited drilling program, and the rather drastic variations noted in coal seam thicknesses and intervals within relatively short distances, a regular area-of-influence type of calculation could not be made. Instead, calculations were made from vertical cross-sections of 1000-foot or less centers. These cross-sections were developed approximately perpendicular to the strikes of the beds. Wherever a relatively major change in strike occurred the directions of the cross-sections were also changed so that they remained approximately perpendicular to strike. At these change-in-strike locations wedge-shaped blocks of coal and rock resulted rather than more regularly-shaped blocks as was the case with those bounded by parallel cross-sections. Reserve blocks bounded by Cross Sections 11-12, 13-14, 16-17, 20-21, 24-25 and 24-26 (Plate II) are wedge-like blocks.

The actual procedure used in calculating reserves consisted of (1) drawing cross-sections, (2) measuring length of each coal seam along dip on each cross-section to the 5200-foot level, (3) averaging the length between cross-sections, (4) determining true thickness of each coal seam at each section, (5) averaging the thickness between cross-sections, (6) measuring width between cross-sections, which was normally 1000 feet, and (7) computing the resulting figures. The process used in calculating the wedge-shaped blocks varied somewhat, but the

TABLE 3

ELK RIVER STUDY AREA COAL RESERVES

BY OWNERSHIP

Reserve Block Bounded by Cross-Section Numbers	NACCO Controlled	Overburden Ratio in Cu. Yd. Rock per Ton Coal	Cominco Controlled	TOTAL	Overburden Ratio in Cu. Yd. Rock per Ton Coal
1-2	199,000	3.8			
2-3	762,000	3.0			
3-4	1,841,100	2.6			
4-5	3,537,600	3.4			
5-6	4,693,700	4.4			
6-7	5,222,800	4.5			
7-8	5,263,700	4.7			
8-9	3,976,900	5.2			
9-10	2,260,300	5.0			
10-11	1,885,200	4.6			
11-12	213,700	6.9			
12-13	2,355,100	5.8			
13-14	1,820,900	6.2			
14-15	2,175,400	5.4			
15-16	1,586,500	6.2			
16-17	814,600	7.6			
17-18	2,708,100	5.4			
18-19	4,186,450	5.3			
19-20	2,891,100	6.1			
20-21	2,383,000	7.0			
21-22	6,298,400	7.9			
22-23	7,855,800	10.0			
23-24	5,261,800	11.2			
24-25	5,381,900	11.8			
25-26	2,025,200		7,410,700	9,435,900	12.8
26-27	1,714,600		9,336,600	11,051,200	11.9
27-28	1,231,100		11,008,200	12,239,300	11.4
28-29	804,300		11,617,400	12,421,700	12.4
29-30	624,900		11,347,100	11,972,000	11.3
30-31	3,159,300		6,704,700	9,864,000	10.9
31-32	2,246,300		4,031,400	6,277,700	11.3
TOTAL	87,380,800		61,456,100	148,836,900	9.1
	58.71%		41.29%		

slightly different method does not warrant discussion here. The equation for computation of tons of coal in each bed in each reserve block is as follows:

$$\text{Tons} = \frac{(\text{Avg. length, feet}) \times (\text{Avg. width, feet}) \times (\text{Avg. thickness, feet})}{23 \text{ cu. ft.}}$$

Note that a conversion factor of 23 cubic feet per ton (87 pounds per cubic foot) has been used. This is an accepted factor often used in bituminous coal fields.

Only the rock that would necessarily have to be moved to recover yardage was calculated by planimetering end-areas and then computing. Total yardage required to be moved in order to strip all seams to the 5200-foot contour level would be 1,353,000 cubic yards.

A summary of the coal reserves and overburden ratios by reserve block and by ownership is presented in Table 3. It is notable that overburden to coal ratios increase considerably in a southerly direction. This is partially due to thinning of practically every coal bed in that direction and partially due to the thicker intervals of rock occurring between the stratigraphically higher coal beds which come into prominence in the south end of the study area. Table 4 lists the various thicknesses of the coal beds at each cross-section used in computing reserves.

TABLE 4

THICKNESSES OF COAL BEDS USED AT EACH CROSS-SECTION

Bed		*SECTION NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	B-C	11'	11'	11'	11'	10'	10'	10'	10'	10'	10'	10'	10'	10'	10'	10'	10'
3	D	10	10	10	9	9	8	8	7	7	6	6	6	6	6	6	8
4	E	28	28	28	31	33	32	30	31	30	30	29	29	25	19	18	19
7	F^1				4	4	4	5	6	7	8	7	7	6	6	6	0
8	F				25	25	25	19	20	21	22	20	20	23	21	19	18
9	G						16	17	17	17	17	17	16	17	15	10	8
10-A	H							7	6	6	6	6	12	14	12	8	4
10	I							21	23	25	23	22	19	17	16	13	11
11	J								11	11	11	11	11	11	11	11	12
12	K								18	18	18	18	18	15	15	15	15
13	N											27	27	27	27	27	27
	P																
	Q																
	R																
	S																
	T																

*Table continued on next page--

TABLE 4 (Cont'd)

THICKNESSES OF COAL BEDS USED AT EACH CROSS-SECTION

		SECTION NUMBER															
Bed		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
2	B-C	10'	12'	14'	10'	10'	6'	11'	11'	8'	6'	6'	6'	6'	6'	6'	6'
3	D	9	15	18	16	15	12	8	6	6	6	6	6	6	6	6	6
4	E	19	20	21	19	18	10	8	10	7	3	7	7	7	7	7	7
7	F'	0	2	4	4	4	5	5	5	5	5	5	5	5	5	5	5
8	F	16	12	10	10	10	10	10	10	11	11	11	11	11	11	11	11
9	G	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
10-A	H	6	8	10	10	10	10	10	10	10	13	11	13	13	13	13	13
10	I	11	12	12	10	9	7	6	6	6	6	6	6	6	6	6	6
11	J	11	10	9	10	12	16	15	13	13	10	7	7	7	7	7	7
12	K	14	12	11	11	11	12	10	8		6	4	4	4	4	4	4
13	N	24	19	18	18	19	20	15	9		10	13	17	17	17	17	17
	P			13	13	13	13	10	10		11	12	10	8	15	21	21
	Q			18	18	17	14	12	15		18	17	12	13	13	12	12
	R											4	4	4	5	6	6
	S				9	11	14	16	18		18	16	17	19	21	22	22
	T											10	10	10	10	10	10

RECOMMENDATIONS

FOR

FUTURE EXPLORATORY WORK

As was pointed out earlier in this report, additional exploration work should be done in the field before actual mine planning and layout commences. Approximately seventeen more drill holes are thought to be desirable (Plate VII). Of these seventeen holes, nine should be cored and eight could be drilled for thickness and interval information only. The type and location of the various proposed holes should satisfactorily prove the structural interpretations outlined in this report; the continuity, thickness and quality of coal seams and their correlations; and the approximate thickness of gravels overlying bedrock in certain areas.

In suggesting where new drill holes should be located as well as which holes should be cored and which should be drilled for interval and thickness information only, many factors have been considered. Among these are (1) relative location with respect to previous drill holes; (2) ease of access to drill site; (3) access to known available water; (4) ownership or lessee control of lands involved; and (5) approximate depth of drilling and coring believed necessary to provide the required information.

In addition to drilling, bulk sampling of portions of the beds cross-cut by the present adit should be done. Resulting waste could easily be hauled out by using mine cars and the track that was found in place in the adit. It is unlikely that more than a ten-foot depth of coal would have to be removed along strike from each seam before bulk sampling could be started. The first bed to be sampled in the cross-cut adit should be the two main splits of the "N" or "No. 13" seam. Measured horizontally, as are all other bed measurements listed in these two paragraphs, the two splits are each eight feet thick. Next to be sampled should be the twelve-foot split of the "J" of "no.11", the fourteen-foot split of the "I" or "No. 10", and the nine-foot split of the "H" or "No. 10A" seams.

Some considerations should also be given to driving the cross-cut adit another 451 feet along line to expose for bulk sampling the fourteen-foot split of the "P" or "No. 8" seam and the twenty-four-foot split of the "E" or "No. 4" seam. Such cross-cut rock work would be quite expensive, probably about one hundred dollars per foot, but the adit could be used for later underground development and mining.

Estimated costs of the future work as outlined above is as follows:

Bulk sampling of coal seams.	$ 10,000
Caterpillar tractor work, 60 days . .	20,000
Drilling and coring	125,000
Camp, board, and incidentals.	20,000
Subtotal	$175,000
Plus optional adit work @ $100/ft.	50,000
Grand Total	$225,000

No consideration has been given herein to a drilling program for the coal measures on the west side of Elk River. A drilling project of sufficient size to prove or disprove a minable reserve in that area would be very expensive under present access conditions. It is recommended that all exploration monies available to the project for 1969 be utilized on the present study area and that exploration on the west side of the river await proof of an economically minable reserve in the study area as well as completion of the forest road now under construction west of the river.

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APPENDIX - NACCO SURVEY STATION COORDINATES

SURVEY STATION NO. BIG WEARY RIDGE	COORDINATES NORTH	EAST	SURVEY STATION NO.	COORDINATES NORTH	EAST
1	39,682.93	9,584.54	36	35,771.91	13,345.15
2	39,670.55	9,878.27	37	35,924.49	13,330.57
3	39,632.49	10,166.87	38	36,192.56	13,390.91
4	39,664.07	10,309.52	39	36,413.60	13,462.91
5	39,497.69	10,540.74	40	36,594.26	13,487.06
6	39,387.98	10,772.09	41	36,714.31	13,427.92
7	39,190.97	10,916.66	42	36,517.70	13,645.84
8	38,955.25	11,082.51	43	36,769.78	13,732.35
9	38,823.85	11,185.18	44	36,917.20	13,777.26
10	38,592.15	11,281.53	45	37,091.32	13,832.77
11	38,397.85	11,240.52	46	37,201.76	13,904.59
12	38,259.84	11,292.83	47	37,464.20	13,931.13
13	37,972.93	11,359.52	48	37,732.88	14,021.21
14	37,776.08	11,463.11	49	37,884.16	14,097.90
15	37,492.05	11,558.46	50	38,125.83	14,191.07
16	37,223.23	11,632.86	51	38,272.78	14,305.66
17	36,971.09	11,741.32	52	38,416.71	14,372.48
18	36,746.21	11,907.83	53	38,548.96	14,524.67
19	36,638.89	11,941.16	54	38,663.97	14,640.89
20	36,501.81	12,070.06	55	38,856.34	14,801.65
21	36,228.11	12,184.09	56	39,080.37	14,860.65
22	35,951.46	12,292.55	57	39,219.13	15,030.46
23	35,751.77	12,375.04	58	39,372.32	14,981.63
24	35,469.67	12,462.77	59	39,639.33	14,967.80
25	35,182.36	12,523.10	60	39,834.34	15,043.85
26	34,888.12	12,538.78	61	40,029.58	15,038.44
27	34,637.95	12,535.18	62	40,262.70	15,073.22
28	34,465.83	12,504.32	63	40,539.30	15,032.87
29	34,311.32	12,521.80	64	40,286.71	14,989.70
30	34,579.39	12,644.10	65	41,066.01	15,048.31
31	34,807.59	12,765.25	66	41,211.93	15,109.60
32	34,960.21	12,917.27	67	41,490.11	15,174.12
33	35,131.81	13,070.71	68	41,665.23	15,105.38
34	35,251.26	13,160.79	69	41,835.20	15,085.92
35	35,508.95	13,300.95	70	41,928.79	15,084.17

SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST	SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST
71	42,180.00	15,098.10	75A	43,311.68	15,074.40
72	42,438.74	15,066.40	75B	43,553.90	14,985.10
73	42,640.76	15,082.61	75C	43,674.20	15,015.06
74	42,827.14	15,115.22	75D	43,832.54	14,949.55
75	43,034.80	15,119.59	75E	44,014.39	14,898.88
76	43,072.46	15,057.05	75F	44,285.20	14,844.73
77	42,829.65	14,913.62			
			LITTLE WEARY RIDGE		
78	42,594.91	14,747.65	1	50,683.17	7,216.70
79	42,454.02	14,603.38	2	50,937.51	7,141.48
80	42,374.78	14,340.33	3	51,189.23	7,057.80
81	42,324.28	14,092.06	4	51,481.62	6,994.37
82	42,177.14	13,876.10	5	51,764.62	6,914.01
83	41,979.63	13,672.52	6	51,982.52	6,844.28
84	41,756.12	13,493.19	7	52,142.48	6,779.79
85	41,538.76	13,351.87	8	52,413.27	6,839.57
86	41,302.32	13,184.56	9	52,623.90	6,919.07
87	41,078.55	13,007.73	10	52,812.98	6,975.19
88	40,975.15	12,899.02	11	52,945.13	7,021.13
89	40,858.06	12,770.76	12	52,951.37	7,192.83
90	40,993.96	12,537.92	13	52,814.53	7,280.34
91	41,133.12	12,356.69	14	52,668.17	7,447.45
92	41,306.53	12,142.84	15	52,955.26	7,404.14
93	41,508.94	11,984.05	16	53,111.32	7,414.47
94	41,602.55	11,768.78	17	52,203.64	7,491.04
95	41,570.33	11,484.77	18	53,140.32	7,652.79
96	41,378.07	11,473.77	19	52,909.69	7,757.91
97	41,178.45	11,422.69	20	52,859.95	7,847.79
98	40,949.06	11,290.70	21	52,974.58	7,930.55
99	40,728.50	11,106.84	22	53,142.39	7,920.72
100	40,592.12	11,014.27	23	53,265.72	7,879.65
101	40,355.95	10,915.87	24	53,435.76	8,033.59
102	40,237.81	10,852.93	25	53,513.03	8,247.55
103	40,093.83	10,930.28	26	53,650.95	8,340.67
104	39,918.95	10,636.04	27	53,668.25	8,494.85
105	39,740.68	10,467.45	28	53,919.20	8,649.13

SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST	SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST
29	54,212.68	8,676.86	64	50,716.91	7,301.77
30	54,465.16	8,675.33	7A	52,334.88	6,753.23
31	54,666.48	8,654.94	7B	52,574.23	6,682.99
32	54,879.60	8,657.42	7C	52,756.37	6,600.10
33	55,160.54	8,660.33	7D	52,903.70	6,592.78
34	55,445.32	8,639.75	36A	55,939.48	8,521.38
35	55,592.05	8,583.58	36B	56,180.35	8,515.80
36	55,689.15	8,516.35	36C	56,410.65	8,482.04
37	55,531.79	8,525.89	36D	56,700.66	8,418.29
38	55,301.37	8,526.82	36E	56,916.17	8,405.87
39	55,137.53	8,520.97	36F	57,065.19	8,447.23
40	54,845.17	8,543.20	36G	57,310.39	8,471.82
41	54,628.82	8,525.02			
42	54,471.73	8,476.74			
			DRILL HOLE UNCORED		
43	54,268.28	8,440.52	HOLE 1A	35,000.51	12,934.81
44	54,162.26	8,299.18	64A	40,890.20	15,027.87
45	53,979.10	8,272.43	HOLE 2	40,859.36	15,068.73
46	53,742.44	8,172.01	84A	41,700.41	13,363.22
47	53,625.96	8,147.72	HOLE 3	41,749.29	13,362.15
48	53,557.51	8,435.86	HOLE 4	41,507.45	11,418.03
49	53,389.78	8,455.27	104A	39,881.88	10,551.17
50	53,135.84	8,435.00	104B	40,003.88	10,475.42
51	52,937.40	8,392.43	HOLE 5	40,074.40	10,393.06
52	52,665.49	8,418.38	HOLE 6	38,706.49	11,172.01
53	52,569.75	8,505.51	2A	39,668.65	9,782.24
54	52,440.84	8,459.69	2B	39,486.09	9,925.69
55	52,232.72	8,506.25	HOLE 7	39,402.44	9,950.80
56	52,109.02	8,522.12	HOLE 8	35,252.27	10,145.93
57	51,984.67	8,389.67	HOLE 9	43,351.08	8,955.27
58	51,769.79	8,210.42	A	50,406.62	7,328.00
59	51,598.19	8,097.52	B	50,159.13	7,457.00
60	51,473.56	7,949.07	HOLE 10	50,281.17	7,566.97
61	51,257.07	7,791.01	1A	50,563.36	7,107.60
62	51,151.57	7,671.96	1B	50,388.44	6,866.07
63	50,915.80	7,486.42	1C	50,191.15	6,642.12

SURVEY STATION NO.	COORDINATES NORTH	EAST	SURVEY STATION NO.	COORDINATES NORTH	EAST
1 D'	50,052.35	6,463.15	95B	41,888.93	11,434.58
1 E'	49,915.48	6,282.86	95C	42,013.83	11,352.12
1 F'	49,730.08	6,270.34	95D	42,190.03	11,129.21
1 G'	49,606.16	6,300.90	95E	42,430.71	10,955.57
1 H'	49,507.58	6,262.97	HOLE D	42,467.06	10,806.35
HOLE 11	49,407.83	6,275.58	1A	39,850.26	9,600.10
1 B''	50,321.12	6,809.41	1B	40,109.79	9,552.53
1 B'''	50,139.94	6,922.90	1C	40,395.04	9,500.24
1 B''''	50,059.43	6,993.33	1D	40,684.99	9,468.30
HOLE 12	50,016.95	7,040.61	1E	40,966.76	9,428.01
			1F	41,254.05	9,388.72
			1G	41,518.78	9,348.21
DRILL HOLES - CORED					
11A	53,180.80	7,125.35	1H	41,612.18	9,396.07
HOLE A	53,287.56	7,122.13	1I	41,688.29	9,429.29
23A	53,546.42	7,915.84	HOLE E	41,626.72	9,464.72
23B	53,780.21	7,999.30			
23C	53,860.22	7,954.82			
			COAL BEDS BIG WEARY		
HOLE B	53,925.99	7,914.48	26A	34,885.64	12,850.87
A	50,406.62	7,328.00	26B	34,874.43	12,608.57
B	50,159.13	7,457.00	41A	36,721.45	13,450.28
C	49,906.28	7,617.74	41B	36,653.37	13,555.72
D	49,780.85	7,724.67	53A	38,424.85	14,627.44
E	49,627.60	7,928.66	53B	38,358.15	14,652.84
F	49,363.74	8,045.23	53C	38,298.47	14,645.81
G	49,156.94	8,022.00	54A	38,718.60	14,714.27
H	48,973.47	8,027.15	54B	38,586.68	14,779.02
I	48,711.11	8,164.31	54C	38,568.63	14,777.10
J	48,553.72	8,262.93	54D	38,615.34	14,727.84
K	48,279.08	8,371.38	58A	39,195.48	14,979.26
L	47,997.53	8,458.24	58B	39,216.69	14,940.92
M	47,705.02	8,510.49	58C	39,236.41	14,896.63
N	47,464.49	8,570.33	59A	39,733.74	15,002.86
P	47,430.35	8,688.15	59B	39,764.02	14,983.39
HOLE C	47,453.91	8,745.82	59C	39,790.30	14,956.89
95A	41,654.19	11,494.63	62A	40,133.83	15,075.80

SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST	SURVEY STATION NO.	COORDINATES NORTH	COORDINATES EAST
62B	40,095.04	15,094.60	21A	52,946.03	7,978.55
62C	40,054.79	15,111.05	21B	52,925.99	8,089.32
63A	40,654.15	15,088.50	21C	52,952.25	8,083.82
63B	40,573.17	15,067.89	21D	52,977.55	8,042.40
63C	40,480.79	15,050.88	31A	54,726.33	8,626.99
64A	40,890.20	15,027.87	33A	55,135.49	8,638.34
64B	40,848.58	15,083.82	36B'	56,137.49	8,466.37
64C	40,828.03	15,085.21	36C'	56,164.49	8,452.65
64D	40,807.26	15,085.55	36D'	56,125.56	8,358.16
66A	41,123.98	15,186.84	43A	54,271.05	8,323.48
66B	41,076.57	15,203.04	43B	54,283.24	8,295.62
66C	41,014.24	15,215.45	43C	54,309.83	8,305.14
71A	42,064.30	15,122.13	58A	51,853.85	8,027.68
71B	41,944.61	15,143.02	58B	51,725.46	7,767.88
73A	42,485.42	15,130.49	58C	51,693.24	7,698.36
73B	42,506.11	15,088.13	58D	51,686.31	7,650.22
73C	42,504.43	15,039.97			
74A	42,650.10	15,142.72			
			McELHANNEY'S STA.		
74B	42,580.91	15,147.35	1304	36,542.75	9,540.73
74C	42,511.77	15,150.40	1305	39,571.30	9,614.59
75X	43,079.71	15,170.49	1306	43,383.34	9,074.07
75Y	42,846.30	15,263.86	1307	48,271.84	8,380.16
75E'	44,057.01	14,919.34	1308	53,010.60	6,547.12
75E''	44,004.26	14,927.21	1316	36,877.79	13,676.36
75E'''	43,971.32	14,920.57	1317	38,353.83	14,594.37
75F'	44,328.65	14,905.77	1318	40,049.64	15,058.95
75F''	44,321.01	14,935.60	1319	56,208.91	8,044.23
COAL BEDS					
LITTLE WEARY					
14A	52,737.37	7,381.99			
14B	52,762.16	7,402.71			
14C	52,807.56	7,373.99			
20A	52,777.02	7,844.18			
20B	52,825.19	7,875.30			
20C	52,855.42	7,862.80			

K-ELK RIVER 68 (2) A.

PLATE II

Geology Map of the Elk River Coal Field

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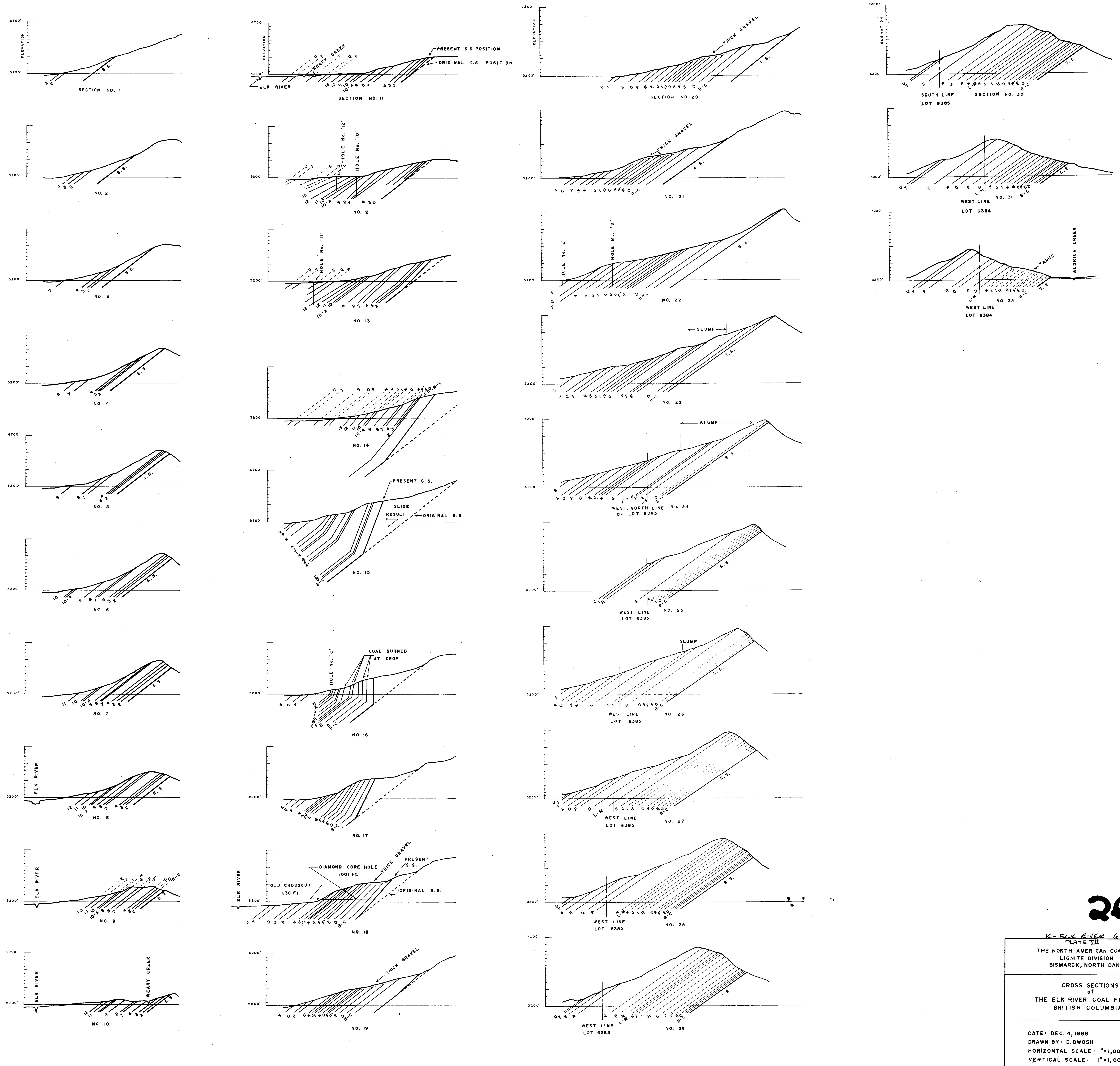

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K-ELK RIVER 68 (2) A.

PLATE III

THE NORTH AMERICAN COAL CORP.
LIGNITE DIVISION
BISMARCK, NORTH DAKOTA

CROSS SECTIONS
of
THE ELK RIVER COAL FIELD
BRITISH COLUMBIA

DATE: DEC. 4, 1968
DRAWN BY: D. DWOSH
HORIZONTAL SCALE: 1"=1,000'
VERTICAL SCALE: 1"=1,000'

K-ELK RIVER 68(2)A

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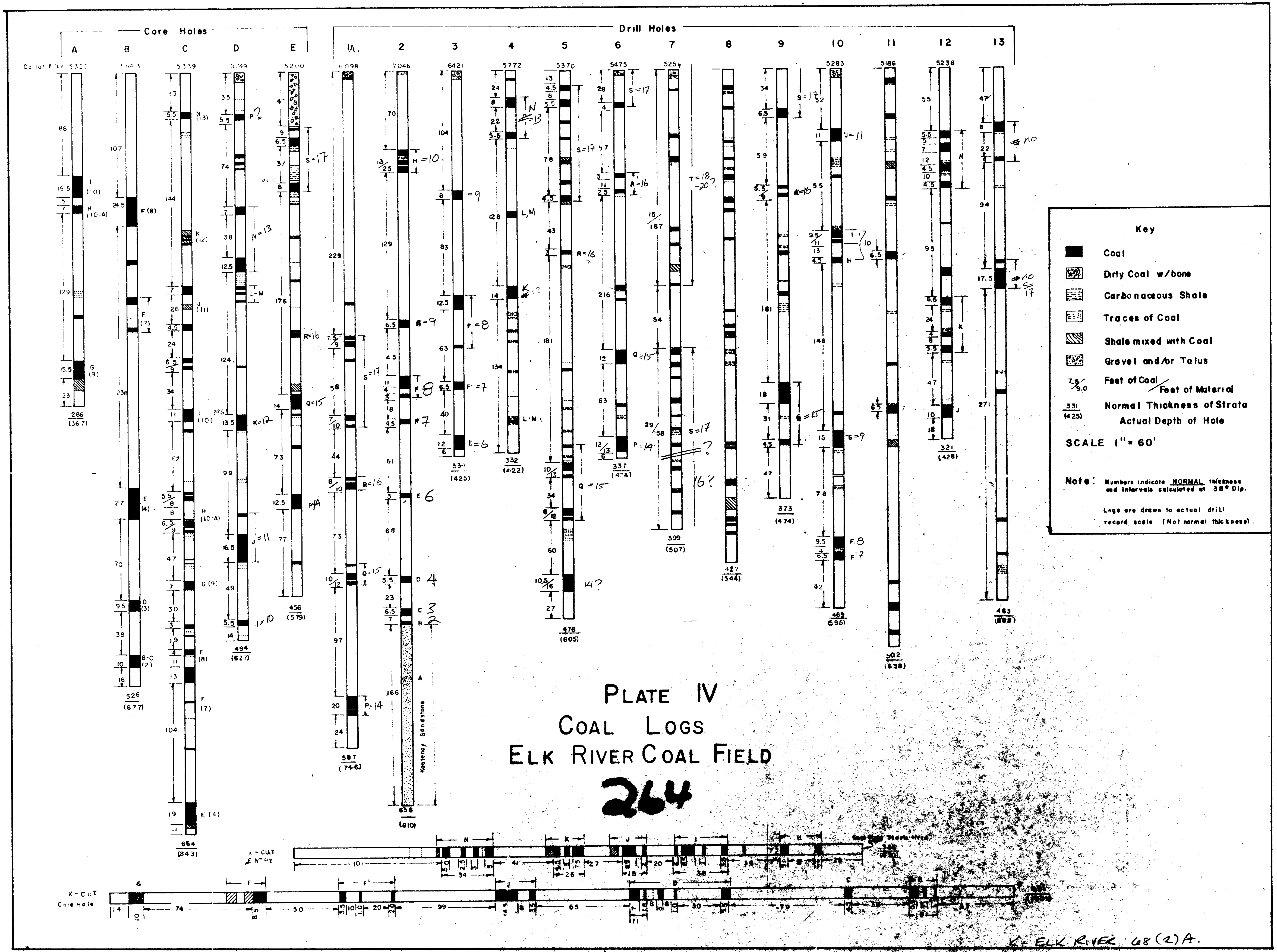
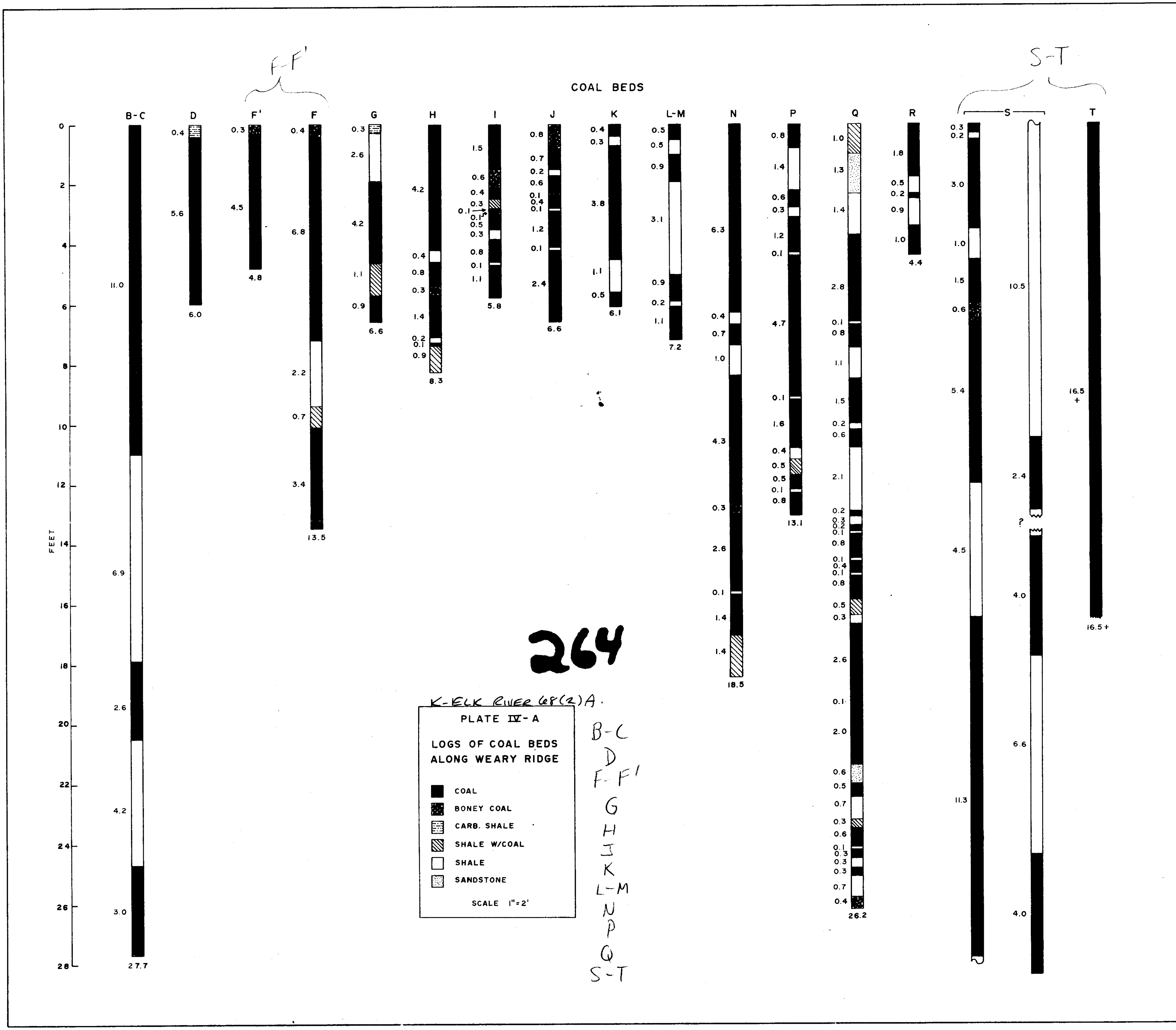
PLATE I - PROBABLE CORRELATION OF VARIOUS PUBLISHED SECTIONS

D.B. DOWLING CANADA GEOLOGIC SURVEY MEMOIR 69 COAL SEAMS NUMBERED UPWARD FROM BASAL KOOTENAY S.S.			F.A. WILKINSON			S. WARD WEST CANADIAN COLLIERIES (1952)			J.W. FURNESS NORTHERN COAL & COKE ALDRIDGE CREEK SECTION AND CROSS-CUT ADIT			J.W. FURNESS NORTHERN COAL & COKE WEARY CREEK SECTION			WALTER GARDNER NORTHERN COAL & COKE WEARY CREEK SECTION			WALTER GARDNER NORTHERN COAL & COKE LOT 8470, ELK RIVER NEAR CADORNA CREEK			W.F. ROBERTSON MINISTER OF MINES, 1909 FROM DOWLING			V.W. CARMICHAEL 1969 THIS REPORT		
SEAM	THICKNESS (ESTIMATED SECTION)	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS	SEAM	THICKNESS	REMARKS
21	(?)	(?)																								
20	(?)	(?)																								
19	(?)	(?)	19	10'		1	17'																	U(No. 18)	2'±	THIN COAL SEAM AND IS HIGHEST SEAM IN THE GEOLOGIC SECTION FOUND NORTH OF BLEASDELL FAULT.
18	(?)	(?)	18	12'	ANALYZED 4.70 % ASH																			T(No. 17)	(?)-16'+	LITTLE IS KNOWN ABOUT THIS SEAM. EXPOSED ALONG PROSPECT ROAD NEAR SOUTH END OF WEARY RIDGE WHERE IT PROBABLY EXCEEDS 16'+. APPEARS TO SPLIT RAPIDLY TO THE NORTH.
			17	2'																						
17	9'	120'	16	14'		2	19.5'	4.5 % ASH	6	10'	26' TUNNEL GOOD COKING										1	14'-2"	GOOD COKING	S(No. 16)	14-25'	A COAL AND CARB. SHALE ZONE UP TO 150' THICK WITH NUMEROUS RELATIVELY THIN COAL AND DIRTY COAL SEAMS INTERSPERSED THROUGHOUT.
																								R	0-8'	THIN, USUALLY LESS THAN 3' AND OFTEN IT IS ONLY CARB. SHALE.
16	11'	78'	15	14'		3	14'	11.5 % ASH	7	7.5'	28' TUNNEL PROB. EXCELLENT COKING													Q(No. 15)	8-22	ONE OF THE MORE MINABLE AND GOOD COKING SEAMS IN WEARY RIDGE. RANGES UPWARD FROM 10' THICK, GENERALLY THINS TOWARD ALDRIDGE CREEK.
15	18'	65'	14	12'	WILL COKE	4 5	9' 5'	10.0 % ASH 14.6 % ASH	1 8	24' 14'	IN X-CUT ADIT DUMP. CLEAN, GOOD COKING IN 22.5' ALDRIDGE CR. TUNNEL, WILL COKE										2	4' 0'-9" 14'	COAL SHALE GOOD COKING	P(No. 14)	5-17'(?)	ONE OF THE MORE MINABLE SEAMS IN WEARY RIDGE, RANGING UPWARD FROM 12' THICK GENERALLY.
									2	6'	PORTAL OF X-CUT ADIT													O	0-6'	USUALLY ONLY A THIN CARBONACEOUS ZONE.
14	27'	90'	13	30'	7.3 % ASH	6	27'	15.7 % ASH NON-COKING	10	9'	GOOD CLEAN COKING COAL										3	3' 2' 9'	COAL SHALE GOOD COKING	N(No. 13)	14-20'	USUALLY SPLIT INTO TWO TO FOUR BEDS WITH ONE OR MORE MINABLE IN WEARY RIDGE.
																								L-M	5'±	RELATIVE THICK ZONE OF CARB. SHALE WITH BUT LITTLE COAL.
13	6'	90'	12	2.5'																				K(No. 12)	5-13'	VARIABLE AND LENSY IN THICKNESS. USUALLY BADLY SPLIT.
12	7.5'	45'	11	10'	HI SULFUR	7	10'	8.3 % ASH	13	7½'	15.5 TUNNEL, WILL COKE W/ DIFFICULTY										4	7' 4'-3" 1'-3"	DIRTY COAL FIRM COAL CLOD	J(No. 11)	6-16'	VARIABLE AND LENSY IN THICKNESS. USUALLY SPLIT WITH ONE BED AVERAGING ABOUT 10' THICK.
11	11'	68'	10	8'	NON-COKING (?)	8	10'	14.0 % ASH	16	6'											5	10'	GOOD COKING	I(No. 10)	5-24'	SPLITS IN SOUTH AND WEST PART OF FIELD. IMPROVES NORTHERLY.
						9	5'		17	5.5'																
10	18'	90'	9	17'	ANALYZED	10	15'	19.5 % ASH																H(No. 10-A)	4-13'	DIRTY AND SPLIT IN SOUTH PART OF FIELD. IMPROVES NORTHERLY.
9	8'	80'	8	7'		11	8'	20.4 % ASH																G(No. 9)	3-15	GENERALLY ABOUT 10' THICK BUT MAY OFTEN BE DIRTY. IMPROVES NORTHERLY.
8 7	14' 5'-3"	3.5' 22'	7	35'		12	18' 2' 5'	11.6 % ASH SHALE COAL				1	12'+	SOFT, COKING		22'								F(No. 8)	8-25'	SEAM SPLITS IN PLACES. TENDS TO INCREASE IN NORTHERLY DIRECTION TO BECOME A MAJOR SEAM NEARER WEARY CREEK.
6	6'	130'	6	5'								2	10'			10'								F'(No. 7)	0-8'	SEAM SPLITS IN PLACES. VARIABLE IN THICKNESS.
			5	6'	ANALYZED																			No. 5 & 6	0-3'	SEAMS OCCUR ALONG WEARY CREEK ONLY.
5	17'	68'	4	15'		13	15'												35'					E(No. 4)	3-30'	INCREASES IN THICKNESS FROM 3' AT TOP OF WEARY RIDGE IN A NORTHERLY AND WESTERLY DIRECTION TO BECOME A MAJOR MINABLE SEAM NEARER WEARY CREEK.
4	3.5'	32'	3	2.5'																						NOT DETECTED
3	7'	10'	2	7'	MAY COKE																			D(No. 3)	7-15'±	GENERALLY 7'±, BUT INCREASING UP TO 15'+ TOTAL COAL WITH SEVERAL SPLITS.
2 1	2' 5'	2'	1	3.5'	MAY COKE	14'	15' .4' 10'	COAL SHALE COAL				3	6'	GOOD COKING		7'			12'					C (No. 2) B	4-14' 4-40' 2-5'	INTERVAL RANGES FROM 4-40'±
																5'	NON-COKING (GEDDES)							A(No. 1)	2-6'+	OCCURS BETWEEN TWO MEMBERS OF THE KOOTENAY S.S. NEAR TOP.


Core Holes
Drill Holes
Collar Elev.
Key
Coal
Dirty Coal w/bone
Carbonaceous Shale
Traces of Coal
Shale mixed with Coal
Gravel and/or Talus
Feet of Coal / Feet of Material
Normal Thickness of Strata
Actual Depth of Hole
SCALE 1" = 60'
Note: Numbers indicate NORMAL thickness and intervals calculated at 38° Dip.
Logs are drawn to actual drill record scale (Not normal thickness).
Kootenay Sandstone
X-CUT ENTRY
X-CUT Core Hole
PLATE IV
COAL LOGS
ELK RIVER COAL FIELD
264
K- ELK RIVER 68 (2) A.



F-F'
S-T
COAL BEDS
B-C
D
F'
F
G
H
I
J
K
L-M
N
P
Q
R
S
T
FEET
264
K-ELK RIVER 68(2)A.
PLATE IV-A
LOGS OF COAL BEDS ALONG WEARY RIDGE
COAL
BONEY COAL
CARB. SHALE
SHALE W/COAL
SHALE
SANDSTONE
SCALE 1"=2'
B-C
D
F-F'
G
H
I
K
L-M
N
P
Q
S-T

PLAN OF PRELIMINARY SURVEY TO LOCATE BOUNDARIES OF ELK RIVER COAL LEASES SITUATED NORTHERLY FROM NATAL B.C.

SCALE: 1 INCH = 1000 FEET

PLATE V

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LEGEND

LOT BOUNDARY LINES AS PROJECTED FROM OLD WOODEN POST FOUND IN 1951 BY S.V. SHAYLER B.C.L.S AT S.E.COR. OF LOT 6848 AND SHOWN ON PLAN R/W 521, LOT BOUNDARY DISTANCES AND BEARINGS DERIVED FROM ORIGINAL FIELD NOTES.

LOT BOUNDARY LINES AS ESTABLISHED FROM TRAVERSE TIES TO PROMINENT TOPOGRAPHIC FEATURES RECORDED IN ORIGINAL SURVEY FIELD NOTES

TRAVERSE LINES

△ TRAVERSE STATIONS (WOODEN HUB)

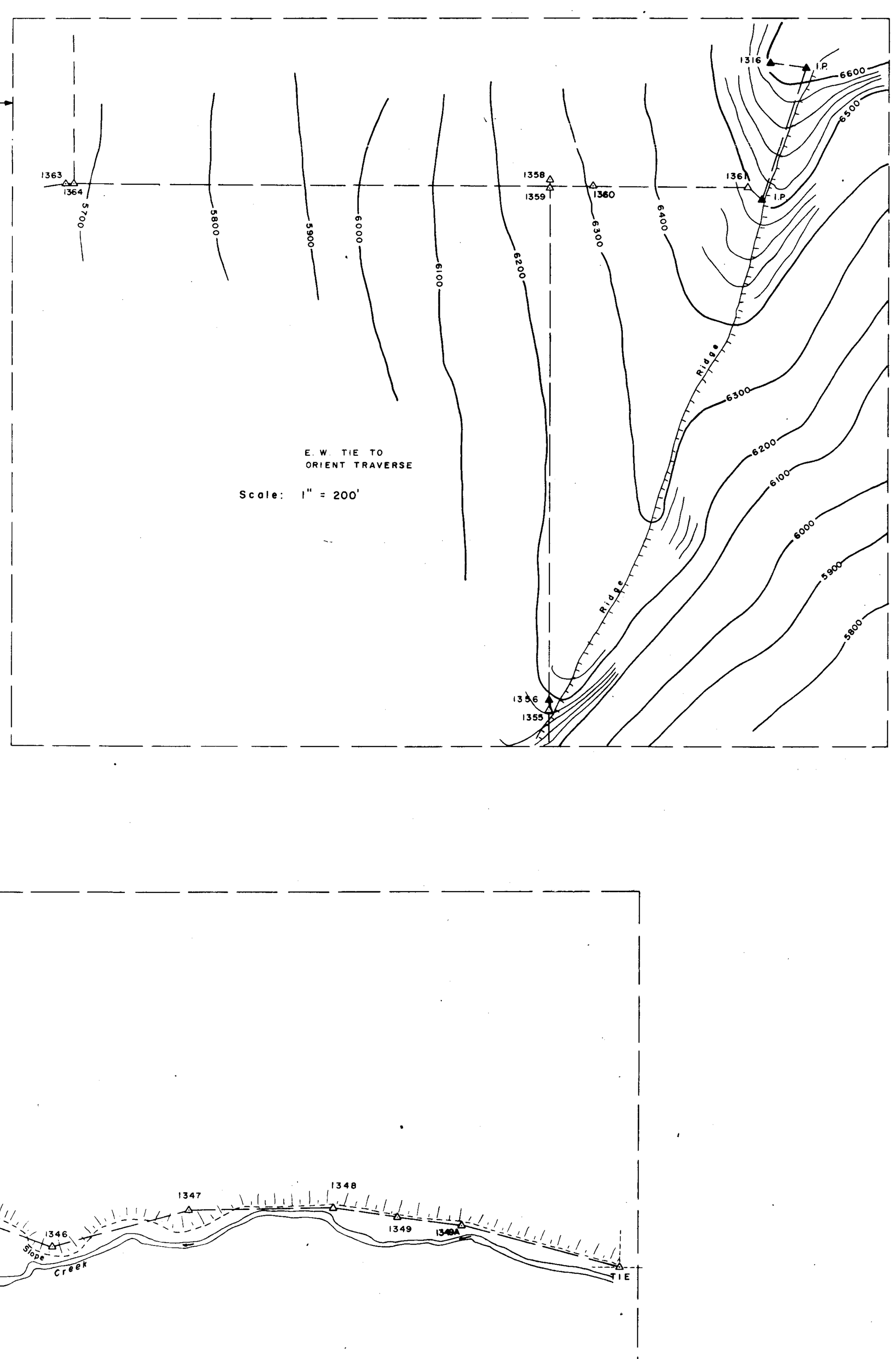
▲ TRAVERSE STATIONS (30" IRON BAR)

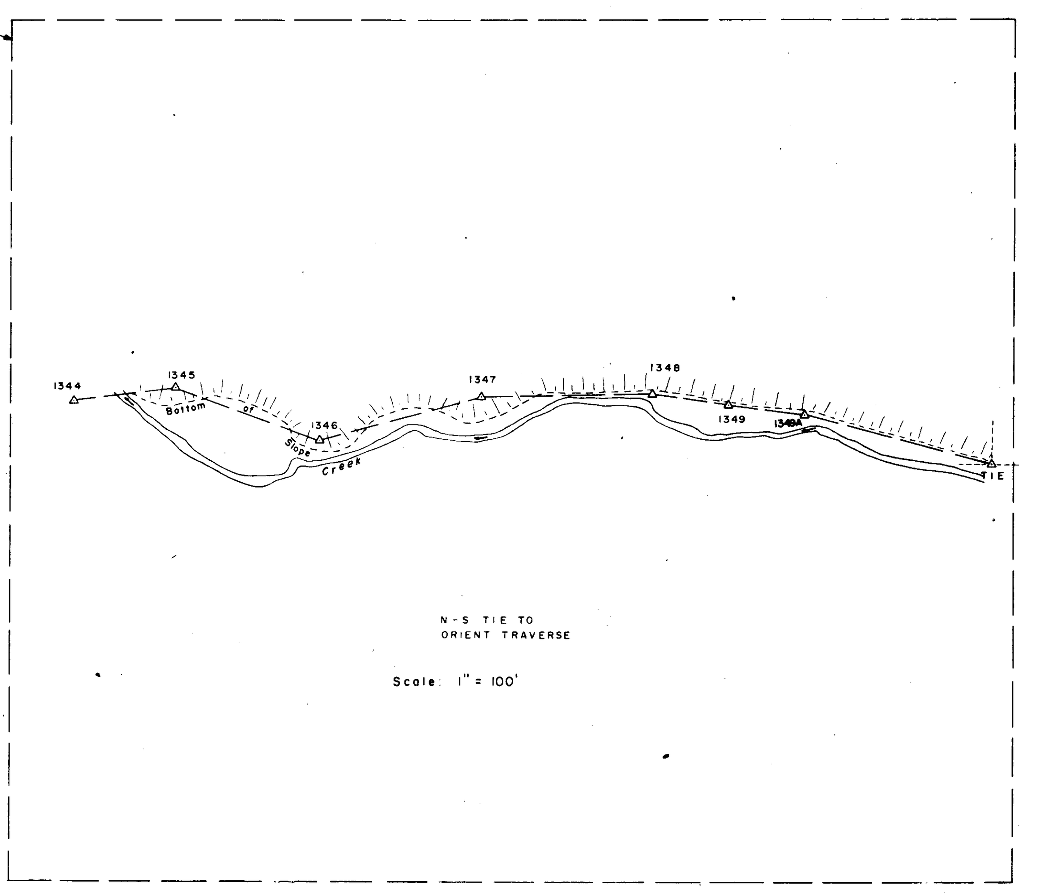
⊙ DRILL HOLES

● O.I.P. IRON POST FOUND

○ OP WOOD POST FOUND

TRAVERSE HUBS 1320 TO 1323 AND 1301 TO 1311 ARE SITUATED ON THE CLEARED, POWER LINE RIGHT OF WAY. BEARINGS ARE DERIVED FROM A STELLAR OBSERVATION AT STATION 1303 AND REFERRED TO THE MERIDIAN THROUGH THIS STATION





TRAVERSE TABLE

	STA	NORTH Co-ordinate	EAST Co-ordinate	BEARING	DIST	APPROXIMATE CO-ORDINATES SCALED FROM MEAN FIT OF SPARTAN MAPPING NORTH	EAST
TRAVERSE ALONG POWER TRANSMISSION LINE	O.P. S.E. COR. L. 6848	Assumed 0.00	1,000.00			267,850	122,495
	I.P. No. 60	2.71	365.01	N 89° 45' 21" W	635.00	267,835	121,860
	I.P. No. 61	302.08	432.03	N 12° 37' 09" E	306.78	268,136	121,919
	1320	537.73	510.21	N 18° 21' 12" E	248.28	268,374	121,990
	1321	5,956.80	2,959.07	N 24° 19' 06" E	5,946.72	273,860	124,282
	1322	11,261.90	5,172.06	N 22° 38' 34" E	5,748.17	279,227	126,343
	1323	16,562.78	7,910.48	N 27° 19' 15" E	5,966.44	284,604	128,929
	1301	26,726.60	10,365.48	N 13° 34' 46" E	10,456.17	294,834	131,092
	1302	27,153.37	10,480.21	N 15° 02' 49" E	441.92	295,264	131,195
	1304	36,542.75	9,540.73	N 5° 42' 50" W	9,436.28	304,622	129,988
	1305	39,571.30	9,614.59	N 1° 23' 49" E	3,029.46	307,652	129,975
	1306	43,383.34	9,074.07	N 8° 04' 14" W	3,850.16	311,447	129,326
	1307	48,271.84	8,380.16	N 8° 04' 45" W	4,937.48	316,314	128,492
	1308	53,010.60	6,547.12	N 21° 08' 50" W	5,080.91	320,998	126,525
	1309	53,622.71	6,341.55	N 18° 33' 47" W	645.71	321,604	126,301
	1310	57,629.53	4,816.94	N 20° 49' 56" W	4,287.07	325,566	124,663
	1311	63,040.80	3,512.66	N 13° 33' 05" W	5,566.23	330,935	123,205
	1304	36,542.75	9,540.73			304,622	129,988
	1303	31,079.39	10,079.23	S 5° 37' 45" E	5,489.82	299,176	130,682
TRAVERSE TO VICINITY S.E. L6825	1301	26,726.60	10,365.48			294,834	131,092
	1340	26,698.28	10,950.81	S 87° 13' 50" E	586.02	294,822	131,678
	1341	26,550.84	11,345.63	S 69° 31' 21" E	421.45	294,686	132,076
	1342	26,340.18	11,555.43	S 44° 53' 02" E	297.31	294,482	132,293
	1343	26,292.08	11,694.78	S 70° 57' 25" E	147.42	294,438	132,433
	1344	26,058.96	12,074.72	S 58° 28' 03" E	445.76	294,215	132,819
	1345	26,072.80	12,191.21	N 83° 13' 19" E	117.31	294,232	132,936
	1346	26,013.17	12,357.32	S 70° 15' 11" E	176.49	294,178	133,103
	1347	26,064.37	12,545.17	N 74° 45' 16" E	194.70	294,234	133,290
	1348	26,066.81	12,741.54	N 89° 17' 23" E	196.39	294,242	133,486
	1349	26,051.96	12,830.31	S 80° 30' 00" E	90.00	294,230	133,575
	1349A	26,043.33	12,919.90	S 84° 30' 00" E	90.00	294,224	133,665
	TIE ±	25,984.54	13,131.90	S 74° 30' 00" E	220.00	294,171	133,878
TRAVERSE TO VICINITY S.E.L.6386, N.E.L.6825, N.E. L.6383, N.E.L.6387 & N.E.L.1934	1303	31,079.39	10,079.21			299,176	130,682
	I.P.	31,268.87	10,060.54	N 5° 37' 45" W	190.39	299,365	130,658
	1330	31,268.25	11,053.17	S 89° 57' 51" E	992.63	299,393	131,650
	1351	31,268.07	11,333.82	S 89° 57' 51" E	280.65	299,400	131,931
	1352	31,267.95	11,525.08	S 89° 57' 51" E	191.26	299,406	132,122
	1353	31,267.09	12,741.66	S 89° 57' 51" E	1,216.58	299,440	133,338
	1354	31,266.98	13,068.33	S 89° 57' 51" E	326.67	299,449	133,665
	1355	35,097.82	13,070.59	N 00° 02' 02" E	3,830.84	303,278	133,557
	1356	35,127.54	13,070.60	N 00° 02' 02" E	29.72	303,308	133,557
	1358	36,555.84	13,070.41	N 00° 00' 28" W	1,428.30	304,736	133,516
	1359	36,537.61	13,070.41	S 00° 00' 28" E	18.23	304,718	133,517
	1363	36,544.38	11,742.52	N 89° 42' 28" W	1,327.91	304,687	132,189
	1364	36,544.38	11,768.23	S 89° 42' 28" E	25.71	304,687	132,215
	1365	38,325.50	11,773.02	N 00° 09' 15" E	1,781.25	306,468	132,169
	1367	46,960.13	11,795.39	N 00° 08' 55" E	8,634.65	315,100	131,944
	1369	51,973.17	6,956.48	N 43° 59' 15" W	6,967.47	319,972	126,964
	1370	52,762.53	6,647.22	N 21° 23' 40" W	847.78	320,753	126,633
	1308	53,010.60	6,547.12	N 21° 58' 02" W	267.50	320,998	126,525
TRAVERSE TO RIDGE ALONG COMMON BDY. TO LOTS 6384 & 6385	1359	36,537.61	13,070.41			304,718	133,517
	1360	36,537.13	13,188.50	S 89° 46' 05" E	118.09	304,721	133,635
	1361	36,535.40	13,614.08	S 89° 46' 05" E	425.59	304,731	134,061
	I.P. NEAR RIDGE TIE	36,498.68	13,653.01	S 46° 40' 05" E	53.51	304,696	134,100
	I.P.	36,863.54	13,774.64	N 18° 26' 20" E	384.60	305,064	134,212
	1316	36,877.79	13,676.36	N 81° 44' 17" W	99.31	305,075	134,113
TRAVERSE LOOP CLOSURES	1302	27,153.37	10,480.21			295,264	131,195
	1316	36,877.79	13,676.36	N 18° 11' 40" E	10,236.20	305,076	134,112
	1304	36,542.75	9,540.73	S 85° 22' 08" W	4,149.20	304,622	129,988
	1302	27,153.37	10,480.21			295,264	131,195
	1317	38,353.83	14,594.37	N 20° 10' 10" E	11,932.15	306,577	134,987
	1304	36,542.75	9,540.73	S 70° 17 04" W	5,368.34	304,622	129,988
	1304	36,542.75	9,540.73			304,622	129,988
	1318	40,049.64	15,058.95	N 57° 33' 49" E	6,538.28	308,285	135,404
	1306	43,383.34	9,074.07	N 60° 52' 53" W	6,850.75	311,447	129,326
	1310	57,629.53	4,816.94			325,566	124,663
	1319	56,208.91	8,044.23	S 66° 14' 29" E	3,526.13	324,238	127,930
	1311	63,040.80	3,512.66	N 33° 33' 22" W	8,198.18	330,935	123,205
	1316	36,877.79	13,676.36			305,076	134,112
	1320	537.73	510.21	S 19° 54' 16" W	38,651.62	268,136	121,919

McElhanney Associates
Professional Land Surveyors
1200 West Pender Street
Vancouver 1, B.C.
Job No. 03097-0

K-ELK RIVER 68 (2)A.

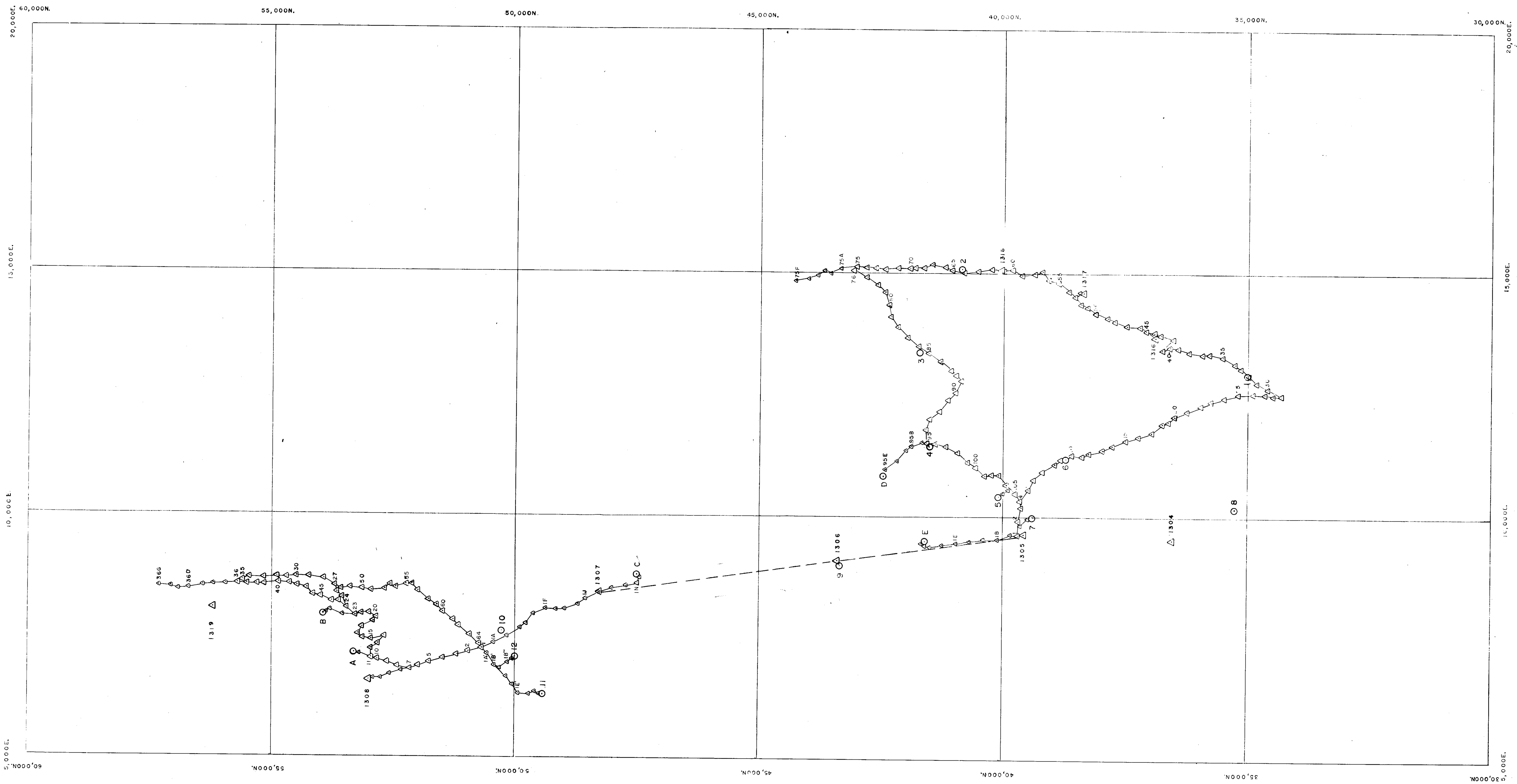


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PLATE VI - NACCO SURVEY OF ELK RIVER COAL FIELD

SCALE 1 INCH = 1000 FEET

K- ELK RIVER 68 (2) A.

LEGEND

- — — TRAVERSE LINES
- △ SURVEY STATION (McELHANNEY)
- △65 SURVEY STATION (NACCO)
- ○8 DRILL HOLE
- ○E CORE HOLE