GEOLOGICAL SURVEY CIRCULAR 310

STRIPPING-COAL DEPOSITS ON LOWER LIGNITE CREEK NENANA COAL FIELD, ALASKA

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By Clyde Wahrhaftig and Joseph H. Birman

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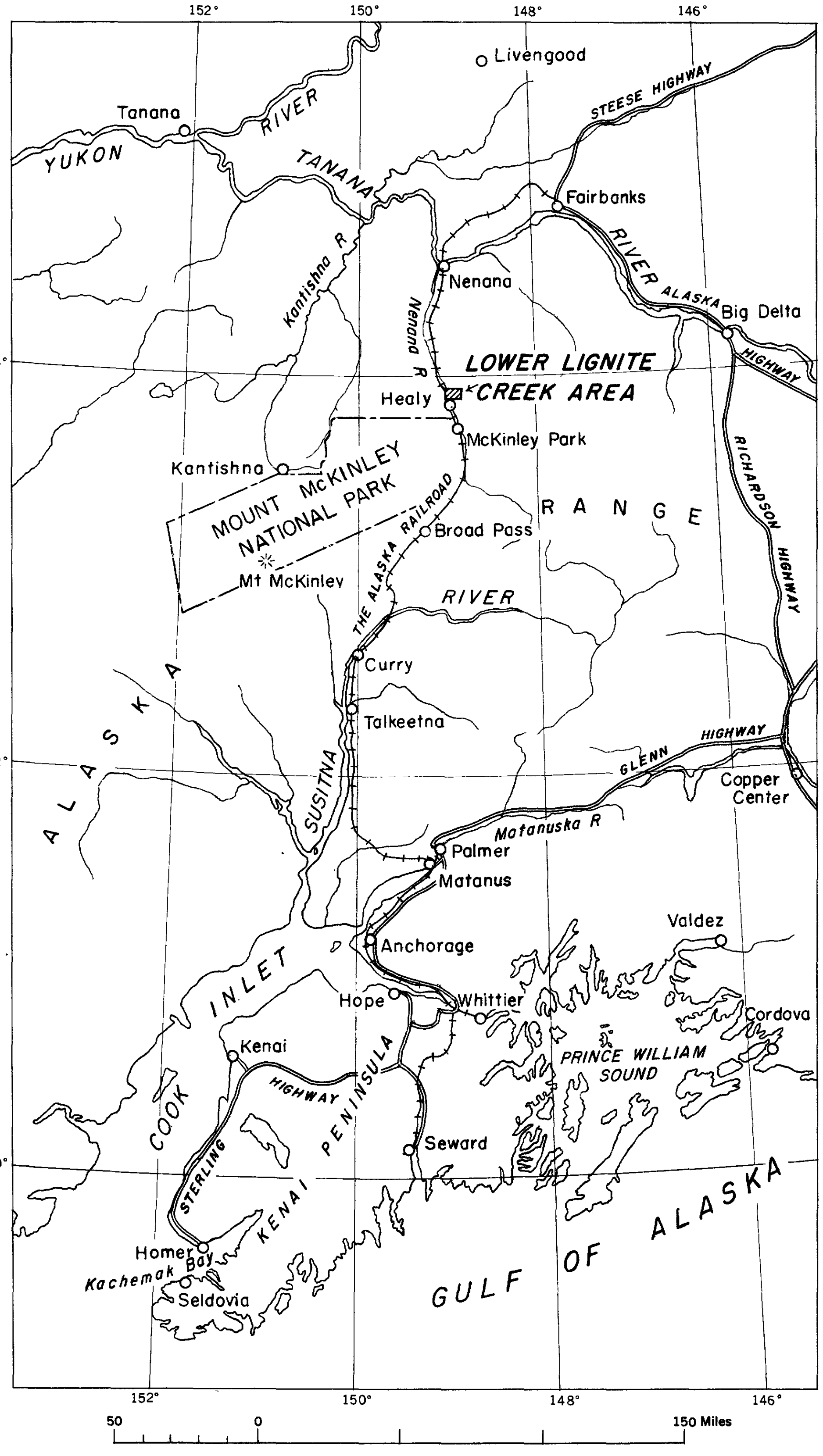

Figure 1.—Map of south-central Alaska, showing location of lower Lignite Creek area.

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ABSTRACT

Stripping-coal reserves in an area of about 24 square miles extending from the Nenana River about 6 miles up the valley of Lignite Creek are estimated to amount to about 95,000,000 tons. The stripping-coal reserves are located in the lower and middle members of the Tertiary coal-bearing formation. Five continuous beds in the middle member range in thickness from 5 to 30 feet, and a discontinuous bed at the base of the lower member is about 60 feet thick. Analyses of outcrop samples, as received at the laboratory, show a heating content of 7,500—8,200 Btu, an ash content of 6 to 14 percent, and a moisture content of 25 percent. The reserve estimate is based on a maximum thickness of overburden of 200 feet. Coal below the level of Lignite Creek or its major tributaries was not considered as it was assumed that stripping would be by hydraulic methods. Uncertainties regarding the position of the coal outcrops and the extent of

burning of the coal beds are the basis for a recommendation that, where possible, the stripping reserves be tested by drilling.

Overburden consists largely of weakly consolidated sandstone and includes some coarse gravel and a few boulders 20 feet or more in diameter. Water for hydraulic mining can be obtained from the Nenana River. Lignite Creek does not appear to be a dependable source. Disposal of debris may affect the channel of the Nenana River causing damage to railroads and structures. Landslides are common in the valley of Lignite Creek and will affect mining operations and transportation routes.

INTRODUCTION

In 1952 the Geological Survey, in an effort to locate and evaluate deposits of readily available stripping coal in Alaska, started an investigation of coal deposits on lower Lignite Creek in the Nenana coal field, where previous investigations had indicated that considerable deposits of stripping coal might be found.

The stripping-coal deposits on lower Lignite Creek lie in the southern two tiers of sections in T. 11 S., R. 7 W., and in the northern tier of sections in T. 12 S., R. 7 W., F. B. M. The deposits are between 1 and 6 miles east of the Alaska Railroad at Lignite, which is on the opposite side of the Nenana River from Lignite Creek. Lignite is 108 miles by rail south of Fairbanks and 248 miles north of Anchorage (fig. 1). At present the only means of access to Lignite Creek is by foot or horseback.

Field investigations of the stripping coal were made during the period June 25 to July 15, 1952. Food and camping equipment were cached at two campsites earlier in June by helicopter. The field work consisted of measuring all coal outcrops on lower Lignite Creek and plotting the coal outcrops, as well as other pertinent geologic information, on manuscript copies of topographic maps that were prepared by multiplex methods by the Topographic Division of the Geological Survey on a scale of 1:20,000. From this information a structure-contour map of a key coal bed was constructed, and areas where the coal beds were overlain by less than 200 feet of overburden were outlined. Attention was paid also to geologic factors, such as landslides, burning of coal beds, and water supply, that would affect the extraction of the coal and its transportation to the railroad.

GEOLOGY

Stratigraphy

The general geology of the Lignite Creek area has been described by Wahrhaftig, Hickcox, and Freedman (1951). The reader is referred to their report for the detailed descriptions of the formations. The lithologic descriptions given in their report are not repeated below but are supplemented where necessary.

Birch Creek schist

The oldest formation in the area is the Birch Creek schist, a highly contorted black to gray quartz-sericite schist cut by numerous veins of milky quartz. The Birch Creek schist crops out over much of secs. 1 and 2, T. 12 S., R. 7 W., and secs. 35 and 36, and the SE$\frac{1}{4}$ sec. 34, T. 11 S., R. 7 W. (See pl. 1.) It forms the core of a westward-plunging anticline and is in fault contact on the south with the Nenana gravel. On the west and north it is overlain unconformably by the coal-bearing formation.

Coal-bearing formation

The Tertiary coal-bearing formation has been divided by Wahrhaftig, Hickcox, and Freedman (1951, p. 147-152) into three members. The lower member crops out chiefly along the north side of Lignite Creek as far west as the western part of sec. 34, T. 11 S., R. 7 W. It contains one thin discontinuous coal bed near the top (fig. 2, sections 2 and 7), which is apparently correlative with the "F" bed of the Suntrana mine and is too thin to be mined by stripping.

A very thick coal bed has been observed at two places at the base of the lower member: in the E$\frac{1}{2}$ sec. 35, T. 11 S., R. 7 W., and at the mouth of the small stream that drains most of sec. 3, T. 12 S., R. 7 W. (pl. 1). Clinker, apparently from the burning of this coal bed, forms bright-red outcrops that rest on schist on the south bank of Lignite Creek in sec. 35 and on the north bank of the creek in sec. 34, T. 11 S., R. 7 W. This coal bed, herein referred to as the "basal coal bed," is about 60 feet in total thickness on the west bank of Lignite Creek in the E$\frac{1}{2}$ sec. 35 (fig. 2, section 6), and is at least 65 feet thick in the exposure at the mouth of the stream that drains sec. 3 (fig. 2, section 4). In sec. 35, however, it interfingers southward at the base with coarse talus breccia consisting of fragments of quartz and Birch Creek schist. To the north it is cut off by a fault that trends about N. 50°-60° E. and passes westward down the middle of Lignite Creek. For most of its length the south side of the fault is the downthrown side. At the east end, however, the north side may be the downthrown side. North of the fault, the lower few hundred feet of the coal-bearing formation is well exposed along the creek in the W$\frac{1}{2}$ sec. 35, and the coal bed south of the fault is not represented in the exposures on this creek, which consist entirely of sandstone and claystone, with a few bony layers. Presumably the fault was active during the deposition of the coal or immediately after its deposition, and the coal accumulated or was preserved in the downtilted portion of a small fault block.

The presence of the lower member of the coal-bearing formation west of sec. 3, T. 12 S., R. 7 W., beneath younger rocks, is uncertain. Evidence gathered by the senior author from other parts of the coal field suggests that it may not extend west of sec. 3; but if it should continue westward, any coal in the lower member would be considerably below the level of Lignite Creek and could be mined only by underground methods.

The middle member of the coal-bearing formation crops out in the hills north of Lignite Creek between the east border of the area shown in plate 1 and the

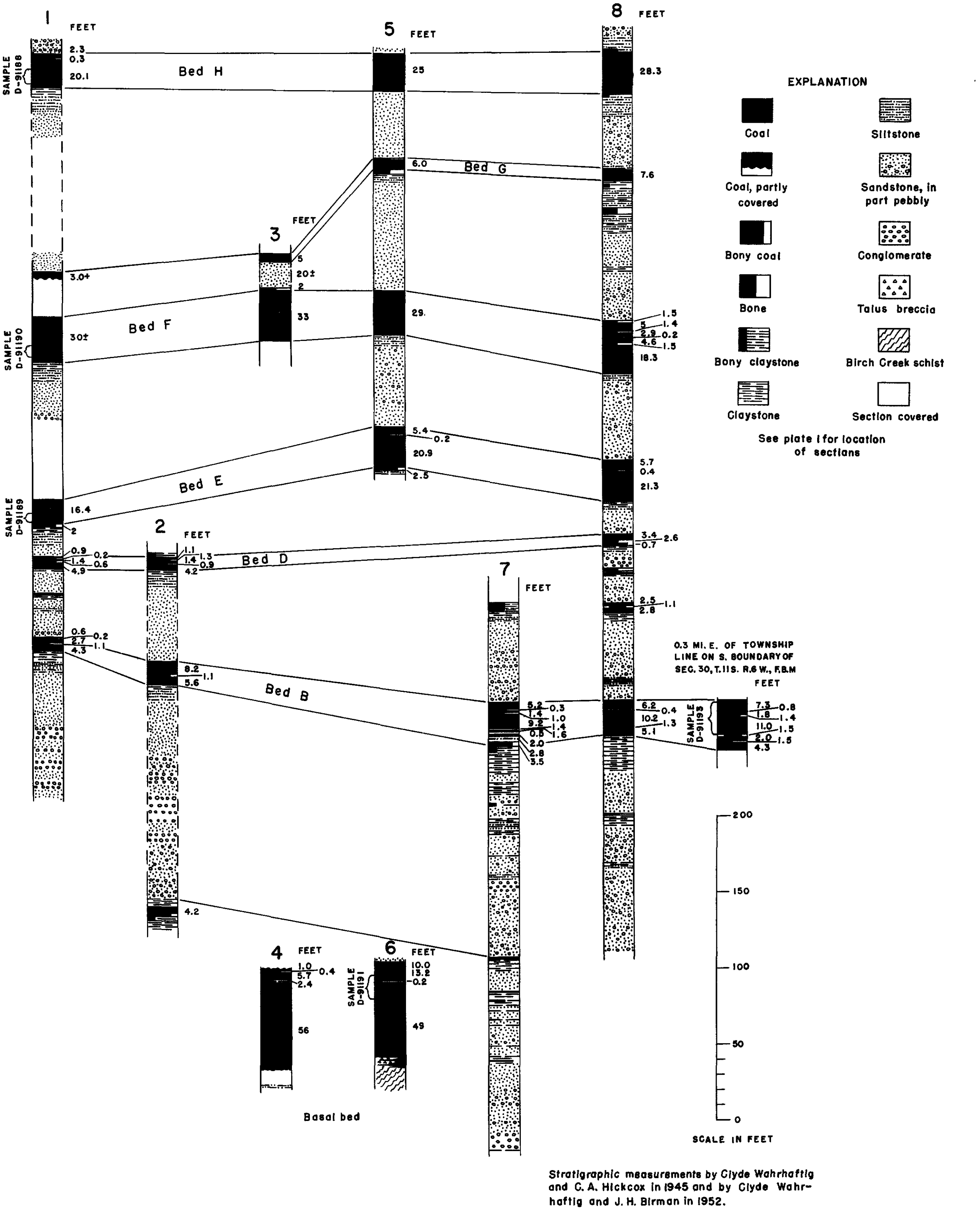

Figure 2. —Correlated stratigraphic sections of the stripping-coal beds on lower Lignite Creek, Nenana coal field, Alaska.

western part of sec. 5, T. 12 S., R. 7 W.; on the south side of Lignite Creek it crops out in parts of secs. 3, 4, and 5, T. 12 S., R. 7 W. A narrow belt of steeply dipping beds of the middle member extends along the south border of sec. 2, T. 12 S., R. 7 W.

The coal beds of the middle member are generally thick and very persistent laterally. They can be correlated with considerable certainty from outcrop to outcrop along Lignite Creek, and most of the same beds have been recognized farther south on Healy Creek and to the north in the basin of California Creek, as well as elsewhere in the Nenana coal field. Outcrops of the middle member on the east bank of the Nenana River 2 miles north of Lignite Creek, on the west bank of the Nenana at Healy, and at the Diamond coal mine $3\frac{1}{2}$ miles southwest of Healy indicate that the middle member underlies all the area shown in plate 1 north and west of its belt of outcrop and south of the great fault along the north border of secs. 9, 10, 11, and 12, T. 12 S., R. 7 W. South of this fault, however, it has been displaced downward to several thousand feet below the surface. All the stripping-coal reserves on lower Lignite Creek, with the exception of those in the thick bed at the base of the lower member, lie in the middle member.

The upper member of the coal-bearing formation crops out north, west, and south of the outcrop area of the middle member. It is in fault contact with the Nenana gravel along the north border of secs. 8, 9, and 10, T. 12 S., R. 7 W. The lithology of the upper member has been described by Wahrhaftig, Hickcox, and Freedman (1951, p. 149 and 151-152) and will not be reviewed here. The upper member contains no deposits of stripping coal.

Nenana gravel

On lower Lignite Creek the coal-bearing formation is overlain with apparent conformity by the Nenana gravel. In the western part of the Nenana coal field the Nenana gravel rests unconformably on the coal-bearing formation (Wahrhaftig, 1951, p. 182-183). Unpublished results of investigations to the east and north of Lignite Creek by the senior author have shown that, in general, the relationship between the two formations is an unconformity and that the apparent conformity on Lignite Creek and Healy Creek is an exception. The lithology of the Nenana gravel has been described by Wahrhaftig, Hickox, and Freedman (p. 152-153) and will not be reviewed here. The Nenana gravel crops out north of the belt of outcrops of the coal-bearing formation in secs. 25, 26, 27, 28, 29, and 30, T. 11 S., R. 7 W., and underlies most or all of secs. 8, 9, 10, 11, and 12, T. 12 S., R. 7 W.

Terrace gravel

Extensive terraces and pediments have been cut by the Nenana River, Lignite Creek, and their tributaries and are mantled by gravel deposits. The terraces and pediments fall into two groups on the basis of height above stream grade. Those of the higher group are 300 to 600 feet above the present level of Lignite Creek and the Nenana River; this group includes the extensive plain at 1,700-1,900 feet in altitude in secs. 4, 5, 8, and 9, T. 12S., R. 7W., and the broad flats 300 to 600 feet above Lignite Creek which form most of the interfluves between tributaries to Lignite Creek from the north. Some of these flats are half a mile wide from east to west and $1\frac{1}{2}$ miles long from north to south. The higher flats north of Lignite Creek slope toward the creek at gradients of about 400 to 500 feet per mile and are mantled with a layer of gravel derived from hills of Nenana gravel to the north. This layer of gravel is commonly between 50 and 100 feet thick but locally reaches a thickness of 150 feet. It is exposed at the tops of bluffs along the north side of Lignite Creek. The broad flat south of Lignite Creek is underlain by a similar layer of gravel, deposited by Lignite Creek and the Nenana River. The thickness of this gravel ranges from a few inches in the eastern part of sec. 4 to 85 feet at the north end of the bluff along the Nenana River in sec. 5. The average cobble size of the gravel exposed in this bluff is between 3 and 6 inches, and the largest boulders observed are 4 feet in diameter. The higher terraces were formed during the later glacial stages of this region and dissected during interglacial and postglacial time.

The lower terraces range in height from 5 to 50 feet above present stream grade. The lowermost generally consist entirely of stream gravel. The higher of this group (more than 10 feet high) generally are bedrock terraces overlain by a veneer of gravel 3 to 10 feet thick. The stream gravel is usually coarse; average cobble size is from 3 to 6 inches, and boulders up to 3 or 4 feet in diameter are common. The lower terraces were formed after the maximum expansion of the latest great ice sheet in this region.

Glacial erratics

Gigantic boulders of granite, greenstone, and conglomerate are widely scattered over the area shown in plate 1 but are not shown on the map. They are sparsely scattered over the terraces and hillsides—one boulder to every acre or every few acres—and there is commonly one every few hundred feet along most of the tributaries of Lignite Creek. A total of 244 boulders larger than 5 feet in diameter was counted in the active floodplain of Lignite Creek in the area of plate 1; the greatest concentration, around a sharp bend of Lignite Creek in the N$\frac{1}{2}$ sec. 3, T. 12 S., R. 7 W., is about 165 per mile. Some of these boulders are as much as 30 or 40 feet on a side. Most of them are granite. They were deposited by an early Pleistocene glaciation on a surface now completely destroyed in this area and have been let down, without much lateral movement, as much as 1,500 feet, as the finer grained materials beneath them were removed by erosion.

Landslides

About 11 percent of the total area along lower Lignite Creek that is likely to be involved in the strip mining and transportation of coal is covered by active or dormant landslides. In some sections, such as secs. 3 and 5, T. 12 S., R. 7 W., this proportion is as high as 20 percent. The landslides are concentrated along the walls of the valley of Lignite Creek and the canyons of its tributaries. In many of the canyons landslides meeting from opposite walls have dammed the creeks and caused them to form alluvial plains underlain by gravel and sand. Geologically, the loci of most of the landslides are bedding planes where ground water is concentrated in fine material on the top of an impervious layer. Such bedding planes are common at the base and top of coal beds, in shale beds, and at the base of the coal-bearing formation. The landslides may be caused by oversteepening of banks, lateral or downward erosion by streams, headward erosion of gullies, burning out of coal beds, or, presumably, by unusual concentrations of ground water at certain horizons during exceptionally wet seasons. Some landslides and earthflows on Lignite Creek have been observed to move with considerable rapidity—as much as several feet per minute on slopes as gentle as 3° or 5°. Many of the landslides on Lignite Creek have slopes of less than 10°. Most of the landslides are slumps characterized by semicircular headwall scarps and by the presence of unit blocks of considerable aerial extent near their heads. Earthflows and debris slides are common, however, particularly on frozen claystone which has been exposed to thawing.

Structure

The major structural features of lower Lignite Creek are a bifurcating, westward-plunging anticline and, bounding the anticline on the south, a steeply dipping reverse fault. (See pls. 1 and 2.) The anticline bifurcates westward in the middle of sec. 1, T. 12 S., R. 7 W. The southern branch trends about due west and lies just south of the township line between Tps. 11 and 12 S. Dips along the north flank of this branch are 5° -12° N. The westward plunge of the axis averages about $3\frac{1}{2}$°, or roughly 300 feet per mile. The plunge of the axis ranges from 2° W., near the east border of sec. 4, to 10° W., in the western part of sec. 5. Between the axis of the southern branch and the fault are several minor folds with amplitudes generally less than 50 feet. These are exposed in cross section on the west wall of the canyon in the E$\frac{1}{2}$ sec. 4. They are indicated on the structure contour map (pl. 2) by waviness of the structure contours in that area. The northern branch trends about N. 55°-70° W. Dips range from 3°-15° N., on its north flank, and 7°-30° SW on its south flank. It plunges gradually westward but has at least one small dome. The syncline between the two forks of the anticline has an amplitude of 200 to 500 feet.

The fault that borders the anticline on the south forms the southern boundary of the area of minable coal on lower Lignite Creek. It is exposed in the valley of Gagnon Creek about 2 miles east of the east border of the area shown in plate 1 (Wahrhaftig, Hickcox, and Freedman, 1951, p. 154 and pl. 18). Here it is a reverse fault with a dip of 65°-75° N. At the east border of T. 12 S., R. 7 W., the fault brings the upper part of the Nenana gravel on the south against Birch Creek schist on the north, and its stratigraphic displacement is about 5,000 feet. West of the east part of sec. 2, T. 12 S., R. 7 W., the coal-bearing formation that wraps around the nose of the anticline in secs. 3, 4, and 5, T. 12 S., R. 7 W., forms the hanging wall of the fault at the surface. The fault passes westward into a southward-dipping monocline, in which the Tertiary rocks exposed in the east bank of the Nenana River dip vertically for a distance of 2,500 feet across the strike. All the stratigraphic units that have been recognized in the Nenana gravel are present in the 2,500-foot section in this bluff, which includes also most of the upper member of the coal-bearing formation. The distance across the strike, however, is not great enough to accomodate the equivalent stratigraphic sections exposed at several localities within a radius of a few miles of this bluff. It is necessary to assume that in the monoclinal folding considerable attenuation of the section has taken place, reducing its thickness by approximately 1,000 feet. The coal-bearing formation on the south side of the fault and its monoclinal westward extension, in T. 12 S., R. 7 W., lie more than 3,000 feet below the surface, beyond the range of possible coal mining.

Two minor faults cut the coal-bearing formation along Lignite Creek. The fault that bounds the basal coal bed, in sec. 35, T. 11 S., R. 7 W., has already been described. A small fault that dips about 35° SE and strikes roughly N. 45° E. cuts the coal beds on the south bank of Lignite Creek in the N$\frac{1}{2}$ sec. 4, T. 12 S., R. 7 W. Its displacement is about 30 to 40 feet.

In this area most of the folding and faulting of the coal-bearing formation took place shortly after the Nenana gravel was deposited. However, a gentle eastward-trending scarp about 50 feet high coincides with the trace of the major fault just south of the north border of secs. 8 and 9 and offsets the gravel-covered terrace south of Lignite Creek. Its presence suggests that there has been activity on this fault in Pleistocene time, after the formation of the terrace, which is the outwash of a presumably early Wisconsin glaciation. The outwash of a late Wisconsin glaciation on the west side of the river is not offset, so presumably the renewal of activity on the fault occupied only a short time within an interglacial epoch during middle Wisconsin time.

STRIPPING-COAL DEPOSITS

Distribution and quality of the coal

Six coal beds on lower Lignite Creek are believed to contain coal that is recoverable by stripping. These are bed H at the top of the middle member, beds G, F, E, and B, and the basal coal bed in secs. 3, T. 12 S., R. 7 W., and 35, T. 11 S., R. 7 W. (pl. 1). With the exception of the basal coal bed, these are all in the middle member and can be correlated with beds at the Suntrana mine on Healy Creek (Wahrhaftig, Hickcox, and Freedman, 1951, pl. 22). Bed H correlates with the no. 6 bed, bed G with the no. 5 bed, bed F with the no. 4 bed, bed E with the no. 3 bed, and bed B with the no. 1 bed. Bed H averages about 25 feet in thickness, bed G about 5 feet, bed F about 28 feet, and bed E about 20 feet. Reserves for bed B were calculated only for the eastern part of the area shown in plate 1; there it averages about 15 feet of coal with many partings. The basal bed contains about 60 feet of coal in the two places where it was measured. Coal beds B through H are separated by 50 to 150 feet of poorly consolidated sandstone, in part pebbly, with minor amounts of claystone and some thin coal beds. The thick coal beds have been traced from the mouth of Lignite Creek to Thistle Creek, 14 miles east, and from Suntrana on the south to MacAdam Creek on the north, a distance of 12 miles. In this area their thicknesses vary uniformly from centers of maximum thickness located near Lignite Creek, and the stratigraphic intervals between them vary within small limits.

Six samples of coal on lower Lignite Creek were collected for analysis during the course of the investigation, five from within the area of plate 1 and one 0.3 mile east of the east border of the area of plate 1. Analyses of these samples, as well as two others reported by Martin (1919, p. 8-9) are shown in table 1.

The coal is black, generally has a dull luster, and a dark-brown streak. The upper few feet of the coal beds above bed F have the appearance of a mat of intertwined twigs, but all beds from bed F downward, and the lower parts of beds G and H, have a blocky fracture. The coal has the same general appearance as coal from the same formations in the valley of Healy Creek, and has comparable heating qualities.

Stripping-coal reserves

Reserves of strippable coal on lower Lignite Creek were calculated in the following manner: a structure-contour map was first prepared on bed H, the uppermost bed, for which the greatest amount of data was available (pl. 2). Then, using the intervals taken from the stratigraphic sections (fig. 2), structure-contour maps of beds B, E, and F were constructed. In preparing the structure-contour map on bed F, the interval between beds F and H was assumed to be 150 feet; in preparing the structure-contour map on bed E, the interval between beds E and H was assumed to be 300 feet. These intervals, although not precise, are believed to be as accurate as the locations of outcrops on the map. For each bed, the points at which the structure contours crossed the topographic contours of the same altitude were joined to give the line of outcrop of the bed. The points at which each structure contour on bed H joined the topographic contour 100 feet higher were joined; between the curve so made and the outcrop, bed H is overlain by less than 100 feet of overburden. Similarly the points at which contours on bed H are crossed by topographic contours 200 feet higher were joined to delimit the area in which bed H is overlain by 100 to 200 feet of overburden. The 200-foot overburden line, at which the thickness of overburden equals 10 times the thickness of the coal bed, was arbitrarily selected as the cutoff for bed H. The areas of these reserves on bed H, as well as stripping reserves for bed B and the basal bed, are shown in plate 3.

The area between the outcrops of beds H and F is the area in which bed F would be overlain by less than 150 feet of overburden. Once bed H was mined out, bed F would be overlain by about 150 feet of overburden in the area formerly occupied by bed H, and so would be available for stripping. Within this 150 feet of overburden would be bed G, averaging 5 feet thick. The area underlain by reserves of bed F is shown in plate 4. Similar considerations apply to bed E, except that only 60-90 feet of sandstone lie between beds E and F. Reserve areas in bed E are shown in plate 4. Reserves of bed B were computed in a similar manner. (See pl. 3.) No coal below drainage level on Lignite Creek or its major tributaries or below a level from which overburden could be sluiced to Lignite Creek was included in the stripping reserves.

For the basal bed different methods of calculation were used. Most of the basal bed in sec. 35, T. 11 S., R. 7 W., has been removed by erosion, so it was assumed that an average of 10 feet remained beneath the area underlain by this bed. In sec. 3, T. 12 S., R. 7 W., a strike length of 500 feet, a dip length of 100 feet, and an average thickness of 60 feet were assumed from the single outcrop of the basal bed.

For all the area except secs. 25 and 36, and the E½ secs. 26 and 35, T. 11 S., R. 7 W., the reserve areas were measured on the multiplex manuscript at a scale of 1:20,000. For secs. 25 and 36, and the E½ secs. 26 and 35, T. 11 S., R. 7 W., a planetable map of the coal outcrops at a scale of 1:4,800 had been prepared during the course of the 1946 investigations. The topography from the multiplex manuscript was enlarged to this scale and superposed on the outcrop map, and the reserve areas were measured at a scale of 1:4,800.

The stripping coal computed for the lower Lignite Creek area amounts to a little over 95 million short tons. Of this amount, 42 million tons lies south of Lignite Creek in secs. 3, 4, and 5, T. 12 S., R. 7 W.; 33 million tons lies north of Lignite Creek in secs. 33 and 34, T. 11 S., R. 7 W., and secs. 4 and 5, T. 12 S., R. 7 W.; and 20 million tons lies north of Lignite Creek in secs. 25, 26, 35, and 36, T. 11 S., R. 7 W. (See pls. 3, 4 and 5.) The U. S. Government coal reservation in sec. 32, T. 11 S., R. 7 W., and secs. 4 and 5, T. 12 S., R. 7 W., contains 21 million tons of stripping coal, nearly all of which lies within 2 miles of the Alaska Railroad.

The coal beds on lower Lignite Creek are exposed at intervals of 1 to 1½ miles, so that reserves calculated on the basis of these outcrops would normally be regarded as indicated reserves. However, several factors combine to make the calculation of stripping-coal reserves much more uncertain. It was felt that the quality of the field data available in the present outcrops did not warrant a detailed planetable survey, especially as the deposits would probably have to be tested by drilling in advance of mining. The multiplex manuscript map was, therefore, used as base. As this map has a contour interval of 100 feet, the positions of outcrops could rarely be determined with greater vertical accuracy than the nearest 50 or 100 feet. This large limit of error introduces very large uncertainties in the stripping reserves. For instance, if bed H were 100 feet lower on the south side of Lignite Creek than is shown on plate 2, very little stripping coal would exist south of the creek. If it were 100 feet higher, the amount of stripping coal south of the creek would be much greater, although the amount in bed H would be less. No allowance was made in the computed reserves for these uncertainties.

Another factor that makes the calculation of stripping reserves uncertain is the burning of coal beds. The coal of the coal-bearing formation has been burning at one time or another since early in the period of deposition of the Nenana gravel, for fragments of burned shale can be found in the lower part of the Nenana gravel (Wahrhaftig, 1951, p. 178). The coal has been burning throughout much of Quaternary time and is on fire at two places on lower Lignite Creek today. Presumably the fires are the result of natural

Table 1.—Analyses of coal on lower Lignite Creek

Bed	Sample no.[1]	Location	Thickness sampled (in feet)	Condition[2]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu	Collector and date
H	D-91188	$NW\frac{1}{4}$ sec. 5	9.9	A	26.0	35.5	28.6	9.9	0.2	7,630	Clyde Wahrhaftig and J. H. Birman, 1952.
				B		47.9	38.8	13.0	.2	10,300	
				C		55.3	44.7		.3	11,880	
F	D-91190	$N\frac{1}{2}$ sec. 5	7.4	A	27.4	34.5	30.1	8.0	.2	7,570	Do.
				B		47.5	41.4	11.1	.3	10,420	
				C		53.4	46.6		.3	11,710	
E	D-91189	$NE\frac{1}{4}$ sec. 5	6.2	A	27.6	35.0	31.6	5.8	.1	7,750	Do.
				B		48.3	43.7	8.0	.2	10,700	
				C		52.4	47.6		.2	11,630	
Basal	D-91191	West bank Lignite Creek in $E\frac{1}{2}$ sec. 35.	15.4	A	26.1	35.0	28.4	10.5	.2	7,810	Do.
				B		47.4	38.4	14.2	.3	10,580	
				C		55.3	44.7		.3	12,320	
Basal	D-91192	South bank Lignite Creek at west border sec. 36.	8.5	A	26.8	31.8	25.9	14.5	.2	6,880	Do.
				B		43.5	36.7	19.8	.3	9,400	
				C		54.3	45.7		.3	11,720	
B	D-91193	South edge $SW\frac{1}{4}$ sec. 30, T. 11 S., R. 6 W. F.B.M.	20.1	A	21.9	37.6	29.4	11.1	.2	8,230	Do.
				B		48.1	37.7	14.2	.3	10,540	
				C		56.1	43.9		.3	12,280	
H	26367	$NE\frac{1}{4}NW\frac{1}{4}$ sec. 5		A	25.30	36.08	32.64	5.98	.26	8,136	G. C. Martin, 1916.
				B		48.30	43.69	8.01	.35	10,892	
				C		52.51	47.49		.38	11,840	
F	26369	$NW\frac{1}{4}NW\frac{1}{4}$ sec. 35		A	23.83	35.55	28.87	11.75	.41	7,007	Do.
				B		46.67	37.90	15.43	.54	9,200	
				C		55.19	44.81		.64	10,879	

[1] Samples D-91188 to D-91193 analysed by Roy F. Abernethy, chemist, U. S. Bureau of Mines, Pittsburgh, Penn. Samples 26367 and 26369 quoted from G. C. Martin, 1919, p. 8-9.
[2] Condition: A, as received; B, moisture free; C, moisture and ash free.

causes: lightning, forest fires, or spontaneous combustion. Probably 60 percent of the outcrops of the coal beds in this area have been burned, and it is likely that burning is a major factor in the erosion of the coal beds, with very little coal being transported downstream.

Little is known of the extent of the burning, although some idea of the probable extent may be gathered from experience at the Suntrana mine on Healy Creek, where coal on the no. 3 bed was burned 50 to 100 feet back from the outcrop (C. E. Garret, personal communication, 1944). The outcrops of beds E, F, and H appear to be largely burned out on the south side of Lignite Creek. However, exposures of coal in gullies less than 50 feet deep, on the south wall of the valley of Lignite Creek, are nearly always unburned, and exposures in the headwalls of landslides are usually unburned. It is thought likely, therefore, that the extent of burned coal is, at most, 50 to 100 feet back from the outcrop and probably averages much less than 50 feet. In computing reserves no allowance was made for possible loss of coal through burning.

The stripping-coal reserves on lower Lignite Creek are shown on table 2. Reserves are computed for each bed in each 640-acre section, except that on the north side of Lignite Creek reserves in the N$\frac{1}{2}$N$\frac{1}{2}$ sec. 4, T. 12 S., R. 7 W., and in sec. 33, T. 11 S., R. 7 W., were computed as a unit, as were those in secs. 26 and 35, T. 11 S., R. 7 W., and in secs. 25 and 36, T. 11 S., R. 7 W., inasmuch as coal could not be mined in either section of these pairs without affecting the reserves in the other. Sec. 5, and the SW$\frac{1}{4}$ and S$\frac{1}{2}$NW$\frac{1}{4}$ sec. 4, T. 12 S., R. 7 W. and sec. 32, T. 11 S., R. 7 W., form a Government reservation (Martin, 1919, pl. 1). Consequently, the reserves in sec. 4 on the south side of Lignite Creek are broken into reserves in the west half, which lie in the Government reservation, and reserves in the east half, which lie outside the reservation.

Recommendations for future exploration

The main uncertainty about the stripping coal on the south side of Lignite Creek is the depth to the coal beds, and whether bed H lies just below the surface of the broad terrace south of the creek or has been removed by erosion. The presence of stripping coal in this bench could be proved by drilling. Because no water for core drilling is readily available on this plain, it is recommended that a power auger be used to test the coal. Two or three holes could be drilled in sec. 4, T. 12 S., R. 7 W., where bed H is covered by less than 100 feet of overburden. (See pl. 3.) If bed H is encountered a short distance below the surface or if the lithology of the sandstone indicates that bed H has been removed from this area (Wahrhaftig, Hickcox, and Freedman, p. 149-150), additional holes should be drilled 500 to 1,000 feet south of the first holes, to locate the outcrop of bed H. Once the outcrop has been determined, holes can be drilled farther south to determine the limits of stripping coal. A 100-foot hole drilled from the top of the bench in the E$\frac{1}{2}$SW$\frac{1}{4}$ sec. 3, T. 12 S., R. 7 W., would probably test reserves of coal in beds E and F (pls. 4 and 5).

After the extent of stripping-coal reserves, particularly of bed H, has been determined, drilling of holes at selected locations along Lignite Creek could be used to check the accuracy of the stratigraphic measurements; because on these would depend the accuracy of estimates of reserves of the lower beds, presumably out of reach of

Table 2.--Reserves of stripping coal on lower Lignite Creek

Bed	Thickness overburden (in feet)	Thickness coal (in feet)	Area (acres)	Reserves (in millions of tons)
	Sec. 3			
H	less than 100	22	32	1.1
G	about 100[1]	4	10	.06
F	less than 150	30	67	3.1
F	about 100[1]	30	5	.2
E	less than 50	19	70	2.1
E	about 50[1]	19	80	2.4
A	less than 50	60	2	.1
Total				9.06
	E$\frac{1}{2}$ sec. 4			
H	less than 100	22	53	1.8
H	100 to 200	22	48	1.6
G	about 100	4	104	.6
F	less than 150	30	37	1.7
F	about 150[1]	30	104	4.9
E	less than 50	17	22	.6
E	about 50[1]	17	136	3.6
Total				14.80
	SW$\frac{1}{4}$ and S$\frac{1}{2}$NW$\frac{1}{4}$ sec. 4			
H	less than 100	22	16	0.55
H	100 to 200	22	85	2.9
G	about 100[1]	4	98	.6
F	less than 150	30	34	1.6
F	about 150[1]	30	98	4.5
E	less than 50	17	21	.55
E	about 50[1]	17	104	2.8
Total				13.50
	Sec. 5, part south of Lignite Creek			
H	less than 100	22	16	0.55
H	100 to 200	22	29	1.0
G	about 100[1]	4	26	.2
F	less than 150	30	26	1.2
F	about 150[1]	30	26	1.2
E	less than 50	16	26	.6
E	about 50[1]	16	11	.3
Total				5.05
	Sec. 5, part north of Lignite Creek and Sec. 32			
H	less than 100	22	18	0.6
H	100 to 200	22	18	.6
G	about 100[1]	4	22	.1
F	less than 150	30	22	1.0
F	about 150[1]	30	6	.3
E	less than 50	16	10	.2
Total				2.80
	Sec. 33, and N$\frac{1}{2}$N$\frac{1}{2}$ sec. 4			
H	less than 100	22	32	1.1
H	100 to 200	22	43	1.5
G	about 100[1]	4	56	.35
F	less than 150	30	61	2.8
F	about 150[1]	30	56	2.6
E	less than 50	16	40	1.0
E	about 50[1]	16	100	2.5
Total				11.85

See footnotes at end of table.

Table 2.—Reserves of stripping coal on lower Lignite Creek—Continued

Bed	Thickness overburden (in feet)	Thickness coal (in feet)	Area (acres)	Reserves (in millions of tons)
		Sec. 34		
H	less than 100	22	43	1.5
H	100 to 200	22	58	5.0
G	about 50[1]	5	50	.4
F	less than 150	30	95	4.4
F	about 150[1]	30	50	2.3
E	less than 50	20	48	1.5
E	about 50[1]	20	114	3.6
Total				18.70
		W½ sec. 35 and W½ sec. 26		
H	less than 100	25	22	0.9
H	100 to 200	25	11	.4
G	about 50[1]	6	14	.1
F	less than 150	28	24	1.0
F	about 150[1]	28	14	.8
E	less than 50	25	21	.8
E	about 50[1]	25	30	1.2
Total				5.2
		E½ sec. 35 and E½ sec. 26		
H	less than 100	25	14	0.6
H	100 to 200	25	11	.5
G	about 50	7	31	[2] .4
F	less than 100	28	15	.7
F	100 to 200	28	31	[2]1.5
E	less than 100	25	34	[2]1.5
B	less than 150	15	24	[2] .6
Basal	---	10	15	.25
Total				6.05
		Sec. 36 and sec. 25		
H	100 to 200	28	27	1.3
H	less than 100	28	25	1.2
G	about 50	7	37	[2] .5
F	less than 100	25	20	.9
F	100 to 200	25	37	[2]1.6
E	less than 100	25	52	[2]2.3
B	less than 150	15	22	.55
Total				8.35
Grand total				95.36

[1] Overburden after next overlying thick bed has been mined.
[2] Includes reserves beneath overlying beds, available when overlying beds have been removed.

the power auger on the plain to the south. Vertical holes drilled where each of the coal beds crosses Lignite Creek would determine the approximate distance to the next bed below. Churn or core drilling could be used for these holes, as water from Lignite Creek would be available.

The chief uncertainty regarding stripping coal on the north side of Lignite Creek west of sec. 34, T. 11 S., R. 7 W., is the extent to which the coal has burned. The area underlain by stripping coal, shown in plates 3, 4, and 5 is a steep hillside; the coal dips gently into the hillside, and it would be impracticable to test this coal by drilling. Deep trenching far in advance of development also would be impracticable. A possible method of testing would be to sink test slopes from the outcrops of the burned coal beds to determine the distance to which burning has penetrated the bluff. Such slopes would require extensive timbering, because the broken and slumped ground above the burned coal beds is very heavy. Probably the most practical way of testing in advance of mining would be to hydraulic narrow strips down the slope, spaced a quarter to half a mile apart, using equipment already installed for mining coal on the south side of the creek. Much of the coal in secs. 34, 35, and 26, T. 11 S., R. 7 W., would also have to be tested for burning along steep slopes. However, the presence and condition of coal beneath the high flats in section 34 could be tested by power-auger drilling. Exposures in secs. 36 and 25, T. 11 S., R. 7 W., already indicate that strippable coal, sufficient to justify mining operations, exists in these sections.

FACTORS AFFECTING MINING OF THE COAL

Nature of the overburden

The overburden of the coal beds, and particularly the strata between the coal beds, consists largely of poorly consolidated sandstone and claystone with pebbly layers. Most of this material is perennially frozen. Experience at the Usibelli, Suntrana, and Cripple Creek mines on Healy Creek shows that this material can be removed easily and profitably by hydraulicking if it is allowed to thaw between periods in which water is played on the sandstone (A. Shallit, personal communication). Overlying the coal measures are terrace gravels ranging in thickness from a few inches to 150 feet. Those on the south side of Lignite Creek are thinner than those on the north side; over most of the potential stripping area they probably average less than 15 feet in thickness. However, they are very coarse and would probably have to be removed by bulldozing. The thick gravels on the north side of Lignite Creek are derived mostly from Nenana gravel north of the coal-bearing area. Some of this material is fine enough to be removed by hydraulicking, but some of it also would have to be removed by bulldozing. If planning and foresight are used in the entire mining operation, the gravel removed by bulldozing could be stockpiled and used later as road-metal and ballast beneath railroads, roadways, and structures.

The giant glacial boulders that are common in this area will probably have to be blasted before they can be removed by bulldozer. Those close to Lignite Creek, however, may prove valuable as a local source of riprap.

Source of water for hydraulic stripping

The two possible sources of water are Lignite Creek and the Nenana River. All other streams in the area have too low a normal flow to be considered likely sources for the quantity of water that would be needed. Two rough measurements were made of the flow of Lignite Creek. Cross sections were measured by determining depth to bottom at measured intervals across both ends of selected straight courses. The duration of travel time of chips dropped on the water at the upper end of each course was then determined, and the average of five trips was used for each measurement. Bottom roughness was considerable; boulders were exposed above water surface in many places on the courses. To allow for this extreme bottom roughness, the average velocity of the stream was assumed to be half the surface velocity. The first measurement was made at the east boundary of sec. 4, T. 12 S., R. 7 W., on July 5, 1952, $1\frac{1}{2}$ days after a heavy rain that lasted half a day. The flow of water was about 50 cubic feet per second. The second measurement was made just above the mouth of Popovitch Creek (in the $E\frac{1}{2}$ sec. 36, T. 11 S., R. 7 W.) on July 10, after a week of dry weather. The measured flow was about 20 cubic feet per second. Although these results are only approximate, they were taken during a period of high water on Lignite Creek, when snow was still melting near the headwaters, and probably indicate the maximum dependable water. From these measurements it does not appear that Lignite Creek would be a very dependable source of large quantities of water for hydraulicking.

The Nenana River offers a much more dependable source of water, as its normal flow is far greater than the requirements of hydraulic mining on Lignite Creek. A suitable site for a pumping station would be the low terrace near the southwest corner of sec. 5, T. 12 S., R. 7 W. The lift from this site to the top of the terrace in sec. 5, would be about 500 feet. From there it could be piped to stripping operations in secs. 3, 4, and 5, T. 12 S., R. 7 W., and secs. 33 and 34, T. 11 S., R. 7 W.

Disposal of debris

The hydraulicked debris could be moved by sluices to Lignite Creek, and delivered by that stream to the Nenana River. In order to prevent the debris from silting up the channel of Lignite Creek, the stream will probably have to be deepened and confined between retaining walls. Under such a regime it should be able to handle most of the pediment gravels on the north side of Lignite Creek.

The effect of considerable amounts of debris on the regime of the Nenana River is hard to predict. Assuming an annual production of the Lignite Creek strip mines of 500,000 tons per year and an average ratio of overburden to coal of about 7:1, approximately 80 to 90 million cubic feet of debris would be washed down Lignite Creek each year. This represents the removal of approximately $3\frac{1}{2}$ feet from 1 square mile. Investigations now in progress indicate that the average rate of lowering of badlands in the Nenana coal field is about 1 inch per year, and that, throughout the Pleistocene, approximately half of the erosion of the Lignite Creek basin has been by badland erosion, the remainder being by other processes, such as lateral corrasion and landslides. Badlands in the Lignite Creek basin total $1\frac{1}{2}$ square miles in area and contribute roughly 0.1 foot of material from that area per year. Thus the total amount of debris that is moved down Lignite Creek each year, if average conditions during the Pleistocene are assumed to prevail at the present time, is about 0.2 foot from $1\frac{1}{2}$ square miles, which is roughly equivalent to the removal of 0.3 foot from 1 square mile. The delivery of more than 10 times this amount of debris by hydraulic mining could have a serious effect on the regime of the Nenana River, possibly causing silting of the bed and channel changes on the alluvial fan of the river between Rex and Nenana. Such channel changes might seriously affect the Alaska Railroad, the Clear airport, and the town of Nenana and its dock facilities. The effect of excessive debris delivered to the Nenana River through strip mining on Healy and Lignite Creeks and their tributaries can be appraised more accurately when sediment studies now being made of the Nenana River by the Geological Survey are completed.

Landslides

The extensive landslides along lower Lignite Creek have been described in an earlier section of this report. They are distributed along the walls of the canyons of Lignite Creek and its tributaries and cover approximately 11 percent of the area that is likely to be involved in strip mining (pl. 1). Landslides will affect coal mining on Lignite Creek in many ways. Where landslides have affected the coal beds they have probably rendered the upper beds unfit for mining increasing the thickness of overburden above lower coal beds. This overburden, however, is already broken and is probably thawed and would very likely be moved easily by hydraulicking. The danger of landslides greatly restricts the area in which roads, railroads, and other installations may be built. This aspect of the landslide problem is considered in the following section on access to the coal field. The hydraulic method of stripping coal will probably increase the danger of landsliding. Two kinds of landslide are possible: rock and debris falls from sandstone cliffs, and slumps along bedding planes. The first kind will be a natural and unavoidable consequence of the hydraulicking methods and could be deliberately induced to speed stripping; if desired, it can be kept to a minimum by keeping slopes in sandstone less than 45°. The second kind, slumps along bedding planes, could involve areas as large as 40 acres or more. In order to reduce the danger of these slumps, the strip-mining operation should be planned so that all bedding planes on which sliding could take place would dip into the pit face. Lignite Creek flows along the axis of an anticline, and the beds for the most part dip away from the creek. Thus, it should be possible to keep bedding planes dipping into the pit face while strip mining is going on. The only places where the attitude of the beds is favorable to slumping on a large scale at present are in the $SW\frac{1}{4}$ sec. 3, T. 12 S., R. 7 W., and the $SW\frac{1}{4}$ sec. 34, T. 11 S., R. 7 W. As would be expected, these areas are already the sites of some of the most extensive landslides.

Badland erosion

Once the strip mines are abandoned, they will become the sites of extensive badlands, unless measures are taken to reforest them. The badlands will supply excessive amounts of debris to Lignite Creek and the Nenana River, and will also cause the erosion of valuable coal reserves. The coal beds, if left exposed, would be susceptible to burning. It is recommended that, as soon as strip mining in a given area has reached the limits of economic feasibility, the exposed edges of the coal beds be covered with a mixture of sand and clay and the hillsides graded and planted to forest or other suitable vegetation.

Access to the coal field

The shortest and most practical rail or road route to connect the coal field on lower Lignite Creek with the Alaska Railroad would extend from a point on the railroad about half a mile south of Lignite, cross the Nenana River at a point just north of Lignite Creek, and follow Lignite Creek to the coal deposits. Using this route, the coal deposits closest to the railroad would have a haulage of 1 to $1\frac{1}{2}$ miles, and those in secs. 25 and 36, T. 11 S., R. 7 W., would have a haulage of $5\frac{1}{2}$ to 6 miles.

A road or railroad along Lignite Creek could be laid on the low gravel terraces which border the creek on one or both sides. It should be located so as to avoid, as much as possible, landslides and the danger of landslides. Several of the tributaries on the north side of Lignite Creek drain extensive badland areas and are subject to mudflows of the type that occur on Suntrana Creek at Suntrana. Mudflows are especially likely to occur on the creek in the $W\frac{1}{2}$ sec. 33, on the large creek that flows through sec. 34, on the creek in the west part of sec. 35, and on Popovitch Creek.

A broad low terrace on the north bank of Lignite Creek provides an excellent foundation for road or railroad from the crossing of the Nenana River eastward to the point where bed H crosses the creek. Opposite this stretch the south bank of the creek is an extensive landslide, the upper part of which is still active. In spite of the danger of mudflows from the tributary in section 33, the north bank of Lignite Creek is the best side for a route as far east as the middle of section 4. Landslides are common on the south bank and much of the south bank not now sliding is kept from doing so only because it is perennially frozen, a condition that is not likely to continue after road excavations. Eastward from the middle of section 4 landslides are common on the north bank of Lignite Creek. A terrace 5 to 10 feet high on the south side of the creek provides a good route for a road. In the $W\frac{1}{2}$ sec. 3, a large landslide has moved northward over part of this terrace (pl. 1) but appears to have stopped moving, at least temporarily. The strip of terrace between the toe of the landslide and the creek is about 100 feet wide. Eastward from section 3 conditions affecting roadbuilding are about equal on both sides of the creek. The south bank is subject to rapid creep of fragments of Birch Creek schist and the north bank to mudflows and landslides in the Tertiary rocks.

As strip mining progresses, the natural difficulties affecting roadbuilding on this creek will be eliminated, for the landslides will be hydraulicked away. For this reason it may be desirable to develop the coal deposits of this creek progressively from the mouth of the creek eastward and to extend the road or railroad only as far as mining has eliminated the landslides and other troublesome factors.

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Base from U.S. Geological Survey maps of Healy D-4 (1952) and Healy D-5 quadrangles, Alaska

1 0 1 2 MILES

5000 0 5000 10,000 FEET

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
Datum is mean sea level

Geology by Clyde Wahrhaftig, J. H. Birman, and C. A. Hickcox.
Surveyed in 1945 and 1952

EXPLANATION

QUATERNARY

Qal — Alluvium
Deposits of sand and gravel on river flood plains or in recently built alluvial cones

Qtg — Terrace gravel
Deposits of gravel mantling terraces and pediments along the Nenana River, Lignite Creek, and their tributaries

UNCONFORMITY

TERTIARY

Tn — Nenana gravel
Coarse brown poorly consolidated conglomerate with scattered sand lenses

APPARENT CONFORMITY

Coal-bearing formation

Tcu — Upper member
Interbedded buff-colored arkosic sandstone, in part pebbly claystone, and thin coal beds. Granite, volcanic rocks, greenstone, and conglomerate common as pebbles

Tcm — Middle member
Interbedded "salt-and-pepper" sandstone, thick coal beds, and claystone. Quartz, chert, quartzite, and argillite make up most of pebble bands

Tcl — Lower member
Interbedded sandstone, conglomerate, claystone, and coal. Coal beds lenticular and discontinuous. Prominent brown-weathering claystone at top

UNCONFORMITY

PRE-CAMBRIAN

p€bc — Birch Creek schist
Greenish-gray to black quartz-sericite schist

Landslides

Contact
(Dashed where position approximate)

Indefinite contact

Fault
(Dashed where approximately located; dotted where concealed by alluvium. U, upthrown side; D, downthrown side)

Anticline
(Showing trace of axial plane and direction of plunge of axis. Dashed where approximately located; dotted where concealed)

Syncline
(Showing trace of axial plane and direction of plunge of axis. Dashed where approximately located; dotted where concealed)

40 — Strike and dip of beds

90 — Strike of vertical beds

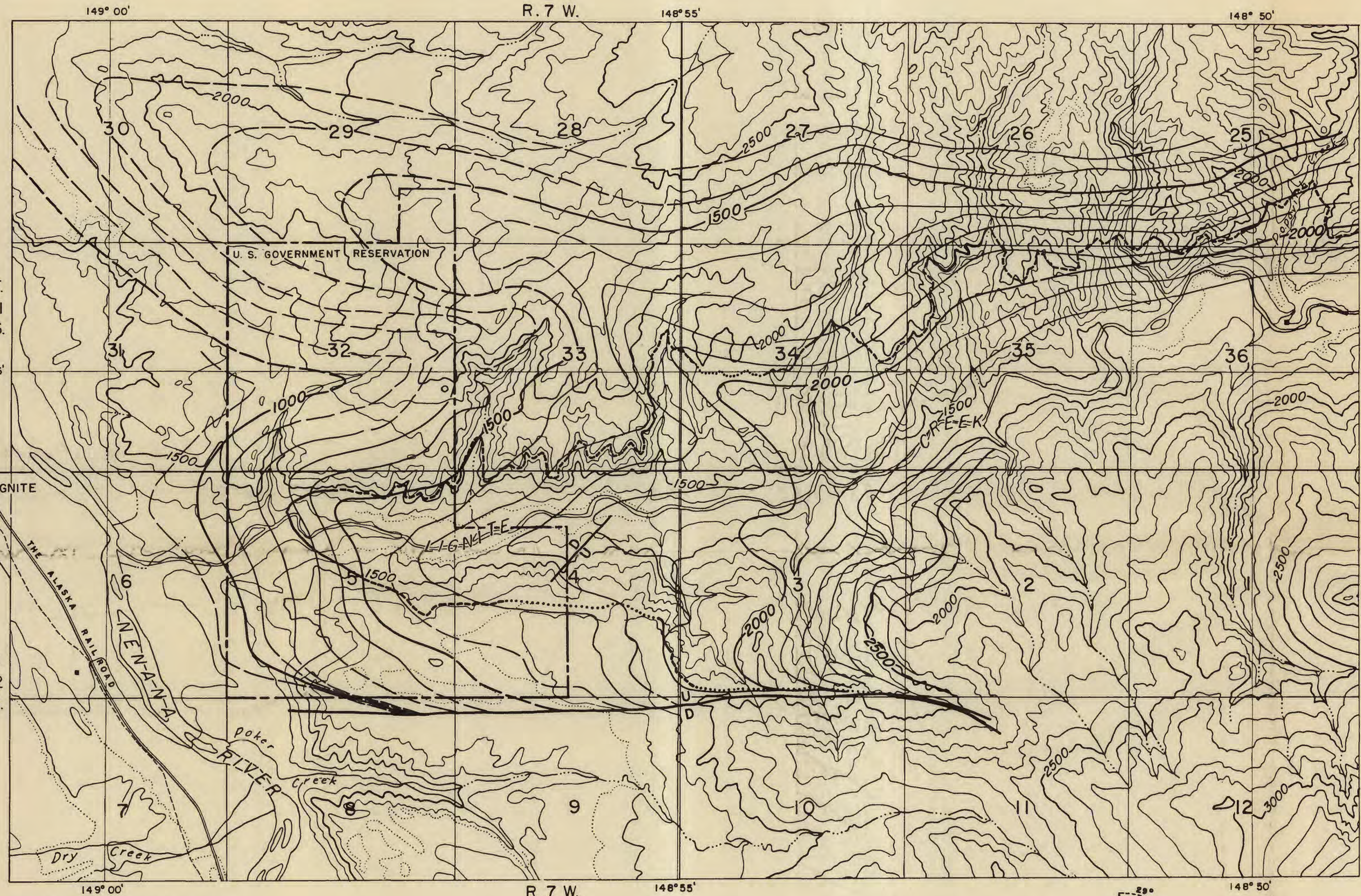
65 — Strike and dip of overturned beds

Horizontal beds

5 6 — Position of measured section (See fig. 2)

29° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1951

GEOLOGIC MAP OF THE VALLEY OF LOWER LIGNITE CREEK, NENANA COAL FIELD, ALASKA



Base from U. S. Geological Survey maps of Healy D-4 (1952) and Healy D-5 quadrangles, Alaska

1 0 1 2 MILES

5000 0 5000 10,000 FEET

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
Datum is mean sea level

TRUE NORTH, MAGNETIC NORTH, 29°
APPROXIMATE MEAN DECLINATION 1951

EXPLANATION

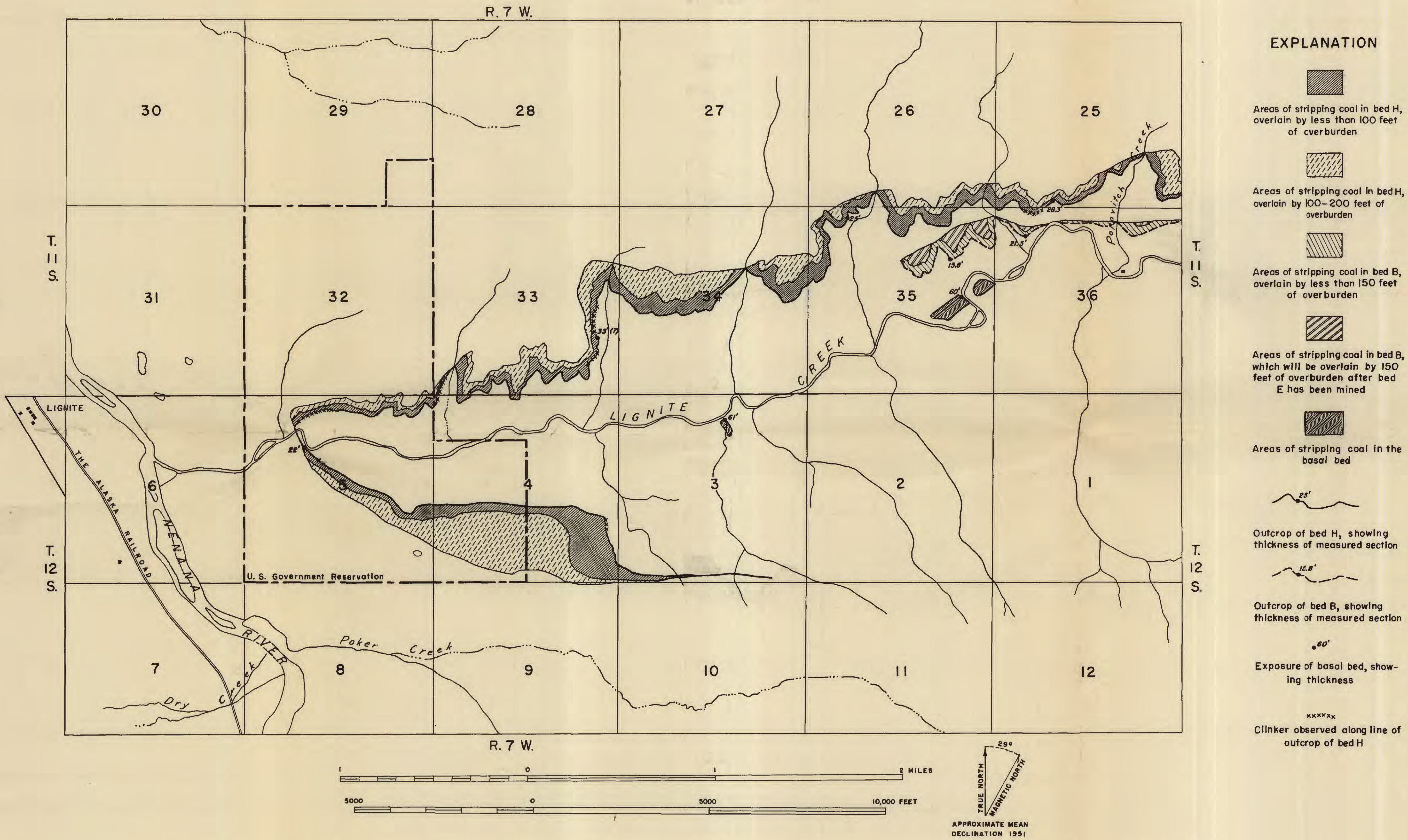
Structure contour on top of Bed H
(Dashed where position uncertain)

(Contour interval 100 feet. Datum is mean sea level.)

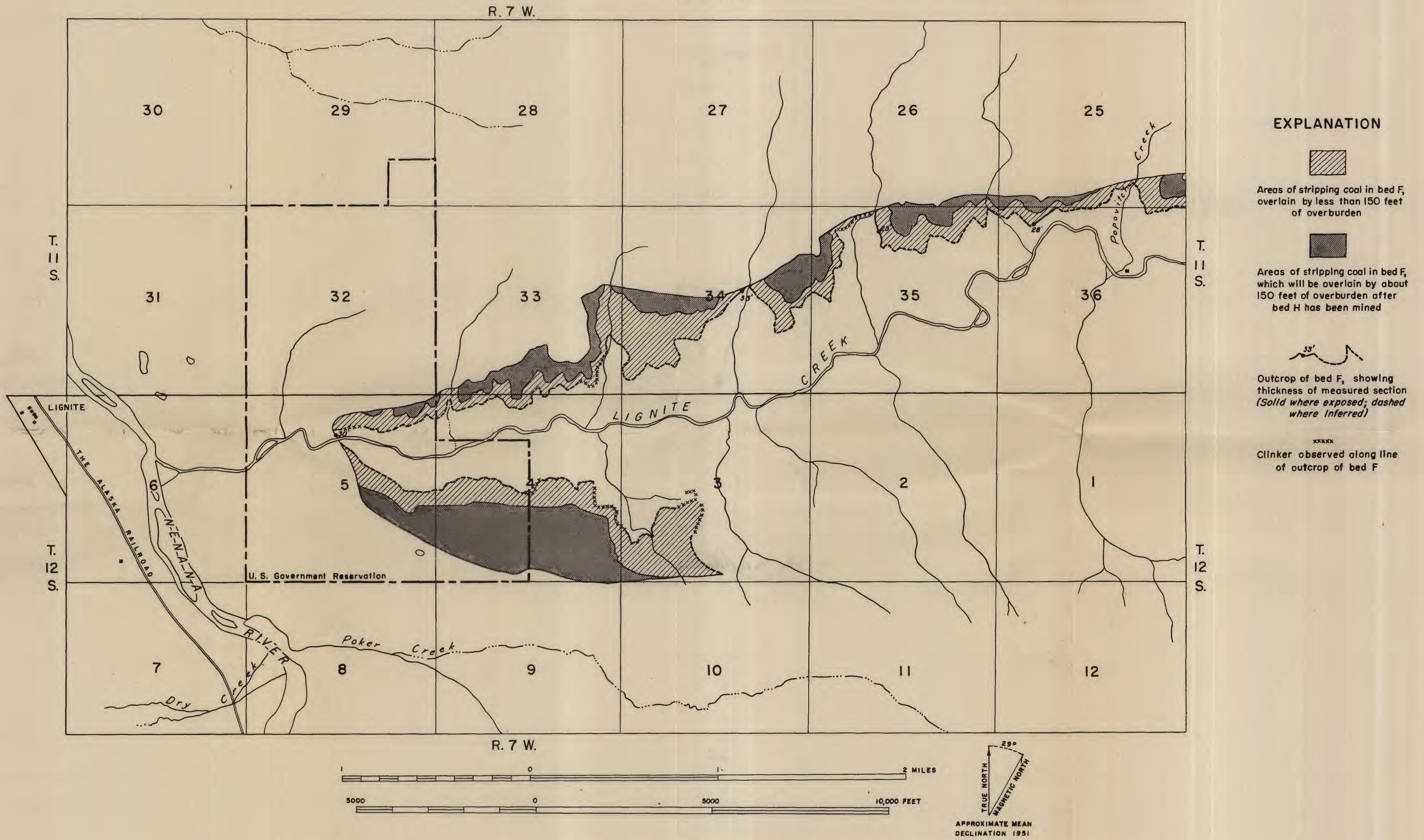
U
D
Fault
(U, upthrown side; D, downthrown side.)

Trace of outcrop of Bed H
(Solid where exposed or where clinker indicates position; dashed where concealed by soil and vegetation; dotted where concealed by terrace gravel)

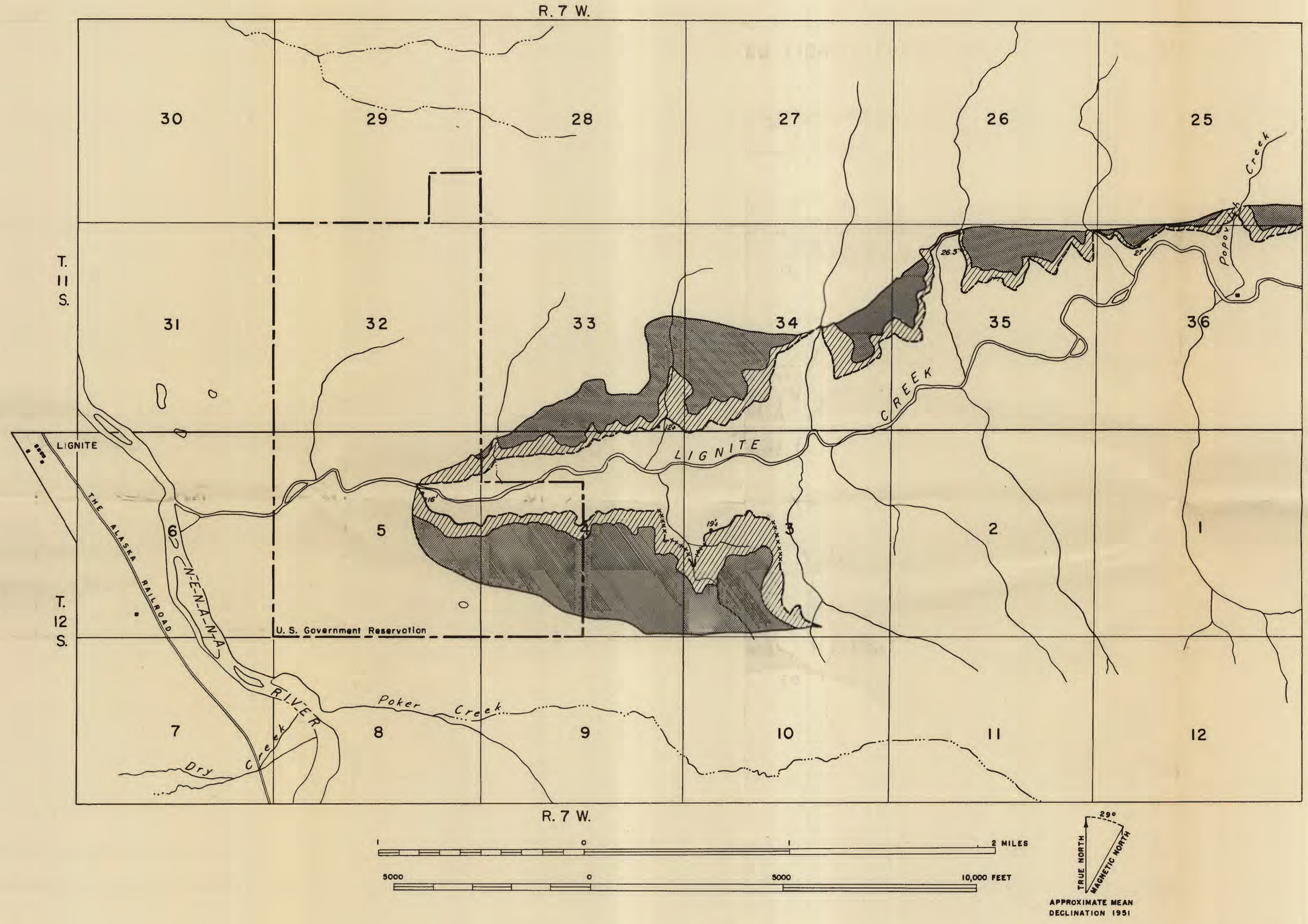
STRUCTURE-CONTOUR MAP OF BED H, LOWER LIGNITE CREEK, NENANA COAL FIELD, ALASKA



AREAS OF STRIPPING COAL IN BEDS H AND B AND THE BASAL BED ON LOWER LIGNITE CREEK, NENANA COAL FIELD, ALASKA



AREAS OF STRIPPING COAL IN BED F ON LOWER LIGNITE CREEK, NENANA COAL FIELD, ALASKA



EXPLANATION

Areas of stripping coal in bed E, overlain by less than 100 feet of overburden

Areas of stripping coal in bed E, which will be overlain by 50-100 feet of overburden after bed F has been mined

Outcrop of bed E, showing thickness of measured section (*Solid where exposed; dashed where inferred*)

Clinker observed along line of outcrop of bed E

AREAS OF STRIPPING COAL IN BED E ON LOWER LIGNITE CREEK, NENANA COAL FIELD, ALASKA