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GEOLOGY OF THE UPPER MATANUSKA VALLEY, ALASKA

BY
STEPHEN R. CAPPS

WITH A SECTION ON THE IGNEOUS ROCKS

BY
J. B. MERTIE, JR.

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PREFACE

By Philip S. Smith

Industrial development is controlled to so great an extent by the availability of power that organizers of enterprises involving the growth and future of Alaska inevitably are led to consider the resources that may supply this essential. The Geological Survey, recognizing the necessity for data on this subject, early began to examine and report on the known deposits of coal in the Territory, and it was in pursuance of the plan of collecting at first hand data on the potential coal fields that the investigations described in the accompanying report were undertaken.

Although the coal in the Matanuska region is said to have been known to prospectors as early as 1894, the first published information regarding it was in the report by Mendenhall of his explorations in 1898, which appeared in 1900. Since that time a large part of the Matanuska Valley and adjacent regions have been studied by the Geological Survey as development warranted and as opportunity permitted. Many of these studies were carried on or directed by G. C. Martin, whose broad knowledge of the Mesozoic and Tertiary history of the whole of Alaska made him the best authority on the formations in which the coals of this region occur. In 1913, in the continuation of his work, Mr. Martin covered part of the area described in the accompanying report. At that time no detailed map was available, and the data he collected could not be plotted on the map that was subsequently made with the exactness deemed necessary for the adequate portrayal of the complex geology. As a result, the publication of the report was suspended until further field work could be done. The interruptions caused by the World War and the fulfillment of many pressing duties prevented early resumption of the work. In the years that elapsed new mining developments took place in the region, and new geologic data collected from other parts of Alaska necessitated reconsideration of the whole problem. In 1924 it became practicable to take up the work again, but Mr. Martin had resigned from the Geological Survey. S. R. Capps was therefore assigned to the work of completing the study of the eastern part of the coal field and of bringing up to date the studies of the western part of the upper Matanuska Valley, already largely shaped up by Mr. Martin and the other geologists who had been associated with him. The large share borne by Mr. Martin in making this report possible entitled him to be named as joint author, but in deference to his definitely expressed wishes and because Mr. Capps mapped the eastern part of the field and also did the actual work of putting the report in the form in which it now appears, Mr. Capps has taken the responsibility for all the opinions expressed, except where specific reference is made to the work of other geologists.

The significant economic fact brought out by this report is that the upper Matanuska Valley contains considerable bodies of coals of quality as good as any others on the Pacific coast. The mining of these coals will involve many technical problems, as the beds are much folded and faulted and here and there are intruded by igneous rocks. Considerable prospecting should therefore precede any extensive expenditures. The mining will doubtless be costly, and at present there are no adequate means of transportation available, so that development of the field, to be successful, should be undertaken only after the mining and marketing costs have been carefully determined. The competition which these coals would now face in the markets of the Pacific coast from cheap California oil will inevitably decrease as the supply of oil for fuel becomes depleted. It is therefore safe to predict that at some future time, if not now, the coals in the upper Matanuska Valley can be profitably mined and will be a valuable aid in the development of the Territory's industries.

GEOLOGY OF THE UPPER MATANUSKA VALLEY, ALASKA

By Stephen R. Capps

INTRODUCTION

LOCATION

The area described in this report covers about 190 square miles in the upper part of the valley of Matanuska River, between Chickaloon

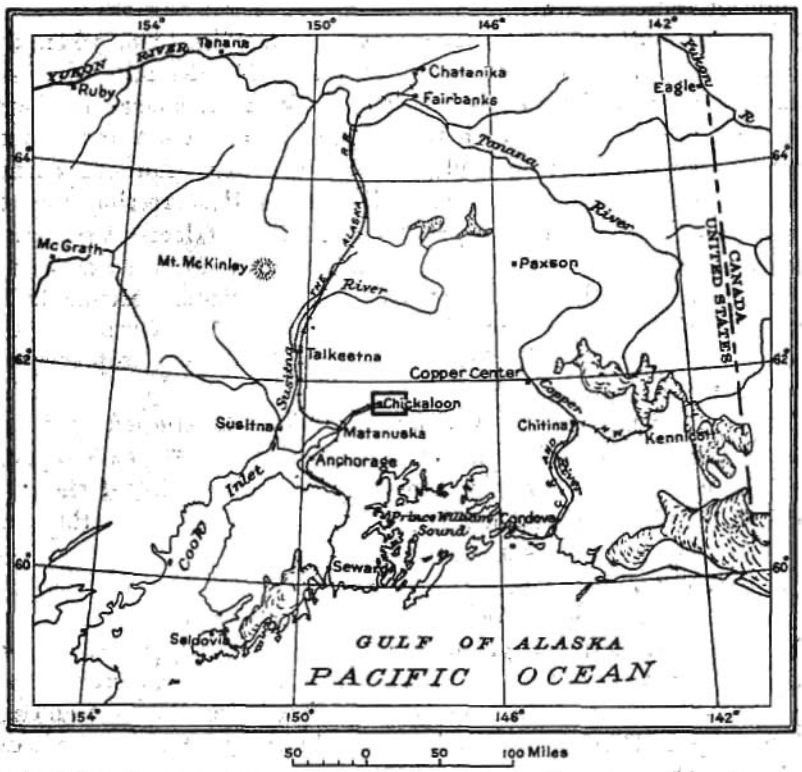

Figure 1.—Map of south-central Alaska, showing position of Matanuska coal field

River and Hicks Creek. Matanuska River is a tributary of Knik Arm, which is a northeastward projecting embayment of Cook Inlet. (See fig. 1.) The part of the Matanuska Valley that lies below the town of Chickaloon is usually referred to as the lower Matanuska Valley, and the part above Chickaloon is called the upper Matanuska Valley. Chickaloon is at the end of the Chickaloon branch of the Alaska Railroad, 28 miles northeast of Matanuska and 74 miles by rail northeast of Anchorage. For the purpose of squaring out the area here described a portion of the area adjacent to Chickaloon River, previously mapped by Martin and Katz[1] as the lower Matanuska Valley, is included in the accompanying geologic map (pl. 2).

ACCOUNT OF INVESTIGATIONS

EXPLORATORY AND RECONNAISSANCE SURVEYS

The investigations upon which this report is primarily based were preceded by other investigations which revealed the general features of this district and contributed in a large degree to the results presented below.

The first authentic information was gained in 1898, when the Matanuska Valley was traversed by W. C. Mendenhall, who was attached as geologist to a military expedition in charge of Capt. Edwin F. Glenn, Twenty-fifth Infantry, United States Army. Mendenhall's explorations covered areas on the west shore of Prince William Sound and a route extending from Resurrection Bay to the head of Turnagain Arm, thence by way of Glacier Creek and Yukla Creek (Eagle River) to Knik Arm, up the Matanuska Valley to its head, and thence northward to the Tanana. Mendenhall's account[2] of his explorations includes a general description of the geologic and geographic features, accompanied by a topographic map on the scale 1:625,000.

The coal of part of the Matanuska Valley was studied by G. C. Martin in a reconnaissance made in August, 1905. Martin's report[3] includes a brief account of the geology and geography of the area covered by his work and a more extensive description of the coal, including detailed measurements of many coal beds and analyses of representative samples.

This region was visited again in 1906 by a Geological Survey party which mapped, both topographically and geologically, on the reconnaissance scale 1:250,000, all of the Matanuska and Talkeetna Valleys, as well as part of the mountain area bordering the western edge of the Copper River basin north of the Matanuska Valley. This expedition, which was in charge of T. G. Gerdine, topographer, was

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pl. 5, 1912.

[2] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898; U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 265–340, 1900.

[3] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S Geol. Survey Bull. 289, 1906.

accompanied by R. H. Sargent, topographer, and by Sidney Paige and Adolph Knopf, geologists, whose report[4] on the geology described for the first time an approximately complete section of the Mesozoic and Tertiary rocks and was accompanied by a geologic map showing the areal distribution of the larger geologic units.

In 1909 a topographic survey in charge of R. H. Sargent was carried out in the lower Matanuska Valley, and the resulting map on the scale 1:62,500 was published in 1912.

DETAILED SURVEYS

A detailed geologic survey of the lower Matanuska Valley was made in the summer of 1910 by G. C. Martin and F. J. Katz, assisted by Theodore Chapin, who used as a base the detailed topographic map made by R. H. Sargent in 1909. The report on this work, accompanied by the maps, was published in 1912.[5]

A detailed topographic map of the part of the upper Matanuska Valley that lies immediately east of the area covered by the earlier map (Bull. 500, pl. 4) was prepared by R. H. Sargent in 1913. This map is included in this report (pl. 1, in pocket).[6] In 1913 detailed geologic surveys were begun by G. C. Martin and J. B. Mertie, jr., assisted by R. M. Overbeck, their attention being directed mainly to the study of the occurrences of coal and to reconnaissance examinations of surrounding areas. A preliminary report on the phases of their work that had an economic bearing has already been published,[7] and another report was partly prepared. At the time their field work was done, however, the detailed topographic map was not yet available to them. Their field notes were therefore plotted on the old reconnaissance base map and later transferred to the detailed topographic map, with inevitable loss of accuracy. Further field work was necessary to complete the detailed geologic mapping, and the report was withheld from publication until this could be done, but the intervention of the World War delayed the carrying out of the plans until 1924. In the meantime the completion of the Alaska Railroad, with its branch line to Chickaloon, and several years of intensive mining and prospecting in the coal fields of the lower Matanuska Valley, with the consequent study of the character and structure of the coal beds, had added greatly to our knowledge of this field. In 1917 G. C. Martin made a brief visit,

[4] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, 1907.

[5] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

[6] These two maps were compiled as a single sheet and published in 1918 as "Topographic map of lower Matanuska Valley," scale 1:625,000. This sheet, Alaska 602A, may be purchased from the Director, Geological Survey; price, 10 cents.

[7] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina Valleys: U. S. Geol. Survey Bull. 592, pp. 273–299, 1914.

the results of which have been published.[8] In 1918 and 1919 Theodore Chapin, of the Geological Survey, was stationed at Anchorage with the main purpose of studying the structure of the coal beds of the Matanuska field and of making correlations between the beds there exposed. His studies resulted in two reports.[9] A considerable number of reports on the geology and coal resources and on engineering problems related to mining in this field have been made by other persons, but most of these have not been published and so are not generally available. Perhaps the most comprehensive of such studies was that carried out by Capt. W. P. T. Hill, T. E. Savage, and W. T. Foran for the Navy Alaska Coal Commission from July 1, 1920, to April 30, 1922. Their work included the careful plotting of the geology of the mine workings and structural studies of most of the coal sections exposed in this field. During the period of their study extensive mining developments were carried out at Chickaloon, a number of diamond-drill holes were sunk near Chickaloon and in the Coal Creek area, and many hundreds of feet of gangways and counters were driven on the coal beds on the east bank of Coal Creek.

In 1924 S. R. Capps, with Kenneth K. Landes as assistant, spent the months of July and August in this district. They visited all the working mines, but their attention was directed mainly to a study of the geology and structure of the part of the coal field that lies east of Chickaloon River and to a geologic reconnaissance of the part of the Chugach Range that lies immediately south of Matanuska River between Gravel Creek and Kings Mountain. Some refinements were made in the mapping of the area east of Chickaloon River and north of Matanuska River, and the writer alone is responsible for the geologic boundaries of the area south of the Matanuska. (See pl. 2, in pocket.)

ACKNOWLEDGMENTS

So many geologists have contributed to the study and mapping of this field that it is impossible to measure accurately the credit due to each in the completion of this report. G. C. Martin, who has long been familiar with the Matanuska field, and his coworkers, J. B. Mertie, jr., and R. M. Overbeck, outlined the main geologic units and placed them on the map in about the position shown on Plate 2. The manuscript and illustrations prepared by Martin and Mertie have been largely used in the present publication. The sec-

[8] Martin, G. C., Geologic problems at the Matanuska coal mines: U. S. Geol. Survey Bull. 692, pp. 269–282, 1919.

[9] Chapin, Theodore, Mining developments in the Matanuska coal fields: U. S. Geol. Survey Bull. 712, pp. 131–168, 1920; U. S. Geol. Survey Bull. 714, pp. 197–199, 1921.

tions on stratigraphy and on the igneous rocks are here presented in substantially the form in which these geologists prepared them; some other sections have been revised and in part rewritten. Theodore Chapin, of the Geological Survey, and Capt. W. P. T. Hill, T. E. Savage, and W. T. Foran, of the Navy Alaska Coal Commission, worked out many details of structure, particularly in the area near Chickaloon and Coal Creek. The conclusions reached by Hill and Foran were the result of nearly two years' intensive study and gave the first accurate basis for engineering estimates of the amount of coal available in several parts of the field. Their reports and mine maps have been consulted and freely drawn upon. So much of the information procured by Martin and his associates, by Chapin, and by Hill and Foran has unconsciously been incorporated into the thinking of the writer that it is impossible to determine in each case to whom credit for particular ideas is due. Certainly the present report could not have been prepared without drawing largely on the unpublished as well as the published work of these earlier investigators. The writer alone is responsible for the opinions expressed in regard to probable future developments in this field.

GENERAL DESCRIPTION OF THE DISTRICT

GEOGRAPHY

Matanuska River is tributary to Knik Arm, at the head of Cook Inlet. It rises on the western edge of the Copper River Basin and flows westward between the Talkeetna Mountains on the north and the Chugach Mountains on the south. Matanuska River is about 80 miles in length and has a drainage basin of about 1,000 square miles. Its fall in the lower half of its course is about 20 feet to the mile; upstream it is steeper. This rapid fall gives it a swift current, which, with the overload of sediment and the consequent general diversion into many shifting channels over an aggrading flood plain, makes it unnavigable. The fall is, however, so evenly distributed that there is no readily available water power.

The principal tributaries of the Matanuska from the north are Caribou Creek, Hicks Creek, Chickaloon River, Kings River, and Granite, Eska, and Moose Creeks. The principal tributaries from the south include Gravel, Monument, Coal, Carbon, and Carpenter Creeks and a number of unnamed streams. In general the tributaries of the Matanuska that enter it from the north are larger than those from the south.

The Matanuska drainage basin may be divided into the mountain areas and the valley areas. The mountain areas include part of the Chugach Mountains, south of the river, and the Talkeetna Mountains, north of it. The Talkeetna Mountains are divided by the valley of Chickaloon River into two topographically dissimilar parts which are known to be also geologically unlike. The mountains west of Chickaloon River are in general higher and more rugged than those to the east. The height of the summits is in general 6,000 to 8,000 feet west of Chickaloon River and 5,000 to 7,000 feet east of it. The general altitude of the summits of the part of the Chugach Mountains that lies in the Matanuska drainage basin is from 7,000 to 8,000 feet.

The Matanuska Valley, as the term is used in this report, is the part of the basin of Matanuska River that lies between the high ridges of the Talkeetna Mountains on the north and the Chugach Mountains on the south. It includes the flood plain of the river, as well as the benches on both sides up to the point where the steep mountain slopes rise abruptly above the benches. The Matanuska Valley has a general width of about 6 miles between the approximately parallel and fairly distinct mountain fronts. Within its limits are rounded hills and gravel-covered flats. The hills rise to altitudes of 2,300 to 3,500 feet, and most of the flats to about 1,200 feet, although small gravel-covered benches at the mouths of some of the tributary valleys rise as high as 2,200 feet. Within this broad valley (see pl. 1) the tributary streams occupy smaller valleys, some of which are box canyons, especially along their lower courses. It is noteworthy that the Matanuska, practically throughout its course, is nearer the south wall of the valley than the north, and in most places hugs the south wall (pl. 3).

West of Moose Creek the valley opens out into the Cook Inlet flats, a gravel-covered lowland on which few of the irregular hills and ridges rise higher than 200 or 300 feet. Between these hills are many marshy flats.

CLIMATE

The Matanuska Valley, lying back from the ocean, has a climate more like that of the interior of Alaska than that of the coast. The summer temperatures are rather mild; the winters are severe. The precipitation is light, especially in the summer, when, although cloudy days are not infrequent, there is sometimes only a few inches of rainfall during the whole summer. The snowfall is said to be moderate, a total of 3 or 4 feet usually accumulating annually.

The following table is a summary of observations furnished by the United States Weather Bureau:

Temperature at Matanuska, 1917–1921

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1917	------	------	------	------	------	------	55.3	56.6	45.3	32.6	13.8	−5.6	------
1918	10.6	12.4	15.9	33.2	44.4	55.6	60.2	54.0	48.3	34.7	16.2	14.2	33.3
1919	8.8	21.3	23.0	37.8	47.0	53.6	58.1	54.6	46.8	33.3	14.9	8.4	34.0
1920	4.5	27.4	16.5	29.2	44.2	52.4	55.2	53.0	44.3	33.2	19.8	13.5	32.8
1921	4.6	12.4	26.8	36.2	45.6	56.3	55.8	55.1	46.3	33.8	18.9	14.2	33.8
Mean	7.1	18.4	20.5	34.1	45.2	54.5	56.9	54.7	46.2	33.5	16.7	8.9	33.1
Mean maximum	15.7	27.9	30.4	43.0	56.9	65.8	66.3	62.9	54.4	40.5	24.9	16.8	42.1
Mean minimum	−1.4	8.8	10.6	25.2	33.7	43.1	47.6	46.5	38.0	26.5	8.5	1.1	24.0
Highest	45	49	47	57	71	76	82	76	67	59	48	48	82
Lowest	−34	−22	−16	−6	23	30	36	32	24	−2	−22	−34	−34

Precipitation at Matanuska, 1917–1921

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1917	------	------	------	------	------	------	3.91	0.67	2.12	1.69	0.55	0.12	------
1918	0.72	0.61	0.34	1.41	1.10	0.64	.82	4.27	2.34	.54	.77	1.60	15.16
1919	.58	Tr.	.09	0	.27	.87	2.00	2.23	1.90	1.62	.46	1.42	11.44
1920	.14	.76	.72	.06	.49	1.77	2.50	1.90	.58	.66	.67	.43	11.68
1921	.83	.08	.75	1.25	.81	1.10	1.57	3.93	1.80	3.57	.04	2.26	17.99
Mean	.57	.61	.48	.68	.67	1.10	2.16	2.60	1.75	1.62	.50	1.17	13.91

Temperature at Chickaloon, 1919–1923

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean:												
1919	−0.7	15.3	18.4	35.2	45.0	50.4	56.5	51.8	44.8	30.9	16.8	ª7.4
1920	7.8	24.5	------	25.2	44.2	52.8	53.6	52.2	43.9	28.2	19.8	9.8
1921	2.0	8.7	25.8	------	47.0	54.5	57.1	56.2	45.1	33.2	16.8	14.2
1922	11.2	12.6	15.0	30.8	44.4	52.8	54.0	51.7	43.8	37.0	18.6	9.1
1923	3.6	20.2	17.8	34.8	46.8	53.6	58.8	58.4	45.6	------	22.3	------
Mean maximum:												
1919	7.1	27.0	31.1	46.2	57.9	62.8	67.3	62.8	54.3	37.5	26.9	ª16.6
1920	15.5	32.3	------	36.8	56.8	66.7	64.9	63.9	57.3	36.9	26.8	18.9
1921	11.8	20.7	33.9	------	56.6	66.9	66.5	66.3	56.2	41.0	25.6	25.0
1922	16.7	24.1	27.6	40.4	56.8	65.1	63.3	62.0	53.8	45.6	25.7	15.3
1923	12.7	28.8	30.6	45.0	58.1	65.8	70.8	72.0	54.7	------	29.5	------
Mean minimum:												
1919	−8.5	3.6	5.8	24.1	32.2	38.0	45.7	41.3	35.4	24.2	6.7	ª−1.9
1920	0.1	16.7	------	13.5	31.5	38.8	42.3	40.4	30.5	19.5	12.8	0.6
1921	−7.9	−3.3	17.7	------	37.3	42.1	47.7	46.2	34.0	25.4	7.9	3.3
1922	5.8	1.2	2.3	21.1	31.9	42.4	44.7	41.4	33.9	28.4	11.5	2.9
1923	−5.4	11.5	5.0	24.5	35.5	41.3	46.8	44.7	36.4	------	15.1	------
Highest:												
1919	30	37	43	54	65	72	80	80	64	46	38	ª37
1920	36	47	------	52	73	78	76	75	70	48	49	32
1921	23	40	43	------	68	74	79	77	68	53	38	30
1922	29	44	43	53	82	74	83	71	63	60	40	27
1923	34	44	44	53	67	77	86	89	68	------	36	------
Lowest:												
1919	−42	−15	−15	13	20	28	39	32	24	8.0	−12	ª−27
1920	−20	−20	------	−6	20	29	35	31	26	6	−2	−16
1921	−25	−24	2	------	30	30	38	36	27	2	Zero.	−15
1922	−16	−15	−17	9	22	30	30	29	24	13	−10	−26
1923	−21	−10	−14	14	23	27	36	35	21	------	−5	------

ª Record for 27 days.

Precipitation at Chickaloon, 1918–1923

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1918	1.20	0.50	1.30	1.20	0.25	1.50	0.75	4.35	3.51	0.21	0.30	0.72	15.79
1919		Tr.			.10	.75	1.83	1.80		.44			
1920	.68	2.17											
1921			.79	.48	.28	1.23	2.79	1.49	1.83	2.04	Tr.	1.91	
1922	1.25	.30	.50	.85	.06	.06	2.42	1.66	.53	1.59	.82		
1923	1.39	.60	1.14	.10	0	.34	1.55	.73	5.20		.70		

Snowfall at Chickaloon, 1918–19 to 1922–23

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Seasonal
1918–19	0.1	2.1	3.0	15.0	(a)	Tr.	(a)			
1919–20		4.7	(a)	(a)	8.0	31.0	(a)	(a)	(a)	
1920–21	(a)	6.0	(a)	(a)	(a)	2.0	13.0	4.0	Tr.	
1921–22		6.1	Tr.	33.0	12.5	3.0	5.0	8.5		68.1
1922–23		Tr.	8.2	(a)	17.5	8.0	16.9	1.0		

a No record of snowfall.

VEGETATION

Timber line in this district is at a general altitude of 2,000 to 2,500 feet, above which there is the usual growth of small bushes, moss, and grass. The trees include spruce, birch, and several kinds of cottonwood. Most of Matanuska Valley except the higher slopes was originally covered with a stand of spruce, birch, and cottonwood, but extensive forest fires have swept over large areas above Chickaloon and on the north side of Matanuska River and destroyed the timber. The present growth in general is not dense, and the timber is of only fair quality. Most of the spruce trees are under 12 inches in diameter. The largest one that the writer noted had a circumference of 5 feet. There is no timber suitable for export, and the supply will probably soon prove inadequate for local use if extensive mining is undertaken. Figure 2 shows the area in which timber occurs.

The more open birch forests, as well as the areas which have lately been burned, are covered with a dense growth of grass, chiefly redtop. Large areas of bunch grass also occur above timber line at some localities, especially in the eastern part of the district. These natural meadows are large enough to furnish feed for as much stock as is likely to be needed for local use.

FAUNA

The fauna of the Matanuska Valley is practically the same as that of the neighboring districts of similar geographic character. The game animals include sheep, goats, black and brown bear, moose, and caribou. Of these only the sheep are abundant. Among the

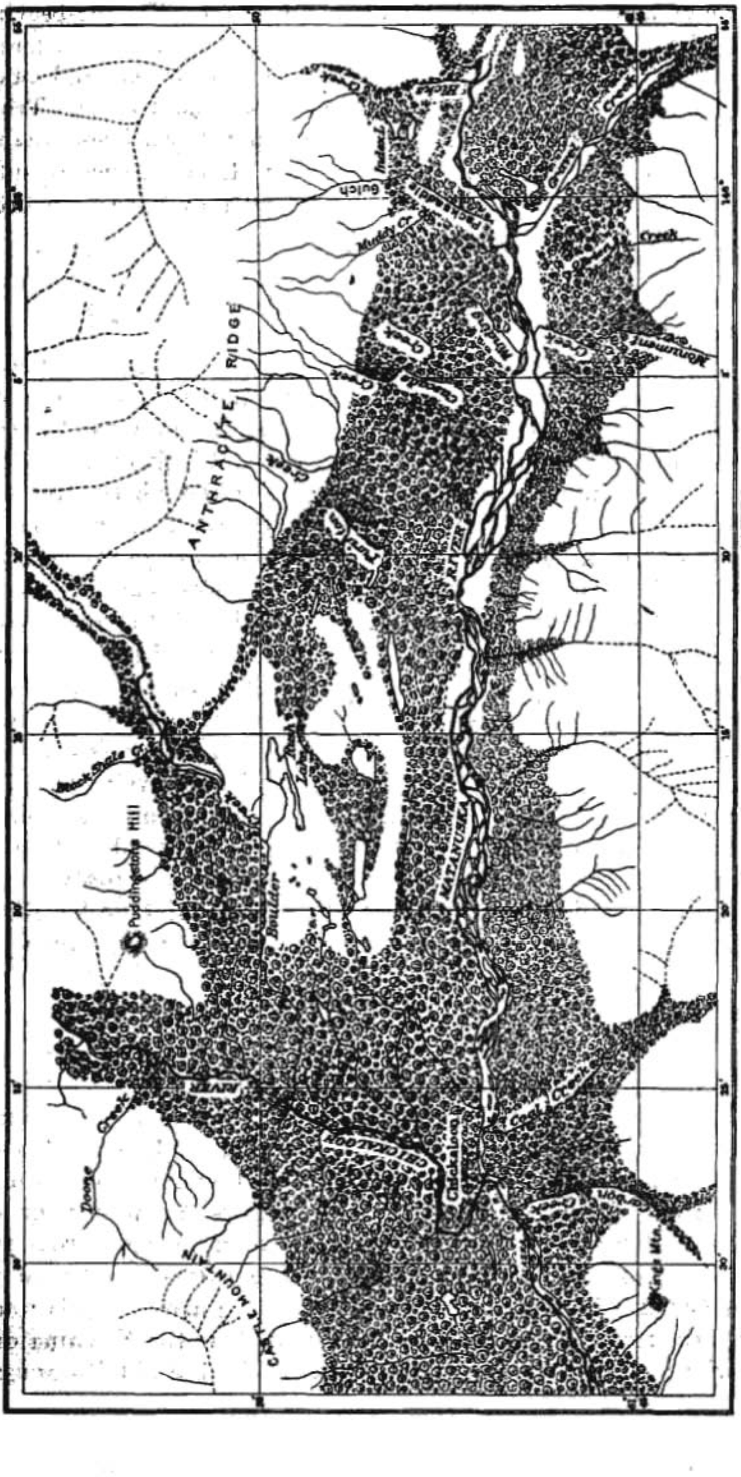

FIGURE 2.—Sketch map of upper Matanuska Valley, showing areas in which timber occurs

smaller mammals are squirrels, rabbits, and conies. The fur-bearing animals were formerly abundant but are now found in only moderate numbers. The abundant game birds are chiefly grouse and ptarmigan, but ducks may be found on some of the small lakes. Trout are present in many of the streams and lakes, but they are not notably abundant. Some salmon run up Matanuska River but not in sufficient numbers to be industrially valuable, and they have been little used even as a local food supply.

ACCESSIBILITY

The upper Matanuska Valley is easily accessible as far as Chickaloon by the Chickaloon branch of the Alaska Railroad, which leaves the main line at Matanuska and has its eastern terminus at Chickaloon. As no active mining was in progress at Chickaloon in 1924, only a single train each week was scheduled, although two regular trains were run from Anchorage to Jonesville and Sutton, some 18 miles west of Chickaloon. Before the completion of the railroad the only established route into the upper Matanuska Valley was by wagon road from Knik, on Knik Arm, to Little Susitna River, and thence by pack trail up Matanuska Valley. Part of that old trail between Moose Creek and Chickaloon is still open, but in places fires have burned the timber, and fallen trees have made the trail impassable. Practically all travel to Chickaloon now goes over the railroad. From Chickaloon eastward only trails are available. The only wagon roads in the district here under discussion are a short stretch a mile or so long that leads from the railroad station at Chickaloon to the buildings on the terrace above the town and a stretch about 2 miles long on the south side of Matanuska River from the tramway across the river to the coal workings on Coal Creek.

TRAILS

The main trail from Chickaloon to the Nelchina district crosses Chickaloon River at a ford a mile above the town and leads thence northeastward along a course roughly parallel to Boulder Creek, which it crosses some 10 miles out, at the Boulder Creek Flats. Another route to upper Boulder Creek follows the west bank of Chickaloon River northward for 6 miles to a bridge across the Chickaloon, now in bad repair, and thence extends eastward to Boulder Creek, where it joins the trail described above. This route is now little used. From the Boulder Creek Flats the Nelchina district may be reached by one of three routes—by the old Matanuska trail around Sheep Mountain, by the Hicks Creek trail, or by way of Boulder Creek. Most of the travel follows the Boulder Creek trail.

The old Matanuska trail extends eastward along the southern base of Anthracite Ridge to the fork of the Hicks Creek trail at Index Lake, a distance of 11 miles. For the last 3 miles of this distance the trail lies through a burned area where fallen trees have almost obliterated it and made travel slow and difficult. The Matanuska trail turns southeastward at Index Lake, follows a ridge between two lakes, and crosses Hicks Creek 1½ miles from the fork. It proceeds thence northeastward up the valley of a tributary of Hicks Creek. The Hicks Creek trail leads from the fork northeastward along the north shore of Index Lake, ascends high along the mountain side to avoid the Hicks Creek Canyon, and thence proceeds northward toward Caribou Creek. This route is now little used.

The trails described above are about the only distinguishable trails in this district. A dim trail, now much obstructed by fallen timber, leaves the old Matanuska trail half a mile east of Cascade Creek and leads to Matanuska River at the mouth of Winding Creek. Packsaddle Creek may also be followed from the Matanuska trail to Matanuska River. The Geological Survey party in 1924 forded Matanuska River with pack horses just above the mouth of Gravel Creek, ascended Gravel Creek almost to the glacier, and then followed the south bank of the Matanuska down to Coal Creek and the tramway across the Matanuska at the mouth of the Chickaloon. Throughout most of that distance little difficulty was encountered save for the necessity of much trail cutting through the brush. That summer Matanuska River was exceptionally high and in most places unfordable, and at a point some 8 miles above Chickaloon River it was necessary to build about a mile of trail high along the mountain side in order to avoid fording the river. Most of the tributaries of Matanuska River from the south between Gravel Creek and Coal Creek emerge from the mountains through precipitous canyons, and much laborious trail building would be required before pack horses could be taken into these valleys.

HISTORY OF DEVELOPMENT

The Matanuska Valley is an ancient route of travel from the interior of Alaska to the sea, by which the Kenai Indians of the interior of Alaska kept in touch with their kindred on the coast. In more recent times it has been the highway along which the Cook Inlet natives travel each summer to hunt on the eastern front of the Talkeetna Mountains with their Copper River kindred and along which the latter in turn come down to the coast to trade.

The first white men in the Matanuska Valley were probably traders and trappers from Knik. It is said that the knowledge of the occurrence of coal was obtained from the Indians by traders and prospectors in 1894. A little prospecting was done during the next year or two, but as Alaska coal deposits were at that time considered of no value, the search was mainly for gold. The presence of placer gold on Caribou Creek was known at least as long ago as 1898.[10]

The beginning of construction of the Alaska Northern Railway from Seward in 1903 revived interest in the coal deposits, which began to be actively prospected in 1904. The interest in the coal fields continued until the withdrawal of Alaska coal lands from entry in 1906, when the attendant suspension of work on the railroad put an end to all activity in the coal fields except on the part of the Government officials. The mining of 1,100 tons of coal by the Government in 1913 for a Navy test,[11] the enactment of a coal-leasing law in 1914, the subdivision of the public lands, the purchase of the Alaska Northern Railway by the Government, and the beginning of construction of the Alaska Railroad from Seward to Fairbanks in 1915, all stimulated interest in the Matanuska coal field. In fact, the position of this field, containing a good grade of steaming coal, was one of the controlling factors in the choice of the route for the Government railroad. Construction of this railroad once started, it became imperative that coal mines in the Matanuska Valley should be developed to supply the railroad with fuel. Furthermore, the needs of the Navy for a coal supply on the Pacific seaboard in American territory, capable of furnishing steaming coal of a grade sufficiently high to meet its requirements, was also a powerful stimulus to the prospecting and development of this coal field. As will be seen from the following brief summary of developments in the Matanuska coal field from 1914 to 1922, a large part of the prospecting and mining of coal has been done under two governmental agencies, the Alaskan Engineering Commission and the Navy Alaska Coal Commission. This pioneer work was necessary, and governmental operation appeared at the time to be the best way in which to assure a coal supply to the railroad and to determine the availability of coal for the Navy. Since 1922, however, privately operated mines have been sufficiently developed to supply the local demand for coal, and in 1923 and 1924 no coal was mined by governmental agencies, although the mines at Eska and at Chickaloon were kept in shape to produce coal promptly in case of an interruption in the supply from private sources.

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[10] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 321, 1900.

[11] Brooks, A. H., The Alaskan mining industry in 1914: U. S. Geol. Survey Bull. 622, pp. 27–30, 1915.

A brief chronologic account of the important coal-mining developments in the Matanuska field follows.

The first mining was done in 1913, when 1,100 tons of coal was mined by the Government for a Navy test. In 1916 some 8,000 tons of coal was mined on Moose Creek from the Doherty mine on a 10-acre permit.[12] This was the first commercial production from the field. By 1917 construction on the Chickaloon branch of the railroad had reached Eska Creek, and active developments on several coal properties were started. The Eska Creek Coal Co. took over the Martin lease on unit 7, began mining in January, and sledded the coal to the railroad at Sutton until the Eska spur was built. In mining, however, faults were encountered, and production soon stopped. In June of that year the property of this company was purchased by the Alaskan Engineering Commission, and at the same time unit 12 on Chickaloon River was set aside by Executive order for the use of the commission. Sumner S. Smith, then of the Bureau of Mines, was placed in charge of the Government-controlled properties at Eska and Chickaloon, and active development of mines was begun. In 1917, also, units 10 and 11, between Chickaloon River and Kings River, were granted to Lars Netland for the Chickaloon Coal Co., and active developments were begun on this property. During the year the Doherty mine on Moose Creek was abandoned. In December, 1917, the Baxter mine, on units 2 and 3 on Moose Creek, was opened, and it was operated until April, 1918, the coal being sledded to the railroad at the mouth of Moose Creek.

In 1918 a large part of the coal produced came from the Government-operated mine at Eska, although the Baxter mine produced coal for a part of the year, and a small tonnage was mined incidentally to development work at Chickaloon.

In 1919 only the Government mines were operated; the Eska mine produced over 40,000 tons and the Chickaloon mines over 4,000 tons.

In 1920 most of the output came from the Eska and Chickaloon mines, but the Evan Jones mine at Jonesville, which later became a notable producer, was opened up, and construction was started on the coal washery at Sutton. In the same year the Navy Department began systematic prospecting to find coal suitable for use by the Navy. This work was directed by the Navy Alaska Coal Commission, of which Commander O. C. Dowling was chairman. Sumner S. Smith was placed in charge of the technical direction of field work and had associated with him Prof. T. E. Savage, of the University of Illinois; Lieut. (now Capt.) W. P. T. Hill, of

[12] Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 140–141, 1920.

the Marine Corps; and W. T. Foran. Prospecting and underground exploration were actively pushed at Chickaloon and on Coal Creek.

The year 1921 saw the continued operation of the Government-controlled mines at Eska and Chickaloon and the opening of a new mine on Coal Creek. Diamond drilling was carried out in the Eska and Coal Creek fields to prospect the coal beds. The Evan Jones mine was systematically developed and produced considerable coal.

The year 1922 was notable in that for the first time since this field was actively exploited privately operated mines were the main producers. Of a total of 51,335 tons of coal mined only 7,908 tons was produced by the Government-controlled mines at Chickaloon, Eska, and Coal Creek, the principal output being from properties on Moose Creek and at Jonesville. Of the coal produced by the Government-operated mines, 5,297 tons was mined at Chickaloon and Coal Creek incidentally to exploration and development, and 2,611 tons was mined at Eska because a fire at the Evan Jones mine threatened a shortage of coal for railroad operation. No coal has since been produced from the Government mines at Chickaloon and Coal Creek. In this same year the Sutton coal washery made a short run, but difficulties in operation disclosed faulty construction and design, and only a few thousand tons of coal was handled. The washery has since been partly dismantled. Mining at the Government-operated properties on Chickaloon and Coal Creek was discontinued in 1922. In 1923 the Eska mine was operated for a few months, and then it too was closed down. The plan was adopted of purchasing coal for the railroad from private producers, but keeping the Eska and Chickaloon mines in condition to resume production in case the supply of coal from private sources should be threatened for any reason.

In 1924 all the coal produced in this field came from privately operated mines on Moose Creek and at Jonesville.

The following table shows the total quantity of coal produced from the Matanuska field, by years, up to the end of 1924:

Coal mined in the Matanuska field, 1913–1924

Year	Tons	Value	Year	Tons	Value
1913	1,100		1921	57,703	$405,342
1916	8,498	$44,622	1922	51,335	308,432
1917	45,370	238,001	1923	82,145	565,914
1918	63,092	368,465	1924	64,159	449,113
1919	44,553	267,318			
1920	35,044	215,800		452,999	2,863,007

STRATIGRAPHY

GENERAL FEATURES

The Matanuska drainage basin and the region immediately contiguous to it may be conveniently divided into three mountainous and three lowland provinces. The major areal division is that made by Matanuska River, which separates the Chugach Mountains, south of the river, from the Talkeetna Mountains, to the north. The Talkeetna Mountains are in turn divided by the valley of Chickaloon River into two parts, which are physiographically and geologically dissimilar. The three lowland provinces are the valley of the Matanuska from its source to the point where it leaves the Chugach and Talkeetna Mountains; the lower Matanuska and Knik Arm flats; and the Copper River basin, on the western margin of which the easternmost tributary of Matanuska River has its source.

West of Chickaloon River the Talkeetna Mountains are composed chiefly of granite, although metamorphic rocks and small areas of sedimentary rocks are known to be present. East of the Chickaloon these mountains are made up of stratified rocks of Jurassic and Cretaceous age, including both sedimentary and volcanic beds, overlain in parts of the area by Tertiary conglomerate, lava, and tuff. The rocks immediately south of the Matanuska include Tertiary and Upper Cretaceous sediments, volcanic rocks of Lower Jurassic age, metamorphic sediments of uncertain age, and granite intrusive rocks. The geology of the Chugach Mountains south of the belt bordering the river is practically unknown, but the rocks are probably in the main metamorphic sediments cut by granitic intrusive rocks.

The Matanuska Valley, which includes the less mountainous area immediately adjacent to Matanuska River, contains mainly Tertiary and Mesozoic sedimentary rocks. The area described in greatest detail in this report lies chiefly within this province.

The Knik Arm flats and the Copper River basin are covered with Quaternary gravel, and the nature of the underlying rocks is unknown.

The accompanying geologic map (pl. 2, in pocket) shows the areal distribution of the rocks of the upper Matanuska Valley. The general stratigraphic sequence in this and neighboring areas is given in the following table. Not all the formations mentioned have been identified within the limits of the area shown on the geologic map, but they occur either here or in near-by regions and are listed in order to round out the geologic section.

Stratigraphic sequence in the Matanuska Valley

Age		Formation	Character	Thickness (feet)
Quaternary.			Alluvium. Glacial and high-level terrace gravels.	
		—Unconformity—		
Tertiary.	Pliocene (?).		Basaltic lava, breccia, and tuff.	1,000+
		—Unconformity—		
	Miocene (?).	Eska conglomerate.	Alternating beds of conglomerate, 5 to 50 feet or more thick, and arkosic sandstone that range from a few inches to 40 feet.	2,500
		—Unconformity—		
	Eocene.	Chickaloon formation.	Coal-bearing shale and sandstone with the flora of the Kenai formation.	2,000±
			Arkose, conglomerate, and shale.[a]	2,000±
		—Unconformity—		
Upper Cretaceous.		Matanuska formation.	Sandstone and shale, sparsely fossiliferous. Shale with some sandstone; carries an abundant marine Upper Cretaceous fauna.	2,100 2,000±
		—Unconformity (?)—		
Lower Cretaceous.		Nelchina limestone.	Massive limestone, with *Belemnites*.	300±
			Conglomeratic tuff and arkose, with *Aucella crassicollis*.	100-200
		—Unconformity—		
Upper Jurassic.		Naknek formation.	Shale, sandstone, tuff, arkose, and conglomerate, with *Aucella* cf. *A. pallasi*, *Aucella* cf. *A. bronni*, and *Cardioceras*.	1,000+
		—Unconformity—		
		Chinitna formation.	Shale, conglomerate, and sandstone with *Cadoceras*.	2,000±
Middle Jurassic.		Tuxedni sandstone.	Sandstone and sandy shale with *Inoceramus ambiguus*, *Trigonia* cf. *T. dawsoni*, and *Stephanoceras* cf. *S. humphriesianum*.	1,000±
		—Unconformity (?)—		
Lower Jurassic.		Talkeetna formation.	Lava, agglomerate, breccia, and tuff, interbedded with lesser volumes of sandstone and shale; contains fossil plants and a marine invertebrate fauna. Basal contact and underlying rocks not exposed.	3,000+
Early Mesozoic or older.			Graywacke, slate, basaltic greenstone, and rhyolite and tuff of the Knik River district. Mica schist and other schistose and gneissic rocks.	

[a] The stratigraphic position of these rocks is not definitely established. They may include beds equivalent to part of the Eska conglomerate and Chickaloon formation as well as beds older than the Chickaloon. (See p. 40.)

The oldest rocks of the Matanuska Valley are a group of metamorphic sediments, locally schistose, that form a large part of the Chugach Mountains. There is no positive evidence as to the age of these metamorphic materials or as to their relations to the other rocks of the Matanuska Valley, except that they appear to be older than the Jurassic volcanic rocks.

The Jurassic section exposed in the Matanuska Valley constitutes one of the thickest and most comprehensive Jurassic sections known in Alaska, although unfortunately it is incomplete in two respects—neither the base of the lower Jurassic volcanic rocks nor any older formation whose age is definitely known is exposed in this district, and some of the Lower Jurassic faunas of the Alaska Peninsula are apparently absent. Otherwise, the section appears to contain representatives of all the marine Jurassic faunas known in Alaska. The section is in general very similar, both lithologically and faunally, to the Cook Inlet section, of which it may be regarded as the detached northeastern extension. The Lower Jurassic volcanic rocks of the Matanuska Valley resemble the rocks of the same age at Seldovia, on the east coast of Cook Inlet, both lithologically and faunally but differ from them by including plant beds. The Middle Jurassic is represented in the district by the Tuxedni sandstone, and the Upper Jurassic by the Chinitna shale and the Naknek formation, all of which contain faunas that are practically identical with those from the same formations on Cook Inlet. The Upper Jurassic rocks of this district are overlain, probably unconformably, by Lower Cretaceous rocks. In this respect the section resembles that of the Alaska Peninsula and differs from that of Cook Inlet, where the Cretaceous is absent.

The Cretaceous rocks of the Matanuska Valley include both Lower Cretaceous and Upper Cretaceous marine sedimentary strata. The Lower Cretaceous tuff and arkose, which carry *Aucella crassicollis*, are somewhat but not altogether similar, both lithologically and faunally, to the Lower Cretaceous rocks of the Alaska Peninsula. The Upper Cretaceous beds are especially well developed, comprising several thousand feet of strata that crop out over a wide area. They contain a fauna that is similar to that of the Upper Cretaceous beds of the Alaska Peninsula, but they differ strikingly from those beds in that they contain neither coal nor the characteristic Upper Cretaceous flora

The Tertiary rocks of the Matanuska Valley include three well-defined formations—the Chickaloon formation, which carries the flora of the Kenai formation of Cook Inlet and is therefore of Eocene age; the Eska conglomerate, which overlies the Chickaloon formation and is possibly of Miocene age; and the lava and tuff that unconformably overlie the Eska conglomerate, which are possibly of Pliocene age. Another assemblage of rocks that consists of arkose, shale, and conglomerate is of doubtful position; as now mapped it probably includes the basal Tertiary beds of this district and may include also the coarse marginal equivalent of the Chickaloon formation, as well as beds that should be referred to the Eska conglomerate.

The Quaternary deposits include a thick covering of glacial and outwash gravel and the alluvial deposits of the present flood plains.

METAMORPHIC ROCKS OF UNDETERMINED AGE

ALTERED GRAYWACKE, SLATE, AND SCHIST

DISTRIBUTION

Metamorphic rocks, including altered graywacke, slate, and schist, were seen 7 or 8 miles up the valley of Gravel Creek and in the valleys of many of the large creeks west of Gravel Creek, at a general distance of 3 or 4 miles south of Matanuska River. The abundance of contorted graywacke, slate, and schist and the practical absence of other material in the gravel of the upper basins of these creeks indicate that the area of these rocks extends at least as far south as the headwaters of the streams. The abundance of pebbles of these rocks in the gravel of Matanuska River indicates that they probably occupy a very considerable area in this part of the Chugach Mountains.

LITHOLOGIC CHARACTER

The following petrographic description of schist from this series of rocks, furnished by J. B. Mertie, jr., was based upon the microscopic study of pebbles obtained in the bed of Gravel Creek:

> The schists are light-gray to dark-gray foliated rocks, cut by numerous veinlets of quartz, calcite, epidote, or other vein minerals. Rarely the vein minerals make up the main part of the rock, giving to it a banded green and white appearance. These rocks have suffered intense dynamic metamorphism, which has resulted in thorough recrystallization, the original structure being entirely obliterated, and in the development of foliation cleavages. One specimen shows typically the impression of a new cleavage upon an early foliation, there being a close folding on a microscopic scale, which is cut by fractures at right angles to the axes of the folds. The minerals commonly developed are quartz, sericite, chlorite, biotite, epidote, and calcite. Iron oxides, apatite, and carbonaceous material are accessory constituents. The quartz has strong undulatory extinction and carries inclusions of mica and epidote. The mica and chlorite have the normal flaky habit which they show in schistose rocks. The plagioclase is either oligoclase-albite or albite and is generally fractured, thus indicating continued metamorphism after its formation. The plagioclase carries submicroscopic quartz-calcite inclusions. The rocks are cut by quartz-calcite, quartz-albite, and epidote veinlets. According to the relative abundance of the above-mentioned constituents quartz-mica schist, quartz-albite schist, and calcite-chlorite schist may be recognized. Where these metamorphic rocks occur in place still other types are probably present.

AGE AND CORRELATION

The schist and metamorphosed sediments of Gravel Creek and vicinity occur in an east-west belt in line with and about midway between the mica schist of the Willow Creek district [13] and the schist of Klutina Lake.[14] It is possible that all three of these occurrences are part of one general schist area, formerly continuous, which is now largely buried beneath younger rocks. A correlation of these rocks with those of Willow Creek and of Klutina Lake has been suggested, but inasmuch as the schist of the Willow Creek area

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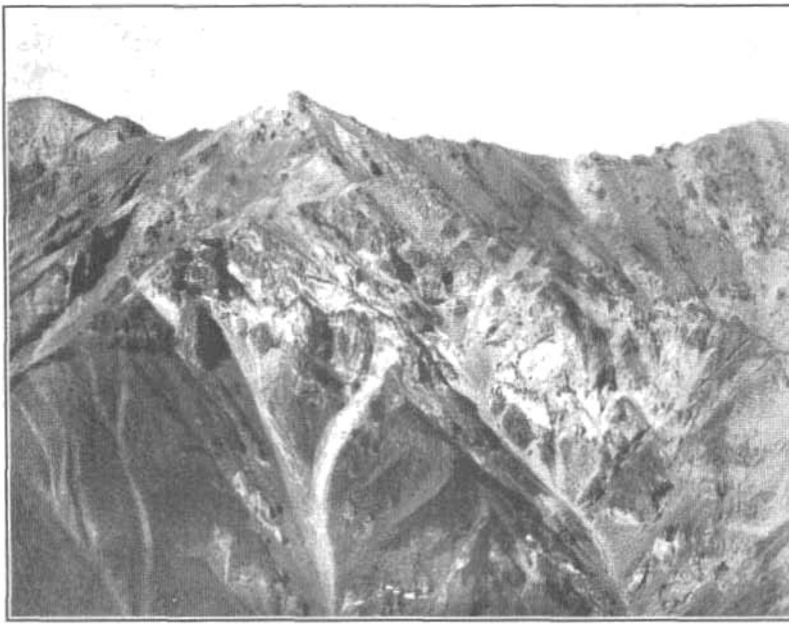
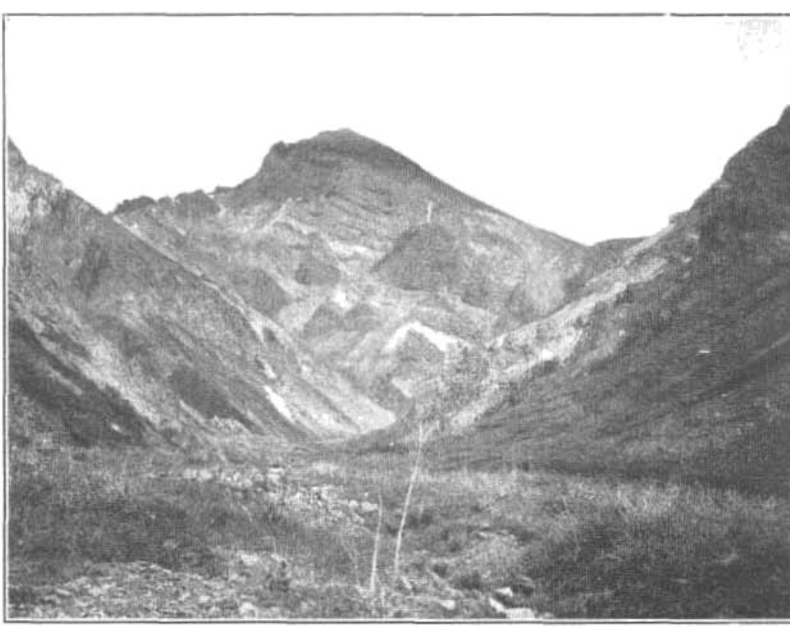
[13] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, pp. 26–30, 1915.

[14] Schrader, F. C., A reconnaissance of a part of Prince William Sound and the Copper River district, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 410, 1900.

SHEEP MOUNTAIN AND GORGE OF THE MATANUSKA FROM GLACIER POINT



A. LOWER JURASSIC ROCKS ON WEST SIDE OF CHICKALOON RIVER NORTH OF CASTLE MOUNTAIN



B. LOWER JURASSIC ROCKS IN SHEEP MOUNTAIN consists largely of highly fissile mica schist, whereas the metamorphic rocks of the Chugach Mountains, though locally schistose and micaceous, are in general much less completely metamorphosed and consist of distorted and crumpled graywacke and slate, it is believed that the metamorphic rocks of this part of the Chugach Range are younger than the schist of the Willow Creek district. They may be as young as early Mesozoic, or they may be older.

LOWER JURASSIC ROCKS

TALKEETNA FORMATION

DISTRIBUTION

The Lower Jurassic volcanic rocks have a wide distribution in and adjacent to the upper Matanuska Valley, where they are known to occur in a number of areas. The Chickaloon River area extends along the valley of Chickaloon River from the vicinity of Castle Mountain (pl. 4, *A*) to the head of the river (pl. 4, *B*) and according to Paige and Knopf,[15] is continuous with a large area in the valley of Talkeetna River. The Boulder Creek area occupies the larger part of the valley of Boulder Creek south of the creek and north of Anthracite Ridge. Its boundaries have not yet been surveyed in detail. South of the Matanuska there is an extensive area of somewhat metamorphosed volcanic rocks that have been tentatively correlated with the Lower Jurassic volcanic rocks. Jurassic volcanic rocks occupy also a small detached anticlinal area in the valley of Hicks Creek, and, outside the district directly considered in this report, areas on Sheep Mountain near the headwaters of the Matanuska, on the headwaters of Alfred and Crooked Creeks, and in the valley of Oshetna River. (See pl. 2.) Martin[16] has proposed the name Talkeetna formation for this group of rocks, and that name is here used as applied by him.

CHARACTER AND RELATIONS

The Talkeetna formation includes lava agglomerate, breccia, and tuff, interbedded with a less volume of sandstone and shale. The beds are composed chiefly of water-laid volcanic detritus. Their total thickness is probably several thousand feet but can not be accurately estimated on account of the complex structure and the lack of recognizable key strata. These beds were deposited largely if not wholly in marine waters, although the fossil plants are possibly

[15] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pl. 2, 1907.

[16] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, p. 219, 1926.

indicative of temporary terrestrial conditions. Neither the basal contact of these beds nor the rocks that underlie them have been observed. They are overlain in the eastern Talkeetna Mountains by the marine Middle Jurassic beds of the Tuxedni sandstone. A detailed account of the petrographic character of these rocks is given by J. B. Martin, jr., on pages 56-60.

FAUNA AND FLORA

The fossils of the Talkeetna formation of the Matanuska Valley include both plants and marine invertebrates. It is impossible from the data at hand to determine their horizon or horizons. All came from one lithologic unit or complex that has not thus far proved to be stratigraphically divisible. Further investigation, however, may show that these beds comprise more than one stratigraphic unit and that the plants and the marine shells are not of the same age. In the list given below the marine invertebrates were identified by T. W. Stanton and the plants by F. H. Knowlton.

The following fossils were collected by G. C. Martin and F. J. Katz in 1910, on the west side of Chickaloon River:

6697. Doone Creek, at mouth of gulch, 3,950-foot point, traverse of August 30; float:

Rhynchonella sp.
Pecten sp. a.
Pecten sp. b.
Pecten sp. d.
Trigonia? sp.
Cardinia? sp.
Deroceras? sp.
Aegoceras? sp.

6706. Creek entering Chickaloon River from west 1 mile above Government Bridge; altitude, 2,000 feet:

Pecten sp. b.
Deroceras? sp.

6707. Creek entering Chickaloon River from west 1 mile above Government Bridge; float from base of falls:

Rhynchonella sp.
Gryphaea? sp.
Ostrea sp.
Pecten sp.
Probably Jurassic.

6708. Creek entering Chickaloon River from west 1 mile above Government Bridge; float above falls:

Pecten sp.
Several undetermined small pelecypods.
Possibly Jurassic.

6709. On same creek as 6708 at altitude 2,200 feet; from talus:

Cardinia? sp.
Jurassic.

6693. Creek entering Chickaloon River from west 1 mile above Government Bridge; altitude, 2,200 feet:

Rhynchonella sp.
Pecten sp. a, smooth form.
Pecten sp. b, strongly ribbed Vola type.
Pecten sp. c, large flat, coarse-ribbed form.

The following fossils were obtained from the same district in 1913 by G. C. Martin and R. M. Overbeck:

8569. West side of Chickaloon River at mouth of creek 3 miles above Government Bridge; from black limestone float:

Rhynchonella sp.
Ostrea sp.
Gryphaea? sp.
Pecten sp., small smooth form.
Pecten sp., fine-ribbed form.
Pecten sp., coarse-ribbed form of Vola type.
Modiola sp.
Gervillia? sp.
Trigonia? sp. of glabrae type.
Thracia? sp.
Undetermined ammonites.
Jurassic, probably Lower Jurassic.

8570. Same locality as No. 8569; from breccia float:

Ostrea sp.
Pecten sp., fine-ribbed form.
Pecten sp., coarse-ribbed form of Vola type.
Probably Lower Jurassic.

The fossil plants listed below[17] were collected in 1913 from the tuffaceous shale of the Boulder Creek valley by G. C. Martin, J. B. Mertie, jr., and R. M. Overbeck.

6700. Crest of spur between first and second tributaries entering East Fork of Boulder Creek above its mouth; elevation 4,780 feet; from shaly and cherty beds interstratified with tuff:

Cladophlebis hirta? Moller.
Dictyophyllum nilssoni (Brongniart) Goeppert.
Sagenopteris? sp.
Otozamites bornholmiensis? Moller.
Nilssonia polymorpha Schenk.
Pagiophyllum falcatum Bartolin.

6698. About three-quarters of a mile up the next to the lowest creek entering the East Fork of Boulder Creek from the south; from sandstone and shale interbedded with tuffs:

Pterophyllum rajmahalense Morris.
Pterophyllum aequale (Brongniart) Nathorst.
Ctenophyllum angustifolium? Fontaine.

6699. Talus from cliff about a third of a mile upstream from No. 6698:

Otozamites pterophylloides Brongniart.
A single specimen.

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[17] Knowlton, F. H., A Lower Jurassic flora from the upper Matanuska Valley, Alaska: U. S. Nat. Mus. Proc., vol. 51, pp. 451–460, pls. 79–82, 1916.

6701. Float from same locality as No. 6698:
Otozamites pterophylloides Brongniart.
A single sample.

The following lot was collected by J. B. Mertie, jr., near the localities that yielded the fossil plants:

8565. Same creek as No. 6698, about 1¼ miles above its mouth; from talus:
Trigonia? sp., fragments.
Probably Lower Jurassic.

The following lot was obtained by a prospector from the eastern part of the Boulder Creek area, but the exact locality is not known:

8561. Near head of Boulder Creek; collected by a prospector:
Pecten sp., rather large form of Vola type.
Probably Lower Jurassic.

The fossils represented by the following list were collected in the Sheep Mountain area by Adolph Knopf in 1906:

6 AK 201. Tributary to Squaw Creek heading under 6,375-foot peak at east end of Sheep Mountain; from fossiliferous tuff associated with lava and coarse pyroclastic rocks.
Rhynchonella.
Lima.
Pecten sp., smooth.
Pecten sp., Vola type.
Trigonia.
Astarte?
Protocardia.
Pleuromya.
Sonninia?

The following were collected by G. C. Martin from the southern face of the same mountain:

8589. Sheep Mountain, altitude 3,400 feet, on creek flowing southeast from 6,375-foot peak:
Rhynchonella sp.
Pecten sp.
Nemodon? sp.
Protocardia sp.
Undetermined gastropod.
Jurassic, either Middle or Lower Jurassic.

AGE AND CORRELATION

The Lower Jurassic rocks of the Matanuska Valley were referred tentatively to the Middle Jurassic by Paige and Knopf on the basis of the following opinion by Stanton concerning the fossils of lot 6 AK 201:

The Jurassic age of this lot is clearly shown by the form of the Trigonia and of the ammonite (Sonninia?). The general aspect of the fauna is that of the lower part of the Enochkin,[18] though it may be somewhat older than

[18] The lower part of the Enochkin formation is now known as the Tuxedni sandstone.

the fauna in lots 88A and 88B. With the exception of the Vola-like species of Pecten there is nothing in it to suggest the Lower Jurassic fauna of Seldovia.

A later and somewhat different opinion concerning the age of these fossils was given by Stanton after examining the collections obtained by Martin and Katz in 1910. This opinion is as follows:[19]

> The lots numbered 6693, 6697, 6706–6709 are referred to the Jurassic and are probably Lower Jurassic, though the paleontologic evidence for the latter reference is not so full as is desirable. The fossils are almost certainly from the same beds from which Mr. Knopf collected his lot No. 201, on the head of Matanuska River, in 1906. Mr. Knopf's collection was at that time doubtfully referred to the "Enochkin formation," but I am now inclined to consider the beds from which he collected equivalent to the supposed Lower Jurassic near Seldovia and to regard them as Lower Jurassic. It is true that not more than two or three species have been found common to the different localities from which these fossils have been collected, but the general character of the fauna in each case is suggestive of Lower Jurassic, and it is probable that more systematic collecting would prove that the different lots really belong to a single fauna.

From an examination of fossil plants from these rocks in the basin of Boulder Creek, Knowlton[20] concludes that the containing beds are of Lower Jurassic (Liassic) age.

Further evidence of the Lower Jurassic age of the Talkeetna formation is found in the fact that it is overlain by the Tuxedni sandstone, which contains fossils of Middle Jurassic age.

The Talkeetna formation of the Matanuska Valley bears some resemblance, both lithologic and faunal, to the supposed Lower Jurassic tuffs[21] near Seldovia, on the east coast of Cook Inlet, although the tuffs near Seldovia are not known to contain plant beds. The available evidence, as suggested by Stanton, is strongly suggestive of this correlation, but it can not yet be regarded as definitely established.

MIDDLE AND UPPER JURASSIC ROCKS

Rocks of Middle and Upper Jurassic age have not been recognized in the part of the Matanuska Valley here under consideration, but they are widely distributed and reach a considerable thickness in the area north and northeast of this district. They include the Middle Jurassic Tuxedni sandstone and the Upper Jurassic Chinitna and Naknek formations, descriptions of which have already

[19] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 31, 1912.

[20] Knowlton, F. H., A Lower Jurassic flora from the upper Matanuska Valley, Alaska: U. S. Nat. Mus. Proc., vol. 51, pp. 451–460, pls. 79–82, 1916.

[21] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 63–67, 1915.

been published.[22] It is entirely possible that Middle and Upper Jurassic rocks may be present in the upper Matanuska Valley beneath the younger formations that now occupy this basin, although no outcrops have been definitely recognized. One fossil collection obtained near the west end of Anthracite Ridge, north of the great fault, suggests that some Jurassic rocks may be included in the area now mapped as Upper Cretaceous. In order to make plain the possible stratigraphic sequence in this district brief descriptions of the Tuxedni sandstone and the Chinitna and Naknek formations are given in this report. These formations are not coal bearing, and no hope is offered of finding coal beds below the Tertiary rocks.

TUXEDNI SANDSTONE (MIDDLE JURASSIC)

DISTRIBUTION

The Tuxedni sandstone has been recognized in five areas in and adjacent to the Matanuska Valley. These areas are on the upper part of Boulder Creek, on Caribou Creek near the mouth of Billy Creek, on the headwaters of Nelchina River, on the headwaters of Alfred and Crooked Creeks, and at the east end of Sheep Mountain.

CHARACTER AND RELATIONS

The Tuxedni sandstone of the Matanuska Valley is composed of sandstone and sandy shale. The thickness has not been accurately determined but is known to be at least several hundred feet and may be 1,000 feet or more. The formation contains abundant marine fossils and was probably deposited wholly in marine waters, although some of the sandstone beds contain abundant poorly preserved vegetable remains, mostly waterworn sticks and stems. The Tuxedni sandstone rests upon the Lower Jurassic volcanic rocks (Talkeetna formation), described above, but the scarcity of well-marked bedding planes in the volcanic rocks makes it difficult to determine whether the contact is conformable or unconformable. It is overlain with apparent conformity by the Chinitna shale, which is described below.

The Boulder Creek area of the Tuxedni sandstone lies north of an area of Lower Jurassic volcanic rocks. The contact with the volcanic rocks along the upper reach of Boulder Creek is apparently a fault. The contact as exposed on the creek north of the extreme west end of Anthracite Ridge is a sedimentary contact, but the lack of well-marked bedding in the underlying volcanic rocks causes

[22] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, pp. 20–22, 1912. Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 32–34, 1918.

uncertainty as to whether or not the beds are conformable. The lower beds of the Tuxedni sandstone at this point are of greenish sandstone that is probably calcareous. Shale and shaly sandstone are also present. Many of the beds are rich in marine invertebrate fossils, and some of them contain poorly preserved vegetable remains, mostly sticks. The thickness of the sandstone here exposed is at least several hundred feet and is probably many hundred feet. This area probably lies in a syncline that pitches northeast and has each limb diagonally truncated by a fault. The center of the syncline is occupied by younger rocks, described below (pp. 35–40).

The Tuxedni formation crops out on both banks of Caribou Creek from Billy Creek to Divide Creek. The exposures at the mouth of Billy Creek consist of much crushed greenish shale that dips 20° W. The shale appears to underlie the volcanic rocks in the canyon of Billy Creek, but the contact is probably a fault. The dip changes to northeast within half a mile below Billy Creek and continues northeast to the mouth of Divide Creek. Within this tract the exposures consist of shaly sandstone and sandy shale with numerous calcareous concretions. These beds yielded the fossils of lots 8584 and 8585. The thickness of the beds exposed between Billy and Divide Creeks is possibly 600 to 700 feet.

The fauna of the Tuxedni formation has been recognized in a collection of fossils (lot 157, p. 28) obtained on Nelchina River about a mile above the tributary that comes from the vicinity of the headwaters of Billy Creek. The rocks at this locality were described by Knopf, in his field notes, as highly fossiliferous "graywacke." The beds have a gentle dip and apparently underlie the neighboring Chinitna formation.

The Tuxedni formation as exposed on Alfred Creek consists of yellowish sandstone. Some of the beds contain abundant fossil sticks and stems, and others contain marine shells.

The low hills at the east end of Sheep Mountain show exposures of sandstone that resemble the Tuxedni sandstone of Alfred Creek. The few fossils that have been obtained here do not yield conclusive evidence as to whether this is the Tuxedni sandstone or not, but they indicate that it is probably Jurassic.

FAUNA

The fossils of the Tuxedni sandstone of the Matanuska Valley, as now known, consist chiefly of marine invertebrates. Some beds contain numerous fossil sticks and stems of indeterminate character, but only one determinable leaf has been collected. The marine fossils listed below were identified by T. W. Stanton.

The following list represents a collection obtained from a highly fossiliferous bed near the base of the Tuxedni sandstone:

8567. Second creek from the north entering Boulder Creek above the canyon (3⅛ miles up creek); collected by G. C. Martin, J. B. Mertie, jr., and R. M. Overbeck, 1913:

Single specimen of plant (Sagenopteris göppertiana Zigno).
Terebratula sp.
Rhynchonella sp.
Camptonectes? sp.
Pecten sp.
Lima cf. L. gigantea Sowerby.
Avicula sp.
Inoceramus ambiguus Eichwald.
Pinna sp.
Cucullaea sp.
Nemodon? sp.
Trigonia cf. T. dawsoni Whiteaves.
Protocardia sp.
Isocardia sp.
Cyprina? sp.
Pleuromya sp.
Pleuromya carlottensis Whiteaves?
Thracia cf. T. semiplanata Whiteaves.
Thracia? sp.
Pleurotomaria sp.
Amberleya sp.
Nerinea sp.
Phylloceras? sp.
Stephanoceras? sp.
Stephanoceras cf. humphriesianum (Sowerby).
Sphaeroceras cf. S. oblatum (Whiteaves).
Middle Jurassic, Tuxedni fauna.

The fossils in the two following lists were obtained from the northeastern extension of the same area, but from a somewhat higher horizon:

8571. Creek entering Boulder Creek from north 3 miles above East Fork; float; collected by G. C. Martin, 1913:

Pecten sp.
Avicula sp.
The ammonite belongs to the Chinitna fauna, but the other fossils probably came from the Tuxedni fauna.

8572. Elevation 4,200 feet on ridge west of creek tributary to Boulder Creek from north, 3 miles above East Fork; collected by G. C. Martin, 1913:

Sphaeroceras sp., fine specimen.
Stephanoceras sp.
Middle Jurassic, Tuxedni fauna.

The fossils represented in the two following lists were evidently derived from an unmapped area of the Tuxedni sandstone in the hills north of Anthracite Ridge:

6 AK 42. North face of Anthracite Ridge near west end, altitude 3,900 feet, 8½ miles N. 75° E. of mouth of Boulder Creek; collected by Adolph Knopf, 1906:

Inoceramus cf. I. lucifer Eichwald.

This species occurs in the lower part of the "Enochkin [22] formation" at Snug Harbor.

8564. Float from tributary entering Boulder Creek from southeast, next below East Fork; collected by G. C. Martin, 1913:

Undetermined corals probably representing several genera.
Rhynchonella sp.
Amberleya sp.
Nerinea? sp.

Probably Middle Jurassic with possibly some Lower Jurassic.

The Caribou Creek area has yielded the fossils represented in the five following lists:

6 AK 88 A. Tributary entering Caribou Creek from the west a quarter of a mile above Billy Creek; collected by Adolph Knopf, 1906:

Inoceramus cf. I. lucifer Eichwald.
Pleuromya.
Pleurotomaria.
Phylloceras.
Stephanoceras.
Oppelia?

6 AK 88 B. Same locality as preceding, but found in float boulder in stream bed; collected by Adolph Knopf, 1906:

Inoceramus.
Natica.
Phylloceras.
Stephanoceras.
Sonninia?, two species.
Belemnites.

The two lots are evidently from the same horizon, and nearly all the species occur in the lower part of the "Enochkin formation" [22] at Snug Harbor.

8584. North bank of Caribou Creek, half a mile below Billy Creek; collected by G. C. Martin, 1913:

Terebratula sp.
Inoceramus ambiguus Eichwald.
Stephanoceras? sp.

Middle Jurassic, apparently Tuxedni fauna.

8585. North bank of Caribou Creek, three-fourths mile below Billy Creek; collected by G. C. Martin, 1913:

Stephanoceras sp. cf. S. humphriesianum.

Middle Jurassic, Tuxedni fauna.

6 AK 98. Canyon entering Billy Creek from the east 2 miles above its mouth; collected by Adolph Knopf, 1906:

Inoceramus cf. I. ambiguus Eichwald.

A young specimen probably belonging to this "Enochkin" [22] species.

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[22] The lower part of the "Enochkin formation" is now known as the Tuxedni sandstone. (See U. S. Geol. Survey Bull. 485, pp. 59-64, 1912.)

The following lot was obtained from the area on the headwaters of Nelchina River:

6 AK 157. Nelchina River, 12 miles N. 17° E. of mouth of Billy Creek; 1 mile above trail; collected by Adolph Knopf, 1906:

Pecten, small smooth species.
Eumicrotis?
Astarte?

These are probably from the "Enochkin[23] formation."

The Alfred Creek area has yielded the following collection:

6 AK 196. Alfred Creek, 7 miles above junction with Caribou Creek; collected by Adolph Knopf, 1906:

The single specimen is a fragment of a large bivalve doubtfully referred to Lima. The horizon is probably in the "Enochkin[23] formation."

The fossils obtained from the area of sandstone at the east end of Sheep Mountain are not definitely known to belong to the Tuxedni fauna. According to Stanton, they might be either "Jurassic or Cretaceous," but are "more probably Jurassic," and as the rocks bear a closer resemblance to the Tuxedni sandstone than they do to any known Cretaceous sandstone or other sandstone of this region, there is believed to be little doubt that the fossils in the following lot belong to the Tuxedni.

8588. Sheep Mountain at altitude 3,400 feet on creek flowing southeast from 6,375-foot peak. Collected by G. C. Martin, 1913.

Inoceramus sp.

Jurassic or Cretaceous, more probably Jurassic.

AGE AND CORRELATION

The Tuxedni sandstone of the Matanuska Valley corresponds very closely in lithologic and faunal character, as well as in its relations to the overlying and underlying rocks, to the Tuxedni sandstone of the type district[24] on the west shore of Cook Inlet. It differs from the Tuxedni sandstone of Cook Inlet in being apparently somewhat thinner and in containing a larger proportion of shaly beds. Its fauna, especially as represented in the large collection of lot 8567, shows no essential difference from that of the Tuxedni sandstone of the type area.

The other Alaskan rocks which carry this fauna and with which these beds may be correlated include at least part of the Tordrillo formation[25] of the Alaska Range, part of the Middle Jurassic rocks

[23] The lower part of the "Enochkin formation" is now known as the Tuxedni sandstone. (See U. S. Geol. Survey Bull. 485, pp. 59–64, 1912.)

[24] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, 1912.

[25] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 87–90, 1911.

of the Alaska Peninsula, and the tuffaceous slate[26] of the lower Chitina Valley.

The relative position of the Tuxedni sandstone among the Jurassic rocks in other parts of the world has not been definitely established. The fossils have not yet been fully studied, but they appear to indicate that the Tuxedni sandstone corresponds approximately to part of the Middle Jurassic or Lower Oolite of the European classification, possibly to the Inferior Oolite or Bajocian.

CHINITNA FORMATION (UPPER JURASSIC)

DISTRIBUTION

Strata that are believed to represent the Chinitna shale of Cook Inlet have been recognized in two areas in the Matanuska Valley. One of these areas is situated on the northern tributaries of Boulder Creek, and the other is in the eastern part of the Talkeetna Mountains, between Nelchina River and the headwaters of Billy Creek. Beds of this same formation in the basin of Little Nelchina River have been described by Chapin.[27]

CHARACTER AND RELATIONS

The Chinitna formation as exposed on Boulder Creek consists of shale and shaly sandstone with lesser amounts of conglomerate and massive sandstone. Calcareous concretions are abundant in the shale. This formation occurs in a synclinal area in which it overlies the Tuxedni sandstone with apparent conformity and is overlain unconformably by the rocks of the Naknek formation. The thickness has not been accurately measured but is probably several thousand feet.

The Chinitna formation in the eastern part of the Talkeetna Mountains on the headwaters of Nelchina River has not been studied in detail. The rocks at one locality in this area were described in Knopf's field notes as blue shales, which strike N. 15° W. and dip 10° NE. and contain numerous limestone nodules. These nodules are similar in lithologic character to float found at the same place that contained the fossils of lot 156. (See p. 30.) The rocks at another locality on Nelchina River were described by Knopf as fossiliferous sandstones with a gentle eastward dip. The fossils of lot 185 (p. 30) were obtained at this place. The formation apparently overlies the Tuxedni sandstone and is overlain by the Naknek formation in this area, but there is no information available as to

[26] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 25–27, 1914.

[27] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 33–34, 1918.

whether the contacts are conformable or unconformable, or as to the thickness. The Chinitna formation in the basin of Little Nelchina River is said by Chapin to consist of concretionary sandy shale and some sandstone, locally conglomerate.

FAUNA

The known fossils of the Chinitna formation of the Matanuska Valley are represented in the following lists. They were identified by T. W. Stanton.

8573. On north side of knob 1 mile from Boulder Creek, about 3 miles above mouth of East Fork; altitude 3,400 feet; collected by G. C. Martin, 1913:

Gryphaea sp.
Cucullaea sp.
Astarte sp.
Cyprina sp.
Pleuromya sp.
Cadoceras? sp.

Upper Jurassic, probably Chinitna fauna.

8571. Float from tributary to Boulder Creek that enters from the north 3 miles above East Fork; collected by G. C. Martin, 1913:

Cadoceras doroschini (Eichwald).

The ammonite belongs to the Chinitna fauna but the other fossils probably came from the Tuxedni fauna.

8576. Tributary to Boulder Creek that enters from the north 5½ miles above East Fork; about 3,000 feet up creek; altitude 3,310 feet; collected by R. M. Overbeck, 1913:

Rhynchonella sp.
Pecten sp.
Avicula sp.
Trigonia sp.
Isocardia sp.
Cadoceras doroschini (Eichwald).
Belemnites sp.

Upper Jurassic, Chinitna fauna.

6 AK 156. Near headwaters of Nelchina River about 10 miles N. 10° E. of mouth of Billy Creek; altitude 5,000 feet; from limestone nodules not in place; collected by Adolph Knopf, 1906:

Cadoceras sp., many immature specimens.
Belemnites, fragments.

The horizon is that of the *Cadoceras* zone,[a] which forms the upper third of the "Enochkin formation."

6 AK 185. Nelchina River, 1½ miles east of trail crossing, about 13 miles N. 27° E. of mouth of Billy Creek; from sandstones; collected by Adolph Knopf, 1906:

Pleuromya.
Cadoceras?, fragmentary imprint doubtfully referred to the genus.
Belemnites.

The horizon is probably in the upper part[a] of the "Enochkin formation."

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[a] The *Cadoceras* zone, constituting the upper part of the "Enochkin formation," is now known as the Chinitna shale. (See U. S. Geol. Survey Bull. 485, pp. 65–68, 1912.)

AGE AND CORRELATION

The Chinitna formation of the Matanuska Valley contains a fauna very similar to that of the Chinitna shale [29] of Cook Inlet and resembles that formation in its stratigraphic relations to the underlying and overlying beds but differs somewhat in containing a larger proportion of sandstone and conglomerate. In this respect it bears a closer resemblance to the *Cadoceras*-bearing beds of the Alaska Peninsula [30] than it does to the *Cadoceras*-bearing beds of the Chinitna shale of Cook Inlet. The occurrence of *Cadoceras* in these beds shows that they are to be correlated approximately with the Callovian of Europe and therefore assigned to the Upper Jurassic.

NAKNEK FORMATION (UPPER JURASSIC)

DISTRIBUTION

The Naknek formation occupies two known areas in and adjacent to the Matanuska Valley—a small area near the headwaters of Boulder Creek and a larger one on the headwaters of Billy Creek and Nelchina River. A part of the Nelchina River area has been described by Chapin.[31]

CHARACTER AND RELATIONS

The Upper Jurassic rocks of the Naknek formation as exposed on Boulder Creek consist of green sandy shale several hundred feet thick, which rests unconformably upon the shale and sandstone of the Chinitna formation and is overlain by Upper Cretaceous and Tertiary rocks. A large part of the original thickness of the Upper Jurassic strata was probably removed during the erosion interval represented by the unconformity above them.

The rocks of the Naknek formation on the headwaters of Nelchina River and Billy Creek lie in gentle folds and cover a large area. As exposed in this area the formation includes beds of shale, sandstone, tuff, arkose, and conglomerate. A lower sandstone and shale portion is overlain by dark-blue fissile shale that contains beds of hard white sandstone. The thickness of the formation is certainly more than 1,000 feet and is probably several thousand feet. It rests upon the Chinitna formation without a known unconformity and is overlain, probably conformably, by the Lower Cretaceous rocks described below.

The Upper Jurassic rocks exposed on Billy Creek and Nelchina River were described by Knopf [32] as follows:

[29] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 65–68, 1912.

[30] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

[31] Chapin, Theodore, op. cit., pp. 36–38.

[32] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 20–23, 1907.

The Upper Jurassic rocks consist largely of blue shales, locally carrying fossiliferous limestone nodules. With the shales are associated various sandstones, conglomerates, and some tuffs and arkoses. Strata of this age have a wide distribution east of Chickaloon River.

The sandstones of this series are usually ordinary yellow sandstones, which in places are conspicuous on account of the multitudes of *Aucella* contained in them, this fossil making up as much as one-half of the rock. In some places the sandstones have light-gray color. This is due to the fact that such beds are highly feldspathic and contain much finely comminuted black mica with an abundence locally of small bits of carbonaceous material.

* * * * * * *

Two conglomerates have been described as occurring in the late Jurassic rock. Of these, the andesite-quartz-monzonite conglomerate[a] overlies a portion of the late Jurassic strata, possibly of upper Middle Jurassic age, and overlaps the greenstones of lower Middle Jurassic age.

The other conglomerate occurs interstratified with shales and sandstones, carrying *Aucella* cf. *bronni*, so that it is definitely known to be of Upper Jurassic age. The granite boulders of this conglomerate do not, however, show the striking freshness so characteristic of the granite of the other conglomerate; hence it seems to have been derived from a granitic land mass which had been exposed for a longer period to subaerial decay. For this reason the andesite-granite conglomerate is regarded as occupying a lower position in the stratigraphic column, probably near the base of the Upper Jurassic, like its analogue on the west coast of Cook Inlet.

Along Nelchina River, immediately below the junction of the north and south forks, the stream bluffs reveal an interdigitation of lenses of sandstone, shale, and coarse conglomerate. The sandstones show cross-bedding and contain remains of *Aucella*. The conglomerates are composed of well-rounded material, boulders a foot through being common. The prevalence of granite rocks is noteworthy. The conglomerate masses serve to emphasize the lenticular habit of the deposit. A lens 25 feet thick and 100 feet long was found completely inclosed by sandstone. Solitary waterworn boulders have been embedded in the center of shale lenses. These various characteristics indicate a deposit formed under near-shore conditions, probably in the vicinity of the debouchure of a swift stream. In harmony with this interpretation is that fact that the *Aucella* characteristic of these rocks, though a true marine species, is often found in beds interstratified with sandstones inclosing abundant carbonaceous fragments.

FAUNA

The following lists represent the known fossils from the Naknek formation of the Matanuska Valley as identified by T. W. Stanton:

8574. Lowest outcrop on creek entering Boulder Creek from northwest 5½ miles above East Fork; from green sandy shale; collected by G. C. Martin, 1913:

- Pecten sp.
- Aucella sp.
- Belemnites sp.

Upper Jurassic=Naknek fauna.

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[a] Mr. Martin refards this conglomerate as of Tertiary age.

8575. From concretions on talus across creek from No. 8574, probably from about the same beds; collected by G. C. Martin, 1913:

Avicula sp.
Astarte sp.
Isocardia sp.
Phylloceras sp.
Cardioceras sp.
Belemnites sp.
Upper Jurassic=Naknek fauna.

8579. Limestone gulch, tributary of Billy Creek from the east; 300 feet below base of Lower Cretaceous limestone; collected by G. C. Martin, 1913:

Aucella sp. cf. A. pallasi Keyserling.
Pseudomonotis (Eumicrotis) sp.
Tancredia sp.
Upper Jurassic=Naknek fauna.

8583. Limestone hills east of Billy Creek; about 200 or 300 feet below base of Lower Cretaceous limestone; collected by G. C. Martin, 1913:

Aucella sp. related to A. bronni Rouillier.
Upper Jurassic.

8581. Near Limestone Gap, east of Billy Creek; 100 or 200 feet below base of Lower Cretaceous limestone; collected by G. C. Martin, 1913:

Pseudomonotis (Eumicrotis) sp.
Aucella sp. related to A. bronni Rouillier.
Upper Jurassic.

6 AK 136. A quarter of a mile up creek entering Billy Creek from the west 8 miles above its mouth; collected by Adolph Knopf, 1906:

Aucella cf. A. bronni Rouillier.
The same species occurs in similar rock in the Naknek formation of Kamishak Bay.

AGE AND CORRELATION

The rocks here described are referred to the Upper Jurassic and are correlated with the Naknek formation of the Alaska Peninsula and of Cook Inlet because of similarity of fauna, of lithologic character, and of stratigraphic sequence. The presence of the two species of *Aucella* related to *Aucella pallasi* Keyserling and *Aucella bronni* Rouillier and of *Cardioceras* sp. is the paleontologic basis of this age assignment and correlation.

LOWER CRETACEOUS ROCKS

TUFF AND CONGLOMERATE

In this general region the Lower Cretaceous rocks include a formation composed of tuff and conglomerate in the Nelchina basin, but this formation is not known to crop out in the district here described in detail. The Lower Cretaceous tuff and conglomerate, however, may be present here beneath the Upper Cretaceous shale and sandstone. They are not coal bearing. A description of these beds and the basis for their correlation are given elsewhere by Martin.[34]

LOWER CRETACEOUS (?) LIMESTONE

DISTRIBUTION AND CHARACTER

Limestone, believed to be of Lower Cretaceous age, occurs in the district here described only in the northwest corner, north of Castle Mountain. This limestone has already been described by Martin and Katz[35] as consisting of a blue and gray to white or pink fine to medium grained limestone, much shattered and full of minute calcite veins. Some exposures show beds that are decidedly cherty. The thickest section noted was at least 50 feet thick. The grain of this limestone ranges from finely crystalline to that of loaf sugar. The rock is highly metamorphosed, and any bedding it once had has been destroyed by shattering and recrystallization.

STRATIGRAPHIC RELATIONS

The limestone north of Castle Mountain occupies a closely compressed overturned syncline and lies upon altered volcanic rocks that are believed to be of Lower Jurassic age. At one place the basal portion of the limestone contains small pebblelike fragments of the underlying volcanic rocks, indicating that it lies unconformably upon the Lower Jurassic volcanic series (Talkeetna formation).

AGE AND CORRELATION

The limestone here described has so far yielded no fossils, and its age determination is based upon its stratigraphic relations and upon its correlation with rocks in neighboring regions. As has been shown, this limestone rests unconformably upon volcanic rocks that are considered to be of Lower Jurassic age. Its correlation with the Nelchina limestone is regarded as highly probable, although not established beyond all doubt. If the altered volcanic rocks north of the west end of Castle Mountain on the tributaries of Kings River are of the same age as the less altered Lower Jurassic tuff on Chickaloon River, then the limestone north of Castle Mountain, which overlies these volcanic rocks unconformably, is certainly younger than Lower Jurassic; in that case, as the Middle and Upper Jurassic rocks of the Matanuska Valley show a fairly complete sequence of several thousand feet of strata from which limestone is absent, the assignment of this limestone to the Lower Cretaceous is subject to

[34] Martin, G. C., Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, pp. 311–313, 1926.

[35] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, pp. 32–53, 1912.

little doubt. If, however, the altered volcanic rocks of Kings River are not the same as the Lower Jurassic tuff of Chickaloon River, then there is no evidence that this limestone is Lower Cretaceous, and the limestone and the underlying volcanic rocks may possibly be correlated with the Upper Triassic Chitistone limestone and the underlying Nikolai greenstone of the Chitina Valley.

The limestone in the Nelchina region seems to be in general remarkably unfossiliferous, although belemnites were seen in some of the thin strata of shale between the massive limestone beds. A large number of fragmentary belemnites were obtained from the residual soil lying on the surface of the limestone in one of the hilltop areas. They apparently could have been derived from no other possible source than the limestone or one of the thin strata of shale interbedded with it.

The following statement concerning these fossils was furnished by T. W. Stanton:

8582. Limestone hills east of Billy Creek; from residual soil on the surface of the limestone:

Belemnites sp., very large stout form.

This species suggests Jurassic rather than Cretaceous.

UPPER CRETACEOUS ROCKS

MATANUSKA FORMATION

DISTRIBUTION

Upper Cretaceous shales and sandstones are widely distributed throughout the Matanuska Valley. The recognized areas in the upper part of this valley include interrupted belts extending along both sides of Matanuska River to a point about 13 miles above Chickaloon River, an area southwest of Gravel Creek, an area in the mountains north of Boulder Creek extending from the valley of Black Shale Creek to Chickaloon River (see pl. 5, *A* and *B*), and an area on the north flank of Anthracite Ridge that is continuous with the Hicks Creek area. The name Matanuska formation has been applied to these rocks by Martin,[36] and that name is here used as he defined it.

CHARACTER AND RELATIONS

The Matanuska formation consists of shale and sandstone and has an aggregate thickness, as exposed on Granite Creek in the lower Matanuska Valley, of at least 4,000 feet, of which the lower half is practically all shale and the upper half alternating beds of sandstone and shale, the sandstone predominating. Conglomerate is present,

[36] Martin, G. C., The Mesozoic stratigraphy of Alaska: U. S. Geol. Survey Bull. 776, p. 317, 1926.

but the beds are not thick or numerous. The most complete section observed is in the gorge of Granite Creek about 12 miles west of Chickaloon River.[37] Other good sections are exposed on Kings River between the main trail and the coal camp and in the cliffs of Matanuska River. Many of these cliffs are not accessible for close study except at a very low stage of the water.

The base of the Matanuska formation has been observed only on the south side of Matanuska River, where, at a number of places, tributary streams from the south emerge through canyons cut into the Lower Jurassic volcanic rocks (Talkeetna formation). In the valleys of those streams the Jurassic rocks are overlain unconformably by beds that at their base include hard, dense sandstone and conglomerate, composed in large part of materials derived from the Lower Jurassic volcanic rocks. At each locality where they were seen these coarse beds dip steeply to the north. They are believed to be the basal portion of the Upper Cretaceous rocks at that place. They may not, however, be equivalent to the basal Upper Cretaceous elsewhere, for their unconformable relation to the Jurassic materials indicates that the Upper Cretaceous sea in which these beds were laid down invaded a land surface, possibly of considerable relief, and the lowest Upper Cretaceous sediments at one place may be either younger or older than the lowest beds at another place.

The Matanuska formation is overlain unconformably, in the lower Matanuska Valley, by Tertiary arkose and conglomerate. The strongest evidence of the unconformity is found in the mountains west of Kings River, where the Tertiary rocks lie horizontally upon the surface of the presumably early Mesozoic granite within a quarter of a mile of a place where the Upper Cretaceous sediments are present in full development with the granite faulted against them.[38] It is evident, therefore, that as the Tertiary rocks are underlain by the pre-Cretaceous granite, at least the full thickness of the Upper Cretaceous sediments must have been removed at this place during the Cretaceous-Eocene erosion interval. At the coal camp on the east bank of Kings River the Tertiary coal-bearing rocks apparently rest unconformably across the upturned edges of the Upper Cretaceous sandstones, but as the coal-bearing beds exposed at this place are believed not to be the basal Tertiary rocks this contact is considered a thrust fault rather than an unconformity.

The Upper Cretaceous rocks of the upper part of the Matanuska Valley are of the same general lithologic character as those in the lower part of the valley. In the belts that extend along the river the folding is so severe that no stratigraphic sequence can be recognized,

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[37] Martin, G. C., and Katz, F. C., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, pp. 34–35, 1912.

[38] See U. S. Geol. Survey Bull. 500, pl. 16, section H–H′, 1912.

as the bedding in many places has been destroyed. The same condition prevails, in general, though to a somewhat less degree, in the Anthracite Ridge and western Boulder Creek areas.

FAUNA AND AGE

The Upper Cretaceous shale and sandstone of the upper Matanuska Valley and adjoining areas have yielded the fossils represented in the following lists, which were identified by T. W. Stanton:

8559. First tributary to Boulder Creek from west above the canyon; float; collected by G. C. Martin, 1913:

Inoceramus sp. cf. I. labiatus Schlotheim.
Inoceramus sp.
Lunatia sp.
Baculites sp.
Hamites? sp.
Phylloceras ramosum Meek?
Upper Cretaceous.

8568. Float from same creek as No. 8559; collected by R. M. Overbeck, 1913:

Undetermined coral.
Inoceramus sp.
Thracia? sp.
Phylloceras ramosum Meek?
Lytoceras sp.
Upper Cretaceous.

8560. About half a mile up first tributary to Boulder Creek above the canyon; collected by G. C. Martin, 1913:

Inoceramus sp.
Upper Cretaceous.

8562. North slope of Anthracite Ridge, near crest and at head of tributary to Boulder Creek next below East Fork; collected by G. C. Martin, 1913:

Discina? sp.
Ostrea sp.
Inoceramus sp.
Nemodon sp.
Astarte? sp.
Corbula? sp.
Undetermined gastropods.
Baculites sp.
Phylloceras ramosum Meek?
Lytoceras (Gaudryceras) sp.
Lytoceras (Tetragonites) sp.
Hamites sp.
Anisoceras? sp.
Upper Cretaceous.

8563. North slope of Anthracite Ridge, elevation 4,600 feet, at head of next to lowest tributary to East Fork of Boulder Creek; collected by G. C. Martin, 1913:

Inoceramus sp., same as in 8562.
Astarte? sp.
Baculites sp.
Upper Cretaceous.

8566. North slope of Anthracite Ridge near head of next to lowest tributary to East Fork of Boulder Creek; collected by G. C. Martin, 1913:

Undetermined worm trails, age not determinable.

3318. Crest of Anthracite Ridge near head of Purinton Creek; collected by G. C. Martin, 1905:

> The very small and fragmentary lot from this locality contains a *Nucula* and fragments of the fibrous shell of an *Inoceramus*. So far as can be determined from these specimens the horizon may be as low as Middle Jurassic or as high as Upper Cretaceous. It is certainly not outside of these limits. (See also last note under 3319.)

3319. South slope of Anthracite Ridge near Purinton Creek; elevation 3,450 feet; collected by G. C. Martin, 1905:

> This lot includes a very young ammonite not generically determinable, a fragment of another ammonoid which apparently belongs to some loosely coiled form like *Hamites*, a part of the phragmacone of a *Belemnites*, several specimens of a small *Ostrea*, and fragments of *Inoceramus* shell. The remarks concerning the age of No. 3318 are applicable to this lot also.

Stanton made the following statement concerning the last two lots after examining the fossils obtained in 1913:

A reexamination of lots numbered 3318 and 3319 in earlier collections from the Matanuska Valley and comparison with more recent collections was made, and they can now be definitely referred to the Upper Cretaceous.

8577. North side of Boulder Creek, at base of waterfall at mouth of tributary 16½ miles above mouth; from shaly sandstone beneath conglomerate; collected by G. C. Martin, 1913:

Inoceramus sp., large, broad species.

Upper Cretaceous.

8596. South bank of Matanuska River, 5 miles above mouth of Chickaloon River; collected by G. C. Martin, 1913:

Pecten sp.

Inoceramus digitatus Sowerby.

Inoceramus sp.

> Upper Cretaceous. The *Inoceramus* referred to *I. digitatus* in this list (8596) is the same species that has been so identified by Whiteaves from Vancouver Island. But according to H. Wood's recent monograph of the Cretaceous Lamellibranchiata of England the type of Sowerby's imperfectly known *Inoceramus digitatus* is a different species, and forms such as this are referred to *I. undulatoplicatus* Roemer.

8595. North bank of Matanuska River, 4 to 5 miles below O'Brien's ford; collected by G. C. Martin, 1913:

Inoceramus sp.

Diplomoceras notabile Whiteaves?, fragmentary imprints.

Undetermined trails or fucoids.

Upper Cretaceous.

8592. Matanuska River, north bank, 10 miles above mouth of Chickaloon River; collected by G. C. Martin, 1913:

Inoceramus sp.

Hamites? sp.

Upper Cretaceous.

8593. About 1,000 feet up third tributary to Matanuska River from south below O'Brien's ford; collected by R. M. Overbeck, 1913:

Inoceramus sp.

Upper Cretaceous.

(48) Small gulch south of lowest tributary to Gravel Creek from southwest; altitude 1,850 feet; collected by R. M. Overbeck, 1913:

Echinoid spines?

Ostrea? sp.

Probably Upper Cretaceous.

8594. Creek at east end of O'Brien Flats (lowest large tributary of Gravel Creek); altitude 1,760 feet; collected by J. B. Mertie, jr., 1913:

Inoceramus sp.

Probably Upper Cretaceous.

8591. Hicks Creek, opposite mouth of next to lowest tributary from the west; collected by G. C. Martin and R. M. Overbeck, 1913:

Ostrea sp.

Anomia sp.

Inoceramus digitatus Sowerby.

Inoceramus sp.

Nemodon sp.?

Mesostoma? sp.

Upper Cretaceous.

8947. Knob 1 mile north of Matanuska River and 6½ miles northwest of Glacier Point; collected by Theodore Chapin, 1914:

This lot contains only fragmentary specimens of *Inoceramus;* probably of Cretaceous age.

8948. Ridge between Hicks and Caribou Creeks, 3½ miles north of Matanuska River; collected by Theodore Chapin, 1914:

Heteroceras? sp.

Upper Cretaceous.

8586. Mouth of Alfred Creek; collected by G. C. Martin, 1913:

Rhynchonella sp.

Inoceramus sp.

Pleurotomaria sp.

Baculites sp.

Lytoceras sp.

Upper Cretaceous.

8587. Alfred Creek, 1,880 feet below main forks; collected by R. M. Overbeck, 1913:

Heteroceras or Anisoceras sp., possibly identical with A. cooperi Gabb, as identified by Whiteaves from Vancouver.

Upper Cretaceous.

8590. Alfred Creek; exact position not known; obtained from prospectors by G. C. Martin, 1913:

Phylloceras ramosum Meek?

Probably Upper Cretaceous.

8578. Billy Creek, about 4⅔ miles above mouth; altitude 3,800 feet; collected by G. C. Martin, 1913:

Inoceramus sp., large, broad form.

Nemodon sp. cf. N. vancouverensis (Meek).

Diplomoceras notabile Whiteaves?

Belemnites or Belemnitella sp.

Upper Cretaceous.

The Upper Cretaceous fauna of the upper part of the Matanuska Valley, as represented in the foregoing lists, is apparently the same as that of the lower part of the valley where marine molluscan remains are fairly abundant in the shales that constitute the lower half of this formation. The marine fauna contained in these shales shows that they are undoubtedly of Upper Cretaceous age. T. W. Stanton submitted the following statement[39] regarding the age and relations of the fauna represented by the material collected in the lower part of the valley by Martin and Katz in 1910:

Of the lots referred to the Upper Cretaceous those numbered 6689, 6694, and 6696 are certainly of that age and belong to the Upper Cretaceous fauna which has been recognized at several points on the Alaska Peninsula and is part of the general Indo-Pacific fauna found in the Chico formation of California, on Vancouver Island, in Japan, and in India. Most of the other lots in this collection, referred to the Cretaceous, contain only fragmentary specimens of *Inoceramus* which are not sufficient in themselves for discrimination between Jurassic and Cretaceous, though it is probable that these fragments belong to the same species that occurs at other localities in the neighborhood where the Cretaceous age of the rocks is definitely determined.

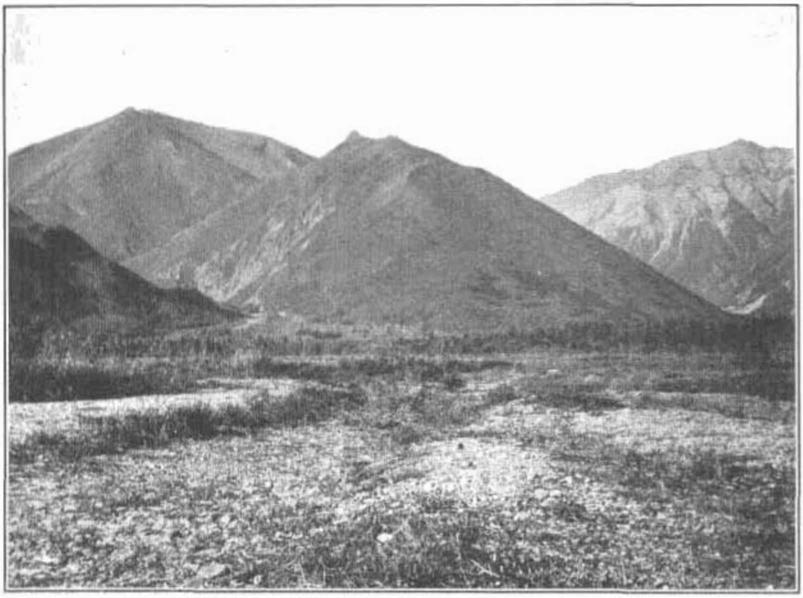
TERTIARY ROCKS

GENERAL FEATURES

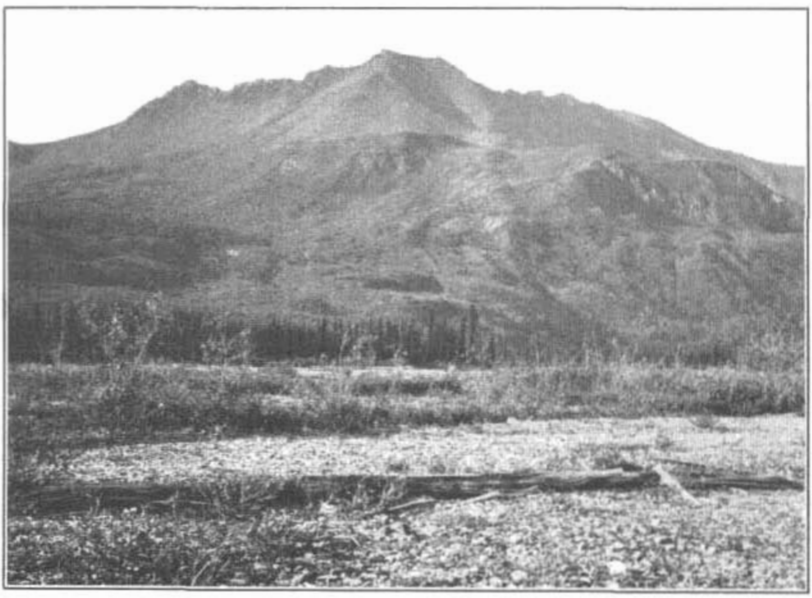
The Tertiary sedimentary rocks of the lower Matanuska Valley have been divided[40] into the Chickaloon formation, which consists of coal-bearing shale and sandstone with a well-developed Kenai flora and which is of Eocene age; the Eska conglomerate, which overlies the Chickaloon formation and which has been referred tentatively to the Miocene; and an unnamed assemblage of arkose, conglomerate, and shale. The position of the last is not well established, but it is believed to include the basal Tertiary beds, as well as the coarse non coal-bearing marginal beds equivalent to at least part of the Chickaloon formation and possibly beds equivalent to part of the Eska conglomerate. This arkose, conglomerate, and shale have not been recognized in the area here described, though they are generally present in the lower Matanuska Valley as a belt of rocks lying between the granitic rocks of the Talkeetna Mountains on the north and the Mesozoic and Tertiary sediments of the Matanuska Valley. The Eska conglomerate is overlain unconformably by lava and tuff that are possibly of Pliocene age. The Tertiary sedimentary formations of the lower Matanuska Valley have not yet been mapped throughout the district herein described, nor has it been possible

[39] Stanton, T. W., quoted by Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 38–39, 1912.

[40] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 24, 39–54, 1912.

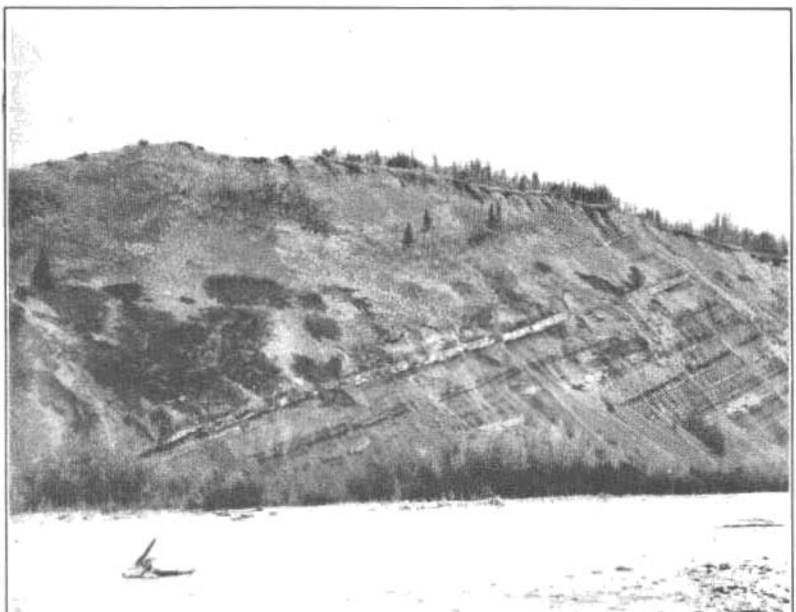


A. JURASSIC AND CRETACEOUS ROCKS NEAR THE LOWER END OF BOULDER CREEK FLATS

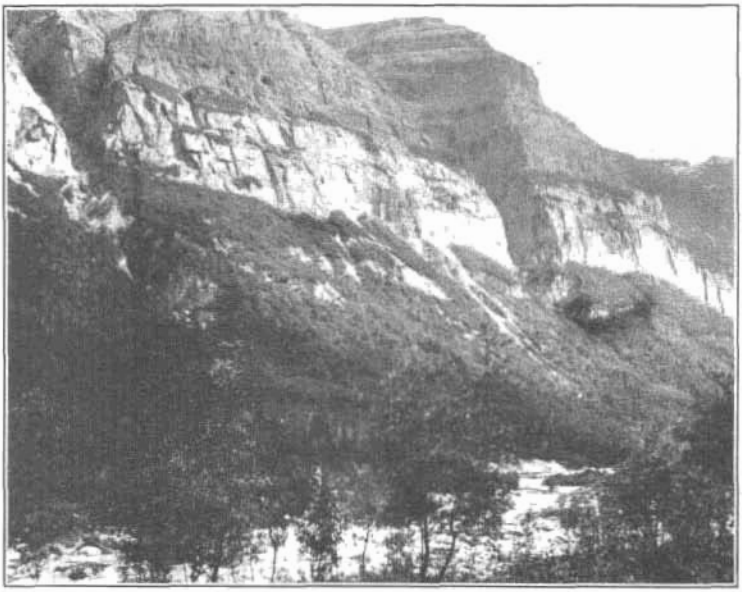


B. MOUNTAIN NORTH OF LOWER END OF BOULDER CREEK FLATS

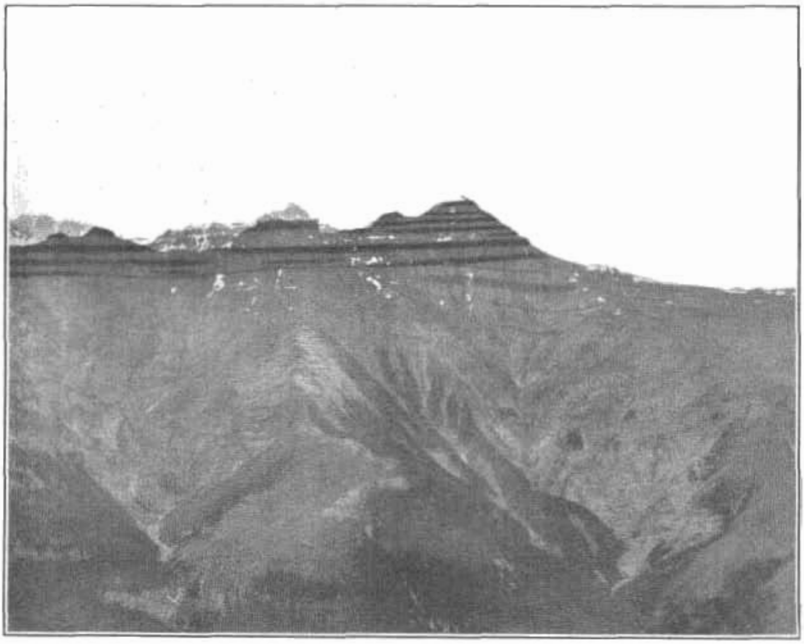
A. TERTIARY SANDSTONE AT ENTRANCE TO CANYON AT LOWER END OF BOULDER CREEK FLATS



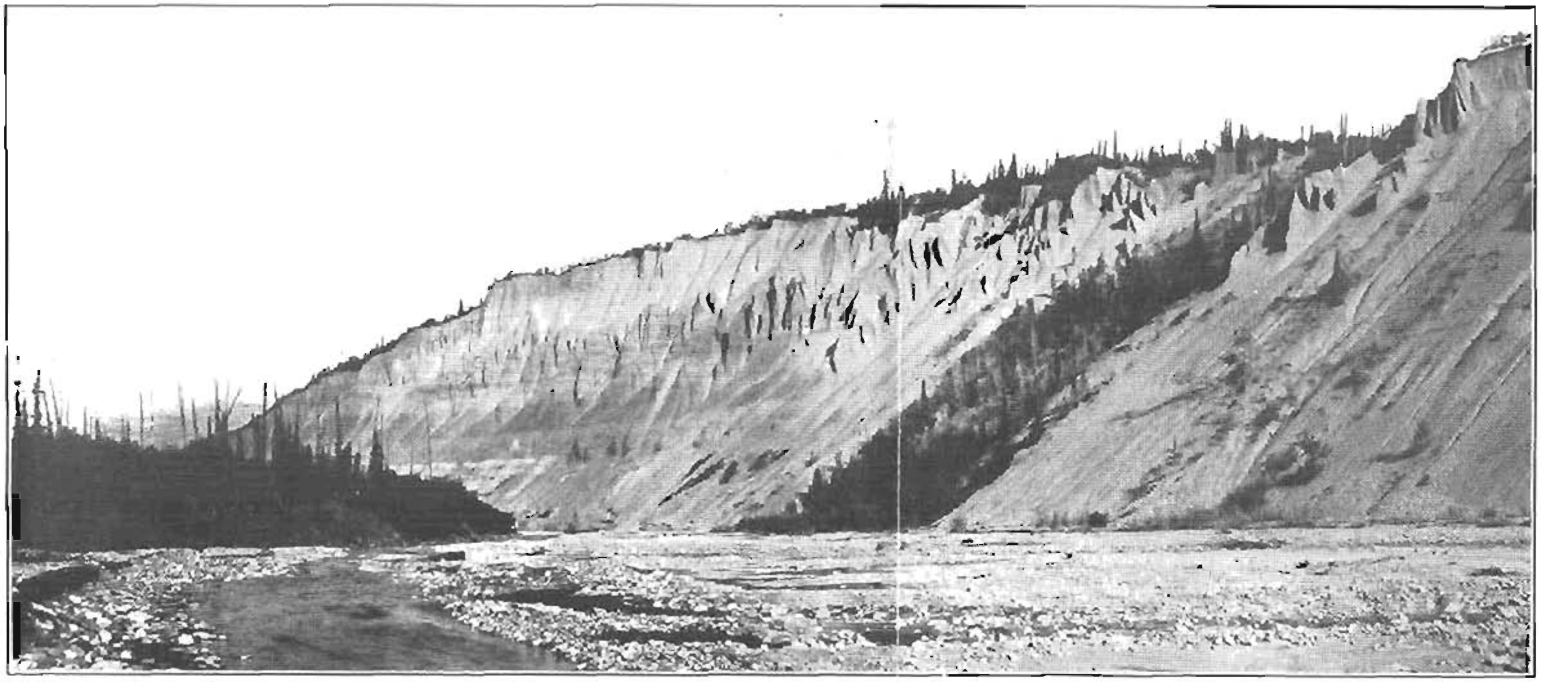
B. TERTIARY SHALES ON NORTH BANK OF MATANUSKA RIVER AT O'BRIEN'S FORD



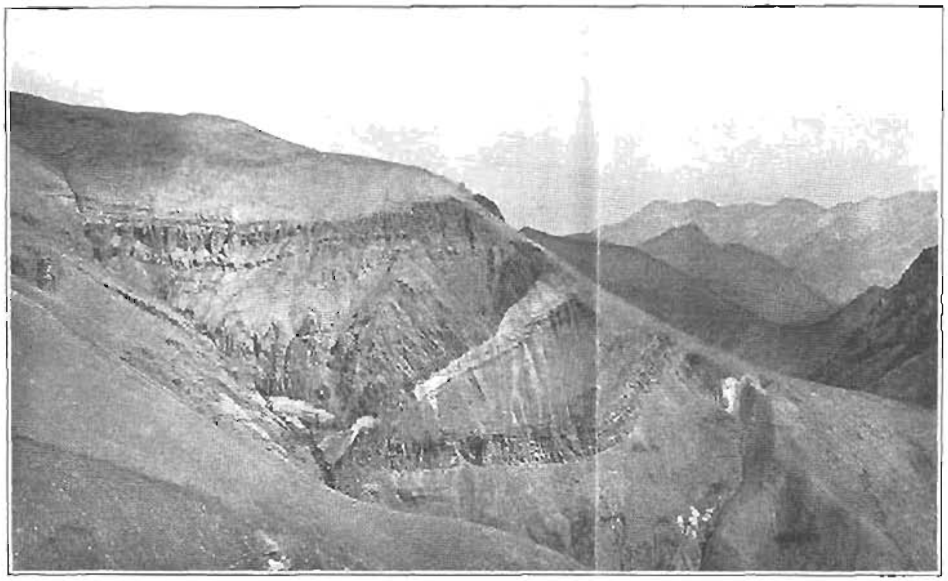
A. TERTIARY CONGLOMERATE ON EAST BANK OF CHICKALOON RIVER



B. TERTIARY LAVAS UNCONFORMABLY OVERLYING TERTIARY CONGLOMERATE ON EAST SIDE OF CHICKALOON RIVER



A. GRAVEL BLUFFS ON EAST BANK OF GRAVEL CREEK



B. FOLDS AND FAULT IN TERTIARY ROCKS NEAR EAST END OF ANTHRACITE RIDGE everywhere to recognize them. The formations that have been recognized will be described with as much completeness as knowledge permits.

CHICKALOON FORMATION

OCCURRENCE AND CHARACTER

A continuous body of Tertiary rocks occupies most of the rolling lowland north of Matanuska River in the area here considered. It extends from the west edge of the area eastward to and beyond Packsaddle Creek, and, with the exception of one narrow belt of Upper Cretaceous beds along the river, it extends from the river north to the base of Castle Mountain and Puddingstone Hill and forms most of the south slope of Anthracite Ridge. These rocks belong to the Chickaloon formation, carry a typical Kenai flora, and in places contain valuable coal beds. Extensions of this same formation south of Matanuska River are found in the Coal Creek-Carbon Creek area, on lower Monument and O'Brien Creeks, and as an isolated patch in the basin of the first large tributary of Matanuska River west of Monument Creek.

The Chickaloon formation was described by Martin and Katz,[41] who studied it in the lower Matanuska Valley, where its characteristics are much the same as in the district here considered. It consists of a rather monotonous succession of shale and sandstone (pl. 6, *A*), in which the shale exceeds the sandstone in thickness (pl. 6, *B*). The shale, much of which is sandy, is gray to drab, poorly bedded, and so soft that it tends to disintegrate upon exposure. At many places it contains nodules of iron carbonate, some of which form fairly persistent beds. The sandstone is gray to yellowish, and ranges from soft slightly indurated rock to hard dense rock. It is generally feldspathic and single beds vary greatly from place to place in grain and in composition. Individual beds are not generally persistent over a large area but are more or less lenticular. The total thickness of the Chickaloon formation is not known, but it appears to be at least 2,000 feet, and it may exceed this estimate.

The Chickaloon formation contains numerous coal beds; all the coal known in the Matanuska Basin occurs in this formation. The exact position of the coal beds within the formation is not accurately known, for the Chickaloon formation is believed to overlie the older formations unconformably and to be the result of fresh-water or estuarine deposition upon a surface of considerable relief. It follows, therefore, that the lowest Chickaloon beds were deposited only

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[41] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, p. 43, 1912.

in the lowest parts of the basin, when sedimentation first began, and that as the area of sedimentation broadened, successively younger portions of the formation were laid down upon the floor of the expanding basin. As a result, the lowest Chickaloon beds at any one place do not necessarily correspond in age with the lowest beds at all other places, but in comparing two sections the basal beds at one may be either older or younger than those at the other. The relation of the Chickaloon formation to the next younger beds, the Eska conglomerate, is also unconformable, Chickaloon time having been succeeded by a period of erosion during which an unknown thickness of materials was removed from the upper part of the Chickaloon. The task of determining the sequence and thickness of the beds in this formation is rendered still more difficult because the areas of Chickaloon rocks are generally bounded by faults, and the normal sequence and relations of the beds are therefore obscured. From the evidence in hand it may be said that the valuable coal beds in this formation appear to be neither in its top nor bottom portions but somewhere about midway.

Fossil leaves are present throughout this formation, but no fossils of other kinds have been found.

STRUCTURE

There are many details of structure in the Chickaloon formation that have not yet been worked out. The beds of this formation in general occupy low-lying areas bordered by mountains, and their surface is in most places covered by a layer of glacial till and gravel that obscures the underlying rock. Good exposures are confined largely to the banks of Matanuska River and its tributary streams, which have at many places intrenched themselves in the relatively soft Chickaloon rocks and so formed good exposures in the stream bluffs. On the south slope of Anthracite Ridge, where the relief is high, many excellent exposures are to be found.

The main area now occupied by the Chickaloon formation is a down-faulted block bordered on the north by the great Anthracite Ridge fault, at the south face of the Talkeetna Mountains. The south border of this block is not so obviously along a single fault line, but faults are present there and have in part produced the low-lying position of the block. Warping, however, has also played a large part in dropping the Matanuska Valley relative to the Chugach Mountains on the south.

Within the area occupied by the Chickaloon formation—the area bounded by Chickaloon River, Packsaddle Creek, Matanuska River, and the Anthracite River fault—there are a number of minor folds, but the dominant structure seems to be a syncline, the axis of which crosses Chickaloon River about a mile northeast of the town of Chickaloon and extends thence northeast to Rush Lake and thence southeast toward lower Packsaddle Creek. The existence of this syncline just north of Chickaloon is considered likely by Hill [42] and its eastward extension to Rush Lake is inferred from the position and attitude of the intrusive masses, most of which are dominantly of sill-like character. A syncline was observed at a point 2 miles east-northeast of the head of Rush Lake and in the valleys of Purinton, Cascade, and Winding Creeks. (See fig. 5.)

Although much of the rolling lowland between Chickaloon River and Packsaddle Creek has a general synclinal character, it should not be understood that the structure is that of a simple, unbroken syncline. At some places there are belts of close crumpling superposed on the syncline, and the structure is complicated by numerous faults, many of which are of small displacement but some of which are large. The underground work at the coal mines on Chickaloon River and Coal Creek has demonstrated the presence of numerous small faults there, and it is likely that the beds throughout this field are similarly broken. On Coal Creek, furthermore, a large fault of unknown displacement crosses the creek near the coal mines, and its extension eastward has been demonstrated by diamond drilling.

As the underground work on Chickaloon and Coal Creek has shown the coal formation there to be cut by rather closely spaced faults it is reasonable to suppose that the Chickaloon formation farther east is likewise cut by faults, the presence of which is concealed by the prevailing mantle of gravel and glacial deposits.

The Chickaloon formation offers abundant exposures along the many steep gulches that drain the south flank of Anthracite Ridge and is there seen to be of highly complex structure. Closely compressed and even overturned folds are common, faults are numerous, and the beds are intruded by large and small sills and dikes. It is apparent that the Chickaloon beds suffered an unusual amount of compression in the vicinity of the great Anthracite Ridge fault, and the resulting metamorphism devolatilized the contained coal and produced the anthracite from which the ridge takes its name. Yet this same metamorphism that raised the rank of the coal so disturbed the beds by folding and faulting that the difficulties that will be met in mining are greatly increased. The details of structure in the anthracite areas still remain to be worked out, and much stripping and underground work will be necessary before the size, attitude, and continuity of the coal bodies can be determined.

[42] Hill, W. P. T., Final report of the Navy Alaska Coal Commission to the Secretary of the Navy, pls. 14 and 15, 1922.

FLORA AND AGE

The fossil plants represented by the following lists were identified by F. H. Knowlton:

6703. Purinton Creek, south face of Anthracite Ridge, about 1⅛ miles above trail on creek half a mile east of camp of August 2; collected by G. C. Martin, 1913:

Sequoia langsdorfii (Brongniart) Heer.
Populus arctica Heer.
Nyssa arctica Heer.
Salix varians Heer.
Several other dicotyledons.
Age, Kenai.

6704. South side of Anthracite Ridge at altitude 3,000 feet, about a quarter of a mile west of Purinton Creek; collected by G. C. Martin, 1913:

Populus arctica Heer.
Glyptostrobus europaeus (Heer).
Sequoia langsdorfii (Brongniart) Heer.
Populus latior Heer.
Fagus macrophyla? Heer.
Quercus sp.?
Smilax? sp.
Age, Kenai.

3673 (2). South face of Anthracite Ridge near 6703; collected by G. C. Martin, 1905:

Material very obscure, the only thing determinable being a poor leaf of what seems to be *Populus arctica?* Heer. The age is uncertain, but if this species is correctly identified it should probably be Kenai.

3959 (6 AK 224). South face of Anthracite Ridge halfway between Boulder and Hicks Creeks, 0.6 mile north of trail; collected by Adolph Knopf, 1906:

Juglans nigrella? Heer.

This lot consists of two small specimens with no margin preserved. Age probably Kenai.

6709. Gulch near middle of O'Brien's coal claims, south of Matanuska River; collected by G. C. Martin, 1913:

Populus arctica Heer.
Sequoia langsdorfii (Brongniart) Heer.
Glyptostrobus europaeus Unger.
Corylus macquarrii (Forbes) Heer.
Quercus sp.
Age, Kenai.

The fossils in the following list, which were obtained from at or near the preceding locality, were identified by Arthur Hollick:

6289. Fossil plants from the T. E. O'Brien coal claims, three-fourths mile south of Matanuska River, 14 miles above mouth of Chickaloon River; collected by George A. Parks, 1911. This collection consists of four pieces of matrix, in which five well-defined species of fossil plants are represented, as follows:

Glyptostrobus ungeri Heer.
Sequoia langsdorfii (Brongniart) Heer.
Taxodium distichum miocenum Heer.
Taxites olriki Heer.
Hedera n. sp.
Age, "Arctic Miocene" (Eocene).

ESKA CONGLOMERATE AND CONGLOMERATIC SANDSTONE OF UNDETERMINED AGE

OCCURRENCE AND CHARACTER

The Eska conglomerate extends from Castle Mountain eastward into the hills north of Boulder Creek for a distance of about 2½ miles east of Chickaloon River (pl. 7, *A*), terminating, possibly, against a fault. Nowhere farther east has the Eska conglomerate been clearly recognized.

A large area of conglomeratic sandstone extends throughout the rolling upland south of Boulder Creek and of the west half of Anthracite Ridge. This conglomeratic sandstone is believed to be Tertiary, but its exact horizon has not been determined. It may be the lateral equivalent of the Eska conglomerate, or a conglomeratic phase of part of the Chickaloon formation, or the conglomeratic arkose of the lower Matanuska Valley.[43]

The Eska conglomerate on Puddingstone Hill is about 2,200 feet thick, though farther west it reaches a maximum thickness of about 3,000 feet. On Castle Mountain and Puddingstone Hill the formation consists of alternating beds of conglomerate 5 to 50 feet or more in thickness and arkosic sandstones that range from a few inches to 40 feet. The basal portion of the conglomerate is coarse and contains pebbles as much as a foot in diameter. The pebbles consist mainly of igneous materials, including acidic porphyry, fine-grained basic rocks, granite, and diorite, as well as quartz, greenstone, and metamorphic rocks of various types. The arkosic sandstones consist of comminuted particles of all these same materials in beds some of which are fairly persistent and some lenticular. These sandstone beds themselves contain scattered pebbles and in places grade into conglomerates.

Large areas of massive conglomerate extend throughout much of the part of the Talkeetna Mountains that lies east of Chickaloon River and north of Boulder and Chitna Creeks. This conglomerate occurs immediately beneath the late Tertiary volcanic rocks and rests upon different formations that range in age from Lower Jurassic to Upper Cretaceous. At most places where it has been closely observed it bears a close lithologic resemblance to the Eska conglomerate, but it is also not strikingly different from some of the conglomerate in the lower Matanuska Valley that has been regarded as basal Tertiary.[43] Some of the conglomerate included here has been regarded by earlier observers [44] as Upper Jurassic, but Tertiary plants have been obtained from it at several localities. (See pp. 46–47.)

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[43] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 39–42, 1912.

[44] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 21, 23, 1907.

This conglomerate lies between two surfaces of profound unconformity and is consequently extremely variable in thickness. At some places it is missing; at others its thickness is 2,000 feet or more. This variability has been previously interpreted [45] as meaning that the conglomerate was laid down in narrow channels rather than in a broad sheet. There is no doubt as to the unevenness of the floor upon which the conglomerate was laid down, and its basal members consequently are lenticular and possibly were restricted to ancient channels, but the writer believes that the unconformity above the conglomerate contributed more largely than the uneven basement to the present irregularity in thickness and that before it was eroded the conglomerate was a widespread and fairly regular sheet.

FLORA AND AGE

The statement below was submitted by Arthur Hollick concerning a small collection of fossil plants obtained by Sidney Paige, in 1906, from thin beds of gray sandstone and shale intercalated in the massive conglomerate east of Chickaloon River. The exact stratigraphic position of the plant-bearing beds is not recorded.

3957. East side of Chickaloon River about 18 miles above its mouth, or 2 miles northeast of mouth of Moss Creek; altitude 3,900 feet:

Taxodium distichum miocenum Heer?, fragment.
Conifer (Juniperus tertiaria Heer?), fragment.
Other fragments not identifiable. Nothing figured.
Age apparently Tertiary.

The fossils represented in the following list were identified by Arthur Hollick in material obtained from white sandstone and associated coal beds overlying a conglomerate that rests upon Upper Cretaceous sandstone near the headwaters of Boulder Creek:

6705. Near waterfall at mouth of small creek entering Boulder Creek from the northwest about 16½ miles northeast of its mouth; collected by G. C. Martin, 1913:

Aspidium meyeri Heer?
Equisetum arcticum Heer, or E. haydeni Lesquereux?
Glyptostrobus europaeus (Brongniart) Unger?
Thuites ehrenswardi Heer.
Corylus macquarrii (Forbes) Heer.

The fossil plants are, for the most part, fragmentary and too poorly preserved for accurate identification. The age, as indicated by the species last named, the identification of which can not be questioned, is Tertiary; and the other provisional determinations are also of Tertiary species.

The fossils represented in the following lists were identified by F. H. Knowlton:

[45] Idem, p. 29.

6706. Mouth of small gulch tributary to Billy Creek from the east, about 2½ miles above its mouth; collected by G. C. Martin and R. M. Overbeck, 1913:

Populus arctica Heer.
Taxodium tinajorum Heer.
Fragments.
Age, Kenai.

6708. West bank of Gravel Creek, 5 miles above mouth; collected by G. C. Martin, 1913:

Taxodium distichum miocenum Heer.
Fragments of dicotyledons.
Material insufficient but presumably Tertiary.

6707. North bank of Matanuska River a quarter of a mile below mouth of Hicks Creek; collected by G. C. Martin, 1913:

Fragments of dicotyledons but nothing determinable.

BASALTIC LAVA AND TUFF

The youngest Tertiary rocks of the Matanuska Valley are the basaltic lavas and tuffs which are widely distributed throughout the eastern part of the Talkeetna Mountains, covering broad areas east of the upper half of Chickaloon River, on the headwaters of Boulder Creek, and in the upper part of the valley of Caribou Creek. Small isolated areas occur on mountain tops in the Matanuska Valley proper, such as the capping of Castle Mountain and of Puddingstone Hill (pl. 7, *B*), and in the valleys of Hicks and Billy Creeks and of Nelchina River. The petrographic character of the Tertiary lavas and tuffs is described by J. B. Mertie, jr., on pages 60–63, and will not be discussed here. They attain a maximum thickness of at least 2,500 feet and rest unconformably upon the Eska conglomerate and upon the possibly equivalent conglomerate in the upper parts of the valleys of Chickaloon River and Boulder and Caribou Creeks. They are probably of late Tertiary age, possibly Pliocene. Their general similarity and probable equivalence to the late Tertiary volcanic rocks of Nizina and Nabesna Rivers and of the Alaska Peninsula have been pointed out by Paige and Knopf.[46] They also resemble the Tertiary volcanic rocks of Iliamna and Clark Lakes,[47] with which they are probably to be correlated.

QUATERNARY DEPOSITS

GLACIAL AND HIGH-LEVEL TERRACE GRAVEL

The Quaternary deposits of the Matanuska Valley include morainic deposits, terrace gravel, and the alluvial deposits on the present flood plains. These deposits cover much of the surface of this region,

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[46] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, p. 30, 1907.

[47] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 78–82, 1912.

except the cliffs, the steeper mountain slopes, and the higher mountain summits. They are represented on the geologic map (pl. 2) only where they are very thick or where they conceal the underlying bedrock over considerable areas. The glacial deposits and terrace gravel are especially well developed throughout the lower Matanuska Valley west of Chickaloon River, where the former glaciers and the glacial streams deposited large volumes of detritus. Farther east, where the glaciers were eroding more actively, the harder rocks of intrusive gabbro and diabase were left in high relief by the removal of the softer surrounding sediments. The surface of the igneous masses is comparatively free of unconsolidated Quaternary deposits, but the surrounding lower-lying sedimentary materials are generally covered with a layer of glacial till or gravel.

Glacial morainic material is present in at least a thin sheet over nearly the entire area here described. The gentler slopes, below an altitude of about 2,000 feet in the valley of Moose Creek and about 3,000 feet in the Chickaloon Valley, are practically all covered with moraine, except where recent stream erosion has removed these deposits or where the slopes are too steep to retain unconsolidated material. The glacial deposits are much thinner in the upper part of the Matanuska Valley, where the glacier had a steeper grade, than in the lower part, where it deployed over the lowlands. The abundance of glacial débris in the lower valley indicates that the glacier was nearly stationary for a long time. This glacier filled the valley from side to side, its margins coinciding approximately with the present positions of the mountain fronts. It extended westward beyond the valley and joined other similar glaciers to form the ice mass that occupied the present area of Cook Inlet. Gravel ridges, which are regarded as bits of lateral moraine and which probably mark a resting stage during the general recession of the glacier, were seen at the base of Arkose Ridge, north of Moose Creek, at an altitude of about 2,200 feet. The distribution of the morainic material and the evidence of glacial erosion indicate that at this stage the margin of the ice rose steeply eastward, being at an altitude of about 3,200 feet between Eska and Granite Creeks and at least 3,500 feet in the vicinity of Castle Mountain. At its most advanced stage, however, the ice surface rose much above the level now marked by these morainic deposits. Its smoothing effect upon the mountain fronts that hemmed it in can be observed at many places, and by plotting the line of the ice surface so indicated it is seen, as is to be expected, that the slope of the glacier surface rose to the east, toward the high mountains at its head. The Copper River basin at that time was also filled with ice, and the Matanuska Valley was one of its outlets.

At the west end of Matanuska Valley,[48] at the mouth of Little Susitna River, the glacial ice at its maximum stood at an altitude of 3,600 feet along the south slope of Government Mountain. At Castle Mountain this upward-sloping ice surface at that time reached a height of about 4,500 feet and on the mountain front at Gravel Creek about 5,000 feet. As the base of the glacial trough of Matanuska Valley at Gravel Creek then had an altitude of 1,500 feet, the glacier at the time of its greatest development was 3,500 feet thick. This great ice stream was joined and augmented by smaller glaciers from tributary valleys from the Talkeetna and Chugach Mountains, and only the higher ridges and peaks projected above its surface. There is, however, no evidence that the whole region was ever overridden by glaciers of the continental type.

The terrace-gravel deposits of the Matanuska Valley are of two types. In the lower Matanuska Valley terraces occur at low altitudes, those noted being not higher than 1,200 feet. These are well-developed gravel benches, which rise in a series of steps along the river. In the valley of Moose Creek they were noted at altitudes of 400 to 1,000 feet. On Eska Creek there are well-developed benches at about 940 and 1,000 feet. Between Eska and Granite Creeks benches were noted at 660 to 1,150 feet. In the valley of Kings River there are many well-developed terraces, of which the highest is at about 1,200 feet. On Chickaloon River the best-developed terraces are at about 1,000 feet.

Gravel-covered terraces of a somewhat different type were seen at higher altitudes in both the lower and the upper parts of the Matanuska Valley. In the lower Matanuska Valley, where Moose Creek comes out from the high mountains, there are gravel benches up to an altitude of about 2,200 feet. Similar benches occur at about the same altitude where Granite Creek emerges from the mountains. On the west side of Kings River, about 2 miles north of the bridge, well-developed benches were observed at an altitude of 1,800 feet; benches occur opposite the coal camp at an altitude of about 1,500 feet and on the east side of the river at about 1,700 feet. Broad gravel-covered flats were seen on both sides of Chickaloon River about a mile above Boulder Creek at an altitude of about 1,600 feet. Terrace gravel attains a greater altitude on Boulder Creek, possibly merging into the glacial gravel that forms the swampy flat northwest of Rush Lake at an altitude of about 2,400 feet. This level coincides with that of the alluvial flats over which Boulder Creek flows just above the canyon.

The terrace overlooking the floor of the Matanuska Valley between Cascade and Winding Creeks has an altitude of about 1,700 feet.

[48] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, p. 39, 1915.

On the opposite bank of the river between Gravel and Monument Creeks the gravel occurs on a well-marked bench at an altitude of about 2,000 feet.

The bluffs on the east bank of Gravel Creek near its mouth are about 400 feet high and are composed of yellowish-gray stratified gravel containing numerous large cobbles and a few layers of fine-grained material stained with iron. The gravel stands in cliffs so steep as to suggest semi-induration (pl. 8, *A*). The faces of some of the bluffs are etched into pinnacles. At the northernmost bluff the gravel seems to rest directly upon the Upper Cretaceous shale; the basal gravel beds are approximately parallel to a broad shallow channel in the eroded surface of the underlying rocks, but the higher beds are more nearly horizontal. Farther up the creek the stratified gravel is underlain by till, which rests upon the shale. The thickness of the till increases gradually toward the south. Opposite the mouth of the lowest tributary from the west the till occupies about two-fifths of the height of the bluff, being about 150 feet thick. The upper surface of the stratified gravel at this locality is at an altitude of 1,800 to 2,000 feet.

Similar beds of stratified gravel were seen at other localities farther east. Their exact altitude has not been determined, but it is believed that the general upper limit of the gravel rises gradually eastward until the deposit merges into the gravel of the Copper River flats in Tahneta Pass, at an altitude of about 3,000 feet.

The significant fact in the distribution of these high-level terraces is that they are apparently restricted to the vicinity of the tributaries of the Matanuska, none having been seen at other points. It is believed that some of them at least were laid down in the ponded waters of these tributaries at times when the main glacier of the Matanuska Valley, during certain stages in its recession, stood across the mouths of the tributary valleys. In other words, the vertical position of these deposits of stratified gravel was determined by the height of the great glacier in Matanuska Valley at a time when the tributary glaciers had shrunk enough to separate themselves from the main ice stream. This interpretation is at variance with that of Mendenhall,[49] who assumed that the distribution of the gravel was determined by river grade and that because this grade is so much in excess of the present grade of the Matanuska River it proved a post-Pleistocene differential uplift of more than 2,500 feet.

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[49] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 332–335, 1900.

ALLUVIUM

Alluvial deposits are well developed on all the larger streams in the Matanuska Valley and on many of the smaller ones. The flats and gravel bars along the whole course of the Matanuska constitute one of the striking features of the geology of this region. The great development of these deposits is due to the fact that the Matanuska is a heavily overloaded glacial stream whose flow, owing to the intermittent and varying supply of water, is very irregular. The Matanuska and its tributaries freeze every winter and frequently take new courses when the spring thaws come. They flow for the most part over unconsolidated deposits and have steep grades. Many of the streams have their sources at the ends of glaciers, and therefore during the summer months of glacial melting are loaded with detritus from the very start. They are consequently choked with sediment during the ice-free season and have a natural tendency to aggrade their beds.

GENERAL STRUCTURE OF DISTRICT

In considering the structure of this region it is desirable first to review briefly the major geographic features. The Matanuska Valley is a narrow lowland area separating the Talkeetna Mountains on the north from the Chugach Mountains on the south and connecting two broader areas of moderate relief—the tidal Cook Inlet lowland and the great interior highland basin, often known as the Copper River basin. Matanuska River drains a large part of the Talkeetna Mountains, a much smaller part of the Chugach Mountains, and a very small area lying on the western margin of the Copper River basin.

The geographic units enumerated above differ in their constituent rocks. The Chugach Mountains are composed chiefly of metamorphic rocks, mainly slate, graywacke, and schist, but include also considerable areas of fragmental volcanic rocks and of granitic intrusive rocks. The main mass of the Talkeetna Mountains west of Chickaloon River is composed dominantly of granitic and gneissic rocks. The eastern part of the Talkeetna Mountains differs markedly from the western part, being composed of Jurassic, Cretaceous, and Tertiary sedimentary rocks with a summit capping of late Tertiary lavas. This subprovince is lithologically similar to the main Matanuska Valley, and should be regarded as its broadened northeastern extension. The Cook Inlet lowland is floored with unconsolidated Quaternary deposits, which are partly if not wholly underlain by Tertiary sediments. The interior highland basin at the east end of the Matanuska Valley—the Copper River Basin—is floored with Quaternary gravel, but the underlying rocks are unknown.

The Matanuska Valley, the term being used to designate the lowland along the river rather than the entire Matanuska drainage basin, is an area of steeply folded and faulted Mesozoic and Tertiary sedimentary and igneous rocks, bordered on the north by the granitic rocks of the western Talkeetna Mountains and the Mesozoic sediments and volcanic rocks of the eastern Talkeetna Mountains and on the south by the metamorphic rocks of the Chugach Mountains. The general trend of the structural lines within the Matanuska Valley, like the direction of the boundaries of the valley, is northeast and east. The boundaries of the valley are marked by zones of faulting.

The Matanuska Valley below Chickaloon River, generally known as the lower Matanuska Valley, is a narrow area of weak rocks, mostly Tertiary and Upper Cretaceous shale and sandstone, lying between the granitic rocks of the Talkeetna Mountains and the slaty and schistose rocks of the Chugach Mountains. The lateral boundaries of the lower Matanuska Valley are sharply defined; the northern boundary against the Talkeetna Mountains is a fault zone. The rocks of the lower Matanuska Valley are steeply folded and are cut by many faults, most of which are approximately parallel to the course of the valley. The general strike of the rocks is also northeast. It may be seen, therefore, that the river, the mountain fronts, and the structural lines all trend in the same direction.

Conditions are somewhat different in the upper Matanuska Valley above the mouth of Chickaloon River. The valley still holds its general character as a long, narrow lowland area of Tertiary and Upper Cretaceous rocks, situated between the sharp linear fronts of the Talkeetna and Chugach Mountains, but its direction has changed slightly, being approximately east. Although the Chugach Mountains, south of the valley, apparently maintain the same geographic and geologic character here as farther west, the Talkeetna Mountains are not of the same character as west of Chickaloon River. The western Talkeetna Mountains, although they contain some gneissic rocks and some Lower Jurassic volcanic rocks, are dominantly a granitic mass, sharply bounded on the south by a linear fault zone but apparently without any well-marked internal geographic or structural trend. The eastern Talkeetna Mountains, above Chickaloon River, are of another type. Granitic rocks are present only in small masses. The mountains are composed of stratified rocks that comprise tilted masses of Jurassic, Cretaceous, and Tertiary sediments overlain by broad cappings of nearly horizontal Tertiary lava. The parallel faults of the lower Matanuska Valley, on crossing Chickaloon River, do not hold to the course of the upper Matanuska

Valley but diverge and form the dominant structural lines of the eastern Talkeetna Mountains. Only the southernmost of the larger faults holds a course parallel to the river throughout the southern face of Anthracite Ridge and forms the northern boundary of the upper Matanuska Valley. The eastern Talkeetna Mountains are consequently akin, structurally, to the Matanuska Valley rather than to the western Talkeetna Mountains. They differ, however, from the Matanuska Valley in their rock constituents, for they contain large masses of Middle and Upper Jurassic and Lower Cretaceous rocks that are absent in the valley and contain only small areas of the Tertiary coal-bearing rocks that underlie large areas in the valley. They are, moreover, sharply separated from the valley by a well-defined zone of faulting.

The upper Matanuska Valley, like the lower part of the valley, is underlain by Tertiary and Upper Cretaceous sedimentary rocks cut by many intrusive masses. These rocks are closely folded and in many places are even intricately crumpled. They are cut by many faults. The general structural trends, including both the trend of the rock masses and that of the major faults, are parallel to the axis of the valley. Minor structural features, including both folds and faults, trend in other directions. The structure is very complex, but owing to the scarcity of exposures, the surface being generally covered with gravel and moss, except in the banks of the larger streams, it can not be described in detail.

Some light is thrown on the structure of the Matanuska Valley by a consideration of the geologic history of the region. It is highly probable, if not absolutely certain, that the position and the form of the Matanuska Valley were determined by dynamic or erosional agencies that operated in Tertiary time. The reason for this assumption is found in the present restriction of the coal-bearing rocks to the main Matanuska Valley. This restricted distribution must mean either that the coal-bearing rocks were never deposited beyond the present limits of the main valley or that, if deposited over a broader area, those within the valley were protected from erosion whereas those without the valley were almost entirely removed by erosion. If the first interpretation is correct, their deposition was restricted to a structural depression or erosional trough formed in early Tertiary (Eocene) time. If the second interpretation is correct, the present distribution of the rocks can be explained only by the depression of the present area of the valley below the level of erosion, and the valley must therefore have been formed immediately after the deposition of the coal-bearing rocks but before the deposition of the Eska conglomerate—that is, probably in early Miocene time. Either interpretation involves an assumption that the present Matanuska Valley was a zone of weakness in Tertiary time. In other words, the coal-bearing rocks of the Matanuska Valley were deposited along a zone of weakness where the late Tertiary and post-Tertiary crustal movements were concentrated and where they resulted in extreme crumpling and crushing of the rocks. This condition, in the opinion of the writer, is the main cause of the local devolatilization of the coal, whereby it has become of higher grade than the stratigraphically equivalent lignite of Cook Inlet. The structure of the Matanuska Valley differs in complexity from place to place, there being localities where it is fairly simple because of local relief of pressure by profound faulting or possibly because of the protecting influence of large bodies of massive rocks, such as some of the larger intrusive masses. At such places, so far as the present evidence shows, the coal is of low grade, and it is believed that this relation between structure and quality of coal will be found to hold generally.

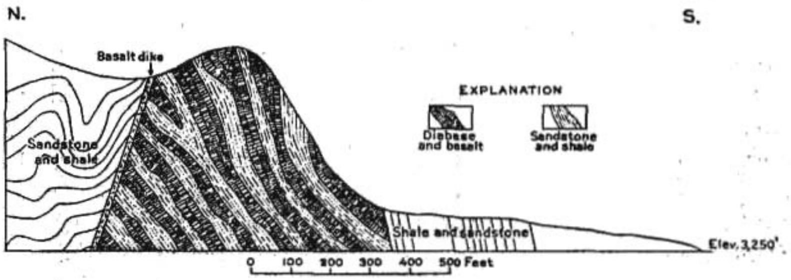


FIGURE 3.—Diagrammatic section of rocks of Chickaloon formation on the next to easternmost tributary of Purinton Creek

Although the structure of the rocks in the upper Matanuska Valley is highly complex and the heavy cover of Quaternary gravel makes impossible a close determination of the structure over much of the area from natural exposures only, yet the facts now in hand warrant certain general statements. Thus it is definitely known that along the great fault that borders the valley on the north the Tertiary sediments are most severely deformed and in places are closely folded, faulted (pl. 13), and intruded by large dikes and sills of gabbro (pl. 10, *B*; fig. 3). This is particularly true of the south flank of Anthracite Ridge (pl. 9), and the coal beds there exposed are the uneroded remnants of close folds (pls. 8, *B*; 10, *A*; and 11). The high quality of the coal found on Anthracite Ridge is undoubtedly due to this close folding and crumpling and perhaps in part also to alteration by the large masses of intrusive rocks, but these very factors, which by devolatilization improved the character of the coal, at the same time greatly increased the difficulties of mining it.

The southern border of the upper Matanuska Valley was also a zone of severe deformation and faulting, as is shown by the coal measures in the O'Brien Creek (pls. 12, 13, *B*) and Carbon Creek areas. On Carbon Creek, too, the coal measures were intimately intruded by sills and dikes. Yet the deformation of the beds on the southern border of the valley was less severe than on the northern border, and the devolatilization of the coal is therefore less advanced there than on Anthracite Ridge.

Much still remains to be done in working out in detail the structure of the coal formation between Matanuska River and Anthracite Ridge, yet the dominant structural feature there is known to be a synclinal trough, the axis of which crosses Chickaloon River about a mile above Chickaloon, extends northeastward to the high point of the gabbro ridge northeast of Rush Lake (fig. 4), and thence extends in an east-southeasterly direction toward Index Lake (fig. 5). A large part of the Tertiary coal-bearing formation east of Chickaloon is believed to lie stratigraphically below the coal beds exposed at

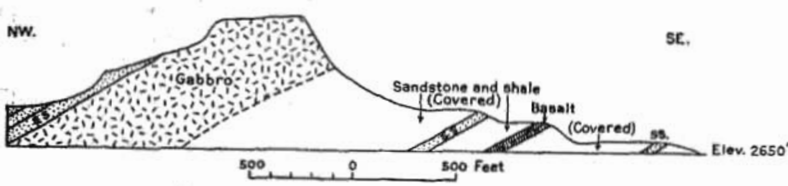


FIGURE 4.—Diagrammatic section of Chickaloon formation and gabbro sills at east end of Rush Lake Ridge

Chickaloon, but so far as is known this lower part of the Chickaloon formation contains no workable coal beds. If this is true, then the coal-bearing area of the upper Matanuska Valley is much smaller than has heretofore been assumed.

IGNEOUS ROCKS OF THE UPPER MATANUSKA VALLEY

By J. B. MERTIE, JR.

Igneous rocks constitute a large part of the geologic section in the upper Matanuska Valley. There are two general types—those which were extruded over the former land surface and those which intruded older rocks and solidified below the surface. The extrusive rocks are of Lower Jurassic and late Tertiary age. The intrusive rocks also can be grouped in a general way according to relative age. The granitic rocks are believed to be late Jurassic, but the numerous masses of basic intrusive rocks, as well as some of the more acidic, are shown to be Tertiary.

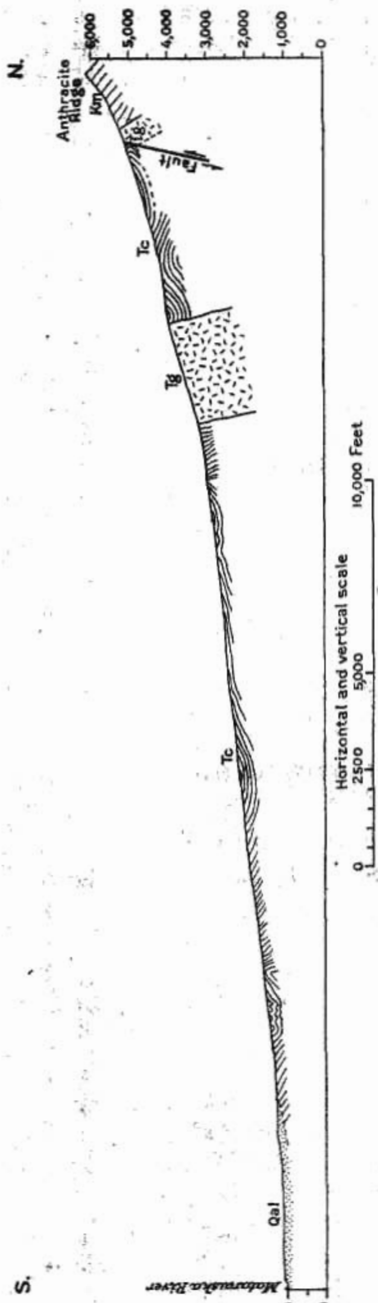


FIGURE 5.—Diagrammatic section from Matanuska River to Anthracite Ridge along Cascade Creek. Qal, Stream gravel, sand, and silt; Tc, Chickaloon formation; Tg, intrusive gabbro, diabase, and basalt; Km, Matanuska formation

LOWER JURASSIC VOLCANIC ROCKS

AREAL DISTRIBUTION

The Lower Jurassic is represented in the upper Matanuska Valley by a series of volcanic and pyroclastic rocks which constitutes perhaps a fifth of the known bedrock and which composes the Talkeetna formation.

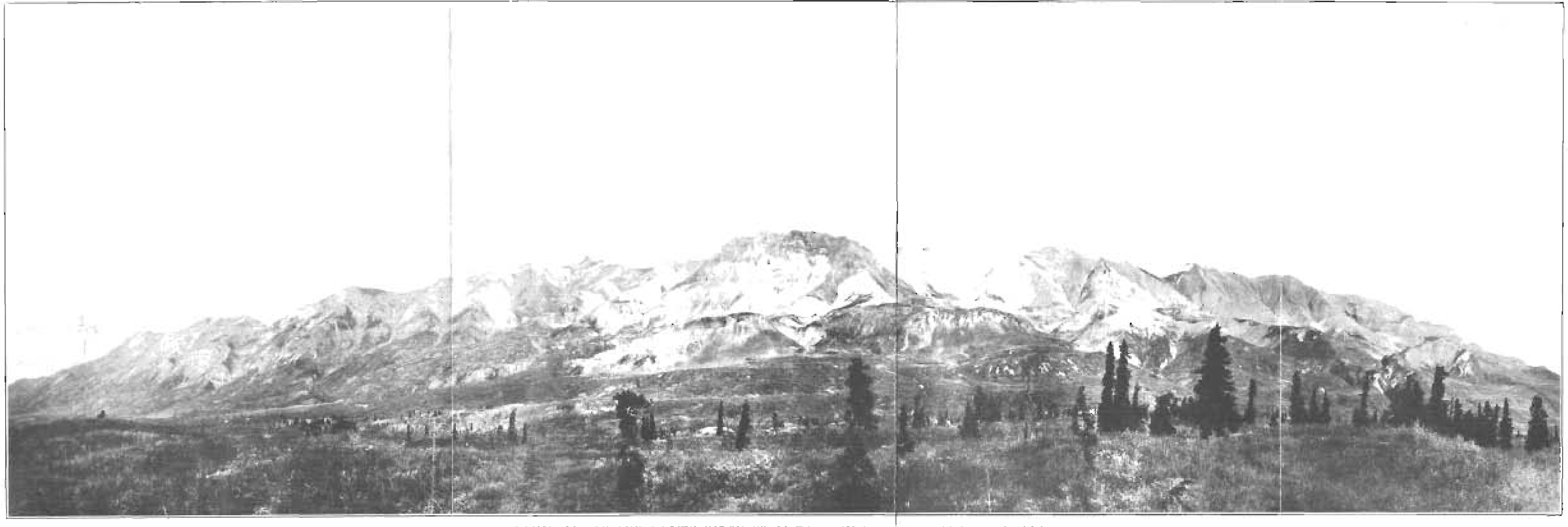
PETROGRAPHIC CHARACTER

These rocks were first studied and mapped by Paige and Knopf,[50] who interpreted their age as "lower Middle Jurassic." Subsequently Martin and Katz [51] were able to assign the volcanic series definitely to the Lower Jurassic.

The Lower Jurassic rocks of the Boulder Creek area are essentially of volcanic origin and include tuff-breccias, tuffs, tuffaceous sandstones, interbedded lava flows, and flow breccias. The fragmental members, which constitute much the greater part of the sequence, are bedded rocks of very diverse appearance. The tuff-breccias and tuffs have commonly a light-green to dark-green aphanitic matrix in which are embedded angular fragments of black, brown, green, blue, or reddish material, likewise aphanitic. These angular pieces range from microscopic size in the finest-grained tuff up to a foot or more in diameter in the coarser breccia.

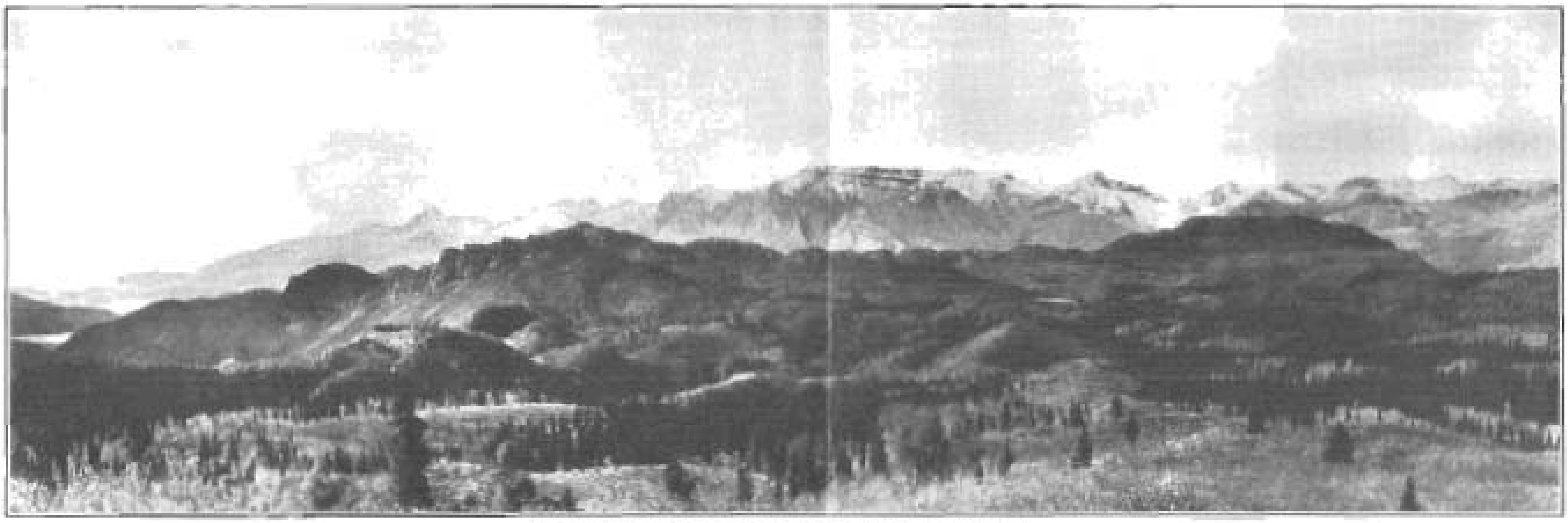
[50] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 18–19, 1907.

[51] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 30–32, 1912.



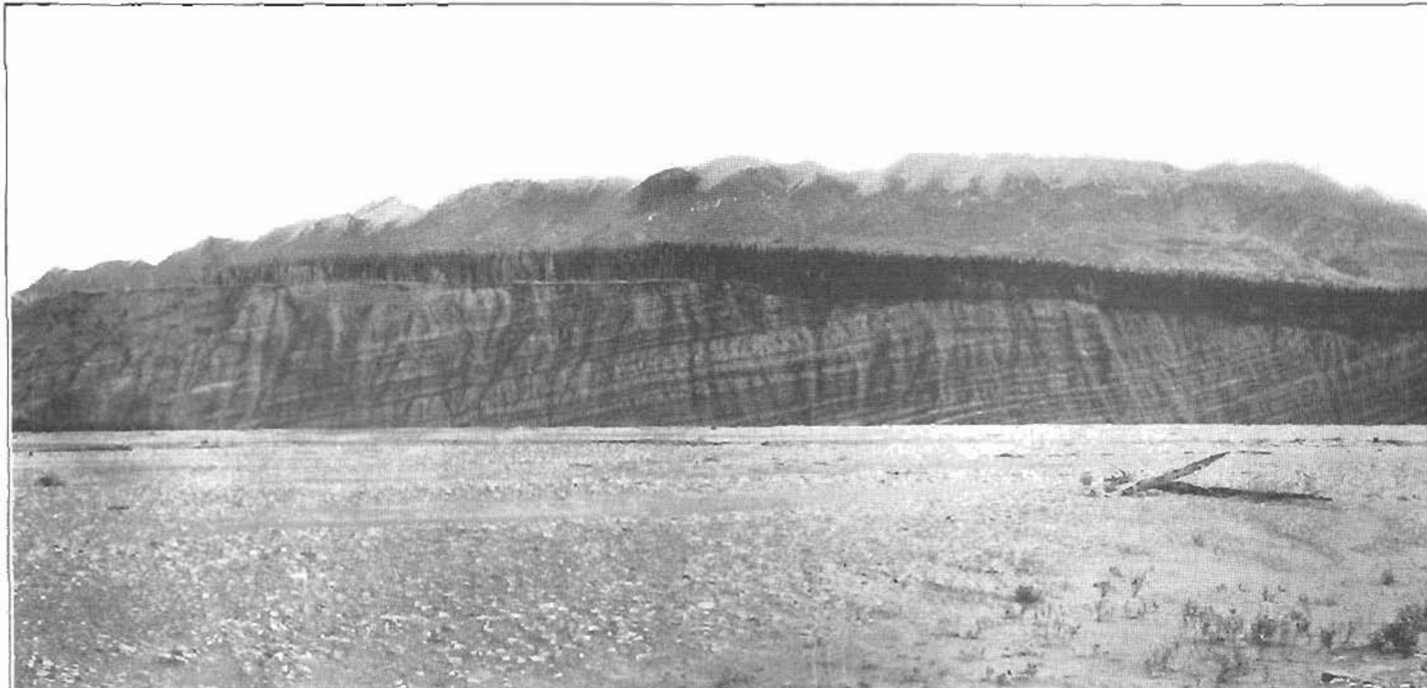
PANORAMA OF ANTHRACITE RIDGE FROM TRAIL IN BASIN OF PURINTON CREEK

A. STRUCTURE OF SOUTH FACE OF ANTHRACITE RIDGE

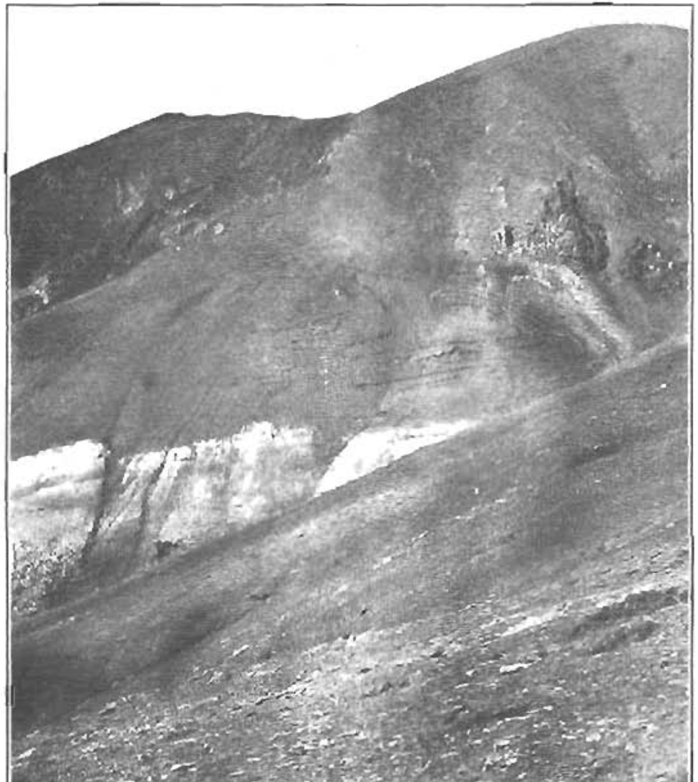


B. DIABASE RIDGES SOUTH OF ANTHRACITE RIDGE

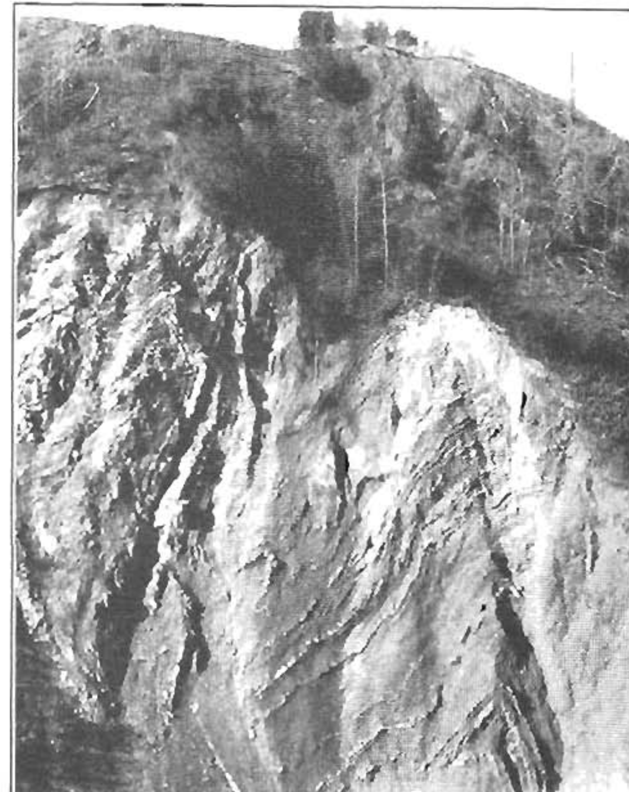
FOLDS AND FAULT ON SOUTH FACE OF ANTHRACITE RIDGE



TERTIARY SHALES ON NORTH BANK OF MATANUSKA RIVER JUST ABOVE O'BRIEN'S FORD



A. FOLDED TERTIARY SHALES OVERTHRUST BY IGNEOUS ROCKS AND BY UPPER CRETACEOUS SHALES ON SOUTH FACE OF ANTHRACITE RIDGE



B. CRUMPLED COAL-BEARING ROCKS IN WEST BANK OF O'BRIEN CREEK

The groundmass or matrix also is in places mottled in green and white tones, owing to filling of veins and irregular cavities and to rock replacement by calcite quartz and zeolites. Thus it is seen that the heterogeneous character and the resulting color contrasts are characteristic of the general appearance of the fragmental rocks of this group. The lava flows proper and the flow breccias are dense dark-green to reddish rocks, many of them with an amygdaloidal habit. All these rocks have undergone much chemical alteration. The tones of green, red, and yellow are due usually to the development of secondary chloritic, hematitic, and limonitic material. The fragmental rocks, being more porous, have been more affected in this respect, but the amygdaloidal fillings in the lava flows, which consist of chalcedony, quartz, calcite, chlorite, and zeolites, also give evidence of extensive chemical alteration.

The fragmental members, including the tuff-breccias, tuffs, tuffaceous sandstones, and volcanic conglomerates, are stratified rocks that were probably in large part water-laid. It is possible, however, that some of the tuff-breccias and tuffs may be of subaerial origin. In most of these rocks the original clastic structure is still preserved. In such rocks microscopic examination shows a mass of angular to rounded pieces of fine-grained igneous rock, plagioclase, quartz, and oxides of iron, embodied in a matrix composed largely of chloritic material but containing some microaphanitic material, which is probably in the main of kaolinic and quartzose character. In one or two specimens altered crystals of hornblende and cloudy grains of orthoclase were noted. All these minerals and mineral aggregates are in an advanced stage of alteration, and in many specimens chlorite, epidote, calcite, zeolites, or secondary albite have completely replaced the original grains. Pyritization is locally prevalent. The feldspars that admit of determination, however, are mainly acidic, with composition ranging from oligoclase-albite to acidic andesine. Rarely more basic varieties were noted. From this it would seem that the original eruptions that gave rise to this series of bedded deposits were mainly of dacitic and andesitic character. Basaltic outflows were apparently less numerous. Among the interbedded lava flows and associated flow breccias rocks of dacitic, andesitic, and basaltic nature were identified. These determinations conform with the petrographic character of the fragmental rocks.

North of Boulder Creek, in the valley of the tributary due north of the west end of Anthracite Ridge, a section of Lower Jurassic volcanic and associated rocks is exposed. These rocks appear to be in part fragmental and in part flows and intrusive rocks. The fragmental rocks are all derived from igneous material and consist of angular pieces of altered igneous rock in a finer-grained matrix that is likewise of igneous origin. They do not differ essentially from the fragmental Lower Jurassic volcanic rocks south of Boulder Creek. There are several varieties of igneous rock, however, in this section. Some are more or less even grained and light colored, therein resembling the felsites at the west end of Anthracite Ridge. Others are darker colored and porphyritic and appear to be more basic. One of the specimens collected from this complex is a fresh-looking diabasic rock that is probably a representative of the later basic intrusive rocks on the south face of Anthracite Ridge. The Lower Jurassic volcanic rocks on Boulder Creek apparently constitute a complex of igneous and associated clastic rocks, which has been intimately intruded by several varieties of younger igneous rock. They are overlain by the Middle Jurassic rocks of the Tuxedni sandstone.

South of Matanuska River, from upper Carbon Creek to Gravel Creek, there is a continuous irregular area of volcanic rocks. These rocks are bordered on the north by Upper Cretaceous and Tertiary sediments and on the south mainly by granitic intrusive masses and metamorphic sediments. They include fragmental volcanic materials and minor amounts of tuffaceous sandstone.

The structural relations of these rocks are not apparent, but they have suffered dynamic metamorphism sufficiently intense to give to some of them a roughly schistose appearance. This, together with the general occurrence of faulted and slickensided surfaces, points clearly to a period of intense deformation. It is probably only the comparative rigidity of the lavas and associated deposits that has prevented the development of a general schistosity. It is possible that there is a gradual transition from these sheared volcanic rocks into the schistose rocks farther south.

In the valley of Boulder Creek, about 5 miles above its mouth, volcanic conglomerate is exposed along the banks for some distance. The rock occurs as immense blocks, some of which are embedded in the banks of the creek and have the appearance of being in place. This conglomerate is massive; therefore the bedding planes are difficult to decipher. Several determinations of strike and dip, taken on what were thought to be bedding planes, are quite discordant. There are evidences of faulting in this vicinity, and the conclusion has therefore been reached that these blocks of conglomerate are the remnants of a portion of the Lower Jurassic volcanic series faulted into this position and now almost entirely removed by erosion.

The matrix of this conglomerate is essentially a water-laid tuff, in which are embedded subangular to rounded boulders as much as 2 or 3 feet in diameter. The matrix is composed of more or less rounded fragments of altered feldspar, in part plagioclase, fragments of glassy basaltic rock, altered hornblende(?) crystals, fine-grained rock containing quartz and acidic feldspar, and granular felsic rock in a microcryptocrystalline groundmass that is probably largely quartzose. The embedded boulders are almost exclusively volcanic rock in an advanced state of alteration.

The following extract from the report by Paige and Knopf[52] constitutes their description of the Lower Jurassic volcanic rocks as a whole, and is based upon the occurrences on Chickaloon, Talkeetna, and Oshetna Rivers, Hicks Creek, and Sheep Mountain, which the writer did not have an opportunity to visit.

The great bulk of the greenstones are clearly products of explosive volcanic activity. They occur largely in the form of stratified breccias, in which angular fragments of dark-blue porphyritic rock, varying in size from microscopic dimensions to several feet in diameter, are inclosed in a matrix of green color. This contrast of colors, which serves to emphasize the breccia character of the rock, is due to the fact that the matrix is abundantly changed into the green mineral chlorite, whereas the large angular fragments, being of a dense, fine-grained texture, have often withstood alteration more thoroughly. With the breccias are intercalated various sheets of amygdaloids, porphyries, and flow breccias. The amygdaloids are frequently studded with numerous large amygdules, whose filling may consist of chalcedony, quartz, calcite, chlorite, or zeolite.

A prominent feature of the greenstones is the great amount of shattering and slickensiding which they exhibit. Where this internal movement has been of a more regular character a rude schistosity has been impressed on them. Extensive pyritization of a diffused character was noted at several localities, but a thin irregular seaming with calcite appears to be the most usual form of mineralization.

Petrographically the greenstones are prevailingly andesitic, usually of hyalopilitic or pilotaxitic texture, and more or less completely chloritized. Examples more basic than andesite appear to be rare and were noted only on Boulder Creek, about 7 miles from its mouth, where greenstones displaying columnar structure make up the north wall of the valley. These prove to be diabase porphyries.

The thickness of the greenstones often exceeds 1,000 feet. The tuffs locally contain fragments of lignite, and at the eastern end of Sheep Mountain, in the upper Matanuska Valley, were found to carry marine shells in a fine state of preservation.

Under the convenient field term "quartz porphyry" have been grouped various rhyolites and dacites, including their tuffs, that are associated with the greenstones. These are widely distributed in the interior of the Talkeetna Mountains. The rhyolites are generally flinty-looking rocks containing glassy phenocrysts but also include some splendid flow-banded phases. Devitrification is common in the rhyolites. Some of the dacites resemble the rhyolites in appearance, but others possess a greenstone habit. These acidic lavas appear to have been erupted either during or soon after the period of the andesitic extrusions, as they contain included in them fragments of microlitic andesite.

During the extravasation of the rhyolites conditions were not uniform over the province. While lavas were accumulating in some portions of the region

[52] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 16–17, 1907.

sedimentation was progressing in others. On the divide between Hicks and Boulder Creeks a white stratum 20 feet thick is prominent. It proves to be a feldspathic sandstone, with some irregular thin white bands, about a quarter of an inch thick, scattered through it. The microscope shows that these bands are composed of microspherulitic particles and fragments of devitrified rhyolite, with fine flow structure, indicating that showers of rhyolitic material were prevalent during this portion of lower Middle Jurassic sedimentation.

RELATIONS AND AGE

From a study of the structure of the Lower Jurassic volcanic rocks in the creeks visited by the writer it is estimated that the thickness of the formation amounts to several thousand feet, but the structure is such that an accurate estimate of thickness is impossible.

The collection of plant fossils described on pages 21–22 indicate that the formation may be assigned definitely to the Lower Jurassic.

TERTIARY VOLCANIC ROCKS

AREAL DISTRIBUTION

The late Tertiary volcanic rocks have a very extensive development in the upper Matanuska Valley, especially east of Chickaloon River, on the headwaters of Boulder Creek, and in the upper Caribou Valley, where they cover wide areas and have a thickness of at least 2,500 feet. In the district here considered they are confined to the summits of Castle Mountain and Puddingstone Hill, where their thickness does not exceed 700 feet.

PETROGRAPHIC CHARACTER

These rocks have been well described by Paige and Knopf,[53] who say:

Overlying the older rocks unconformably is a series of nearly horizontal basalt flows, which, with their intercalated pyroclastics, attain a thickness of 1,000 feet. They have an extensive distribution throughout the Talkeetna Mountains and compose many of the peaks and summits of the region. They weather in tints of red and break down in characteristic erosional forms which lend a picturesque castellated appearance to the mountain crest lines.

The basalt flows with their interbedded tuffs and breccias present a stratified appearance. The surface upon which these volcanics were accumulated appears to have been one of gentle relief, cut across the upturned edges of the older rocks. The discordance with which the nearly horizontal basalts rest upon the underlying strata varies from 10° to 90°. About the headwaters of Chickaloon River this surface slopes gently northward. East of Chickaloon River its altitude is about 5,000 feet. It is somewhat broken by small faults, the maximum displacement noted being 50 feet. At many places the basalts rest upon a conglomerate occupying broad channels in the Lower Cretaceous

[53] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 29, 30, 1907.

limestone. The basal portion of the volcanic series here consists of 100 feet of tuffs and amygdaloid breccias, which interleave with the sandstone beds in the upper portion of the conglomerate.

Locally the conglomerate is capped by an angular wash consisting of fragments of sandstone and cellular lavas, upon which rests the stratiform series of basalts and pyroclastics. At one point a breccia of unusual constitution was found near the base of the volcanic series. This breccia consists of large angular blocks of highly amygdaloidal lava, blocks of sandstone containing *Aucella*, and a few blocks of the Cretaceous limestone characteristic of the region. A basalt block 8 by 10 feet was the largest noted. The matrix in which this angular material is embedded is composed of small, well-rounded gravel. These features are interpreted as indicating a volcanic mud flow occupying an ancient stream course.

The overlying basalts display a wide variation in habit and texture. Highly glassy types, amygdaloids, porphyries, and dolerites are variously represented. They belong to the acidic end of the basalt family and are in general non-olivinitic. The coarse-grained basalts consist of doleritic aggregates of labradorite (Ab_2An_3) and augite. Plagioclase is the dominant constituent, and is in only a few specimens poikilitically inclosed in the augite. The basalt glass from the head of Chickaloon River, in spite of its holohyaline aspect, is found to contain sporadic phenocrysts of plagioclase (Ab_2An_3) and augite, and some small, irregularly shaped doleritic aggregates of labradorite and augite. The glassy base is of a deep, clear, brown color, and contains numerous augite and very minute feldspar microlites, the latter usually having forked terminations.

The basalts overlie a conglomerate of post-Lower Cretaceous origin and of probably late Kenai age. Their petrography suggests that they are the effusive equivalents of the diabase dikes and sills that are so common in the Kenai of the Matanuska basin. These volcanics of the Talkeetna Mountains can be correlated with the great series of Tertiary volcanics of the upper Nizina basin, described by Schrader and Spencer, and with an important volcanic series on Nabesna River, described by Brooks. Both these series are described as comprising andesites, rhyolites, and pyroclastics and were deposited unconformably upon a general uniform surface. The volcanics of the Talkeetna region, however, show a greater petrographic uniformity and consist exclusively of basalts and their fragmental accumulations. In this respect they show a closer resemblance to the late Tertiary lavas of the Alaska Peninsula and the Aleutian Islands, which have been described by Spurr [54] as andesitic basalts.

The occurrence of these rocks in Castle Mountain and their lithologic character, stratigraphic sequence, and relation to the underlying Eska conglomerate have been described by Martin and Katz.[55] The mass that caps Castle Mountain is part of a formerly continuous area that extended across the Chickaloon Valley into the district now being described. This former area of volcanic rocks has been dissected by Chickaloon River, and its eastern remnant crops out on the summit of Puddingstone Hill.

On the east side of Chickaloon River, on the hill east from the Government bridge, there is a mass of volcanic conglomerate that

[54] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898; Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 234, 1901.

[55] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 54–55, 1912.

forms the base of the Tertiary volcanic series. Neither the top nor bottom of this basal member is definitely exposed, but it probably has a thickness of 100 feet or more. It is essentially a water-laid tuff in which are embedded rounded to subangular basaltic boulders, some of which are 2 feet in diameter. The tuffaceous matrix of this conglomerate, as shown by microscopic examination, is not unlike a tuff proper, except that the grains are inclined to be more rounded. Much chemical alteration has taken place, both in the matrix and in the included boulders.

The extrusive rocks overlying the basal volcanic conglomerate consist of basaltic flows interbedded with tuffs, flow breccias, and volcanic conglomerate of like composition. On account of the variety of rock types there is considerable diversity in the appearance of different members of the series. Where the rocks have been but little altered by atmospheric and aqueous agencies, the general color ranges from dark gray to black, but at many places considerable alteration has taken place, giving rise to greenish or reddish tones. The tuffs, flow breccias, and volcanic conglomerates, being more porous than the flows, have in general suffered more chemical alteration and are more generally greenish, reddish brown, or reddish. Some of the lavas are dense; others, probably the greater part, were originally vesicular, but the more or less spherical gas cavities have usually been filled with secondary minerals, thus developing an amygdaloidal habit. As a rule, the most porous varieties have suffered the greatest chemical alteration.

The basalts are fine-grained rocks, composed essentially of plagioclase (generally labradorite), augite, and oxides of iron. The intersertal fabric, wherein small pyroxene individuals occupy the interstices between lath-shaped feldspar crystals, is the common mode of development. The feldspar also occurs as phenocrysts, giving a porphyritic habit to the rocks.

The basalts are commonly more or less altered as a result of secondary processes, in which the feldspar is replaced by calcite, the augite is replaced by a dark-green nonpleochroic chloritic material, and the oxides of iron become hydrated. Another noteworthy secondary process is the development of amygdules, mentioned above. There seems to be no general rule governing the sequence of crystallization in the vesicles. In many of them the filling consists of a quartz lining, surrounding an interior of chlorite, calcite, and sometimes quartz. All these minerals may or may not be developed as spherulites. Much of the chlorite is pleochroic in tones of green and yellow and has a very low birefringence. In the tuffs chemical alteration has proceeded further, giving rise in many rocks to the development of a dirty nonpleochroic cementing material, which surrounds angular fragments of basaltic material.

RELATIONS AND AGE

The series of basaltic lavas and tuffs above described have been shown by Martin and Katz [56] to lie unconformably on the Eska conglomerate at Castle Mountain, west of Chickaloon River. East of the Chickaloon the continuation of these rocks lies stratigraphically above the Eska conglomerate, but the contact is concealed. It is practically certain, however, that the two series are everywhere unconformable. The volcanic series is therefore a younger formation than the Eska conglomerate, and the volcanic eruptions are believed to have taken place in late Tertiary time. The age and correlation of the Tertiary volcanic rocks are discussed in more detail on page 47.

INTRUSIVE ROCKS

GRANITIC ROCKS

AREAL DISTRIBUTION

Granitic rocks occupy most of the mountain province north of Matanuska River and west of Chickaloon River and occur as a small mass on Sheep Mountain, all outside the district considered in this report. These rocks are granite, quartz diorite, and quartz monzonite and are for the most part of moderately coarse granitoid texture, though locally foliated. Within the district considered here granitic rocks are found only south of the Matanuska, where quartz diorite is known to occur in at least two areas.

PETROGRAPHIC CHARACTER

The granitic rocks of the Talkeetna Mountains and of Sheep Mountain have been described as follows by Paige and Knopf: [57]

Much of the rugged interior of the Talkeetna Mountains remains unexplored, but such evidence as is available indicates that the great central area consists wholly of granitic rocks. Extensive exposures of granular crystallines were encountered along the line of travel. The morainal material brought down by the glaciers from the remote recesses of the range and the gravels of the streams heading in the mountainous interior consist prevailingly of granitic material.

A considerable variety of rock types is found, but quartz diorites appear to predominate. A quartz diorite north of Tsadaka Creek carries the dark minerals, hornblende and biotite, and is associated with a quartz-diorite gneiss rich in hornblende. This gneiss is found also on Granite Creek and is doubtless a cataclastic phase of the massive quartz diorite. Along the middle course of

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[56] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 54–55, 1912.

[57] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 19–20, 1907.

Chickaloon Creek quartz-augite diorite appears, but toward the headwaters it gives place to a muscovite granite. Along the upper Talkeetna gneisses again appear, but along the lower course more quartz diorites are exposed. Along the western flank of the Talkeetna Mountains granitic rocks are exposed in great abundance almost continuously from Talkeetna River to Willow Creek and again as a narrow band forming the southern boundary of the crystalline mica-schist area. Near Sheep Creek some uralitic gabbro is found. In the vicinity of Kashwitna River is a light-colored quartzose type, which proves to be a quartz monzonite.

The quartz diorites on the south side of Knik Arm are probably to be correlated with those making up the main mass of the Talkeetna Mountains. Similarly a small isolated boss of epidotized quartz diorite a few miles east of the mouth of Caribou Creek appears to belong to the same general mass.

AGE

Wherever the quartz diorites come in contact with the Susitna formation a recrystallization of the sediments has taken place and finely granulated hornfels has been produced. Along the upper Chickaloon the contact of the granite with the andesitic greenstones is marked by a fine-grained marginal facies. Granite porphyries of nevadite habit, containing greenstone inclusions, appear near the contact and probably represent the chilled border of the invading granite magma.

The quartz-diorite boss east of Caribou Creek, which appears to represent a satellitic intrusion attendant on the batholith of the Talkeetna Mountains, invades the andesitic greenstones of Sheep Mountain, which have been shown by their fossils to be of lower Middle Jurassic age. Accepting the correlation of this quartz-diorite mass with those of the central portion of the province, we have strong presumptive evidence that the batholithic core of the Talkeetna Mountains is later than the Middle Jurassic. From the abundance of granitic material in the coarse conglomerates of Upper Jurassic age it is inferred that the intrusion preceded the deposition of the late Jurassic strata. The granitic complex of the Talkeetna Mountains is thus contemporaneous in a general way with that great series of batholithic intrusions of late Mesozoic age which affected the entire cordilleran region from the Straits of Magellan to the Seward Peninsula of northwestern Alaska.[58]

On Gravel Creek, about 4 miles from its mouth, where a small stream enters from the west, quartz diorite is exposed on the west wall of the valley. A few hundred feet upstream another exposure occurs on the same side of the valley. The rock at the first point mentioned is dark gray to greenish and rather even grained. All the specimens from this locality are more or less altered chemically, and locally the rock is badly fractured and veined. The minerals observed under the microscope are plagioclase, quartz, hornblende, biotite, iron oxides, and apatite. The plagioclase, where fresh, is zonally grown and ranges from andesine in the centers of the crystals to albite on the rims. Much of the feldspar, however, is completely altered to secondary products, such as chlorite and saussurite, and

[58] Lawson, A. C., The cordilleran Mesozoic revolution: Jour. Geology, vol. 1, 1893, p. 579. Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 250, 1906.

is indeterminate. The biotite is in part a secondary product derived from hornblende. In the badly crushed specimens the original mineral grains are scarcely discernible, the rock being altered largely to calcite, zeolite, and epidote. In one of these specimens the zeolite corresponds rather closely to laumontite.

The second exposure on Gravel Creek consists of augite diorite, which differs from the rock just described in the total absence of quartz and in the substitution of pyroxene for hornblende. This is probably a more basic phase of the same dioritic mass.

On the north wall of the third tributary to Monument Creek from the east badly altered quartz diorite is apparently intrusive into rocks tentatively correlated with the Lower Jurassic rocks of Boulder Creek. The specimens collected in this vicinity show the effect of much dynamic as well as chemical metamorphism. Quartz, the only rock mineral which is unaltered, shows strong undulatory extinction. The plagioclase is altered to secondary albite, sericite, epidote, and chloritic products. Hornblende, the common mafic mineral, is also altered to epidote and chlorite.

In the valley of the creek tributary to Matanuska River from the south, 4 miles east of the mouth of Chickaloon River, the creek gravel is largely quartz diorite. The rock is fairly fresh looking and under the microscope shows little alteration. This material doubtless was derived from a mass of quartz diorite at no great distance upstream. The mineral composition of these rocks differs from those previously described chiefly in the presence of small amounts of orthoclase. The other rock-forming minerals present are quartz, zonally grown plagioclase ranging from oligoclase-albite inward to acidic labradorite, biotite, hornblende, magnetite, apatite, and zircon.

The evidence from the lower Matanuska Valley on the age of the granitic rocks of the Talkeetna Mountains has been stated by Martin and Katz[a] as follows:

> The granite is in contact with the Lower Jurassic volcanic rocks and with the probably Lower Cretaceous limestone in the ridge north of the west end of Castle Mountain. The nature of the contact at this point is not as clear as could be wished. Near the contact the granite shows evidence of having been severely crushed, and there is probably some faulting at this locality. The actual contact could not be observed at close range, so it is not known definitely whether the granite is intrusive into either or both of the Mesozoic formations. The contact, as seen in cliffs which were inaccessible, looked very much as if it were intrusive. On the other hand, the granite is not noticeably finer grained near the contact than away from it, nor could it be seen that the limestone or the Lower Jurassic volcanic rocks were more altered near the edge of the granite mass.

[a] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 28–29, 1912.

The date of intrusion of the granitic mass of the Talkeetna Mountains is assigned to the Middle Jurassic by Paige and Knopf [60] on the ground that the Upper Jurassic rocks on the headwaters of the Matanuska contain boulders of granite identical in character with that of the mountains, and the Lower Jurassic volcanic rocks on Sheep Mountain are cut by a small mass of granite. There is a weak point in this evidence, as the small granite mass on Sheep Mountain is 28 miles distant from the main granite mass of the Talkeetna Mountains and may or may not be contemporaneous with it. The evidence is, however, very suggestive and is in harmony with the apparently intrusive character of the contact of the granite with the Lower Jurassic volcanic rocks north of Castle Mountain and with what is known of the date of intrusion of similar granite masses not only in Alaska but throughout the American Pacific coastal mountains.

In the area south of Matanuska River the granitic rocks cut the volcanic series that has been tentatively correlated with the Lower Jurassic volcanic rocks farther north. If the age assignment of the volcanic rocks is correct, these granitic materials are younger than the Lower Jurassic. They are also apparently older than the Upper Cretaceous sediments. It therefore seems safe to correlate them with the granitic rocks of the Talkeetna Mountains, described above.

SODA FELSITE

AREAL DISTRIBUTION

The rocks here grouped under the general designation soda felsite occur to a very minor extent in the upper Matanuska Valley. The locality where they are most abundant is at the west end of Anthracite Ridge. Dikes of the same character were found along the north bank of Matanuska River about 7½ miles above the mouth of Chickaloon River.

North of Anthracite Ridge a large dikelike mass of this felsitic rock extends across the country for several miles, cutting rocks of Jurassic and Upper Cretaceous age. A small felsitic dike was found about 1 mile southeast of the forks of Boulder Creek, at an altitude of about 3,800 feet.

PETROGRAPHIC CHARACTER

The felsites are for the most part light-colored rocks, exhibiting considerable variety of tint. Pearl-gray, light greenish-gray, flesh-colored, buff, pink, and even dark-gray specimens are found. All these rocks are more or less altered, and the variation in tint is probably due largely to this fact. They are all fine grained, being aphanitic in hand specimens. Partly on account of their altered character, they present to the eye a dull, stony appearance. In a

[60] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, p. 21, 1907.

few of these rocks equant phenocrysts of cloudy-looking feldspar may be seen, but in general they are not noticeably porphyritic. Pyrite is in places disseminated throughout the rock, with a local concentration along the cracks.

The felsites, though megascopically aphanitic, are holocrystalline. The groundmass may have either a microgranular or a felsitic habit, and the occasional presence of phenocrysts gives rise to either a granophyric or a felsophyric fabric. Where the rock is porphyritic, the phenocrysts are commonly plagioclase, which is commonly much altered. In such rocks the character is usually indeterminate. In one rock, however, an exact determination was possible, and the feldspar was found to be identical with the feldspar of the groundmass, namely, albite. Zonal development of the plagioclase was not noted in any of the members of this group, and it is therefore probable that the feldspar phenocrysts do not differ in any great degree from the feldspar of the groundmass. The dominant minerals of the groundmass are plagioclase and quartz. The plagioclase shows both Carlsbad and albite twinning, but the latter is much less pronounced in the microgranitic varieties. The composition has been determined as ranging from albite to oligoclase. Quartz probably nowhere constitutes more than 30 per cent of the rock volume, but in a few of the specimens it is so scarce as to be considered only an accessory mineral. In such rocks the habit is distinctly trachytic. The quartz occurs for the most part in anhedral forms in the interstices between the feldspars. Biotite occurs here and there in small amounts among the primary minerals. Oxides of iron are lacking almost altogether in the lighter-colored specimens but are present in considerable amounts in a few of the darker-colored rocks of this group.

From the foregoing description it is seen that these rocks are not true dacites, for they contain scarcely any mafic minerals, and the plagioclase is sufficiently sodic in many specimens to be considered a true alkali feldspar. The complete absence of orthoclase, however, precludes a strict correlation with the aplites or rhyolites. Rocks of this character have been described by different authors under a variety of names. Of these the names quartz keratophyre, oligoclase dacite, and soda rhyolite apply very well to individual members of this group that carry appreciable amounts of quartz; and keratophyre and soda trachyte may be properly applied to the quartz-poor varieties. No one of the terms, however, is broad enough to be used as a group for these rocks, which are therefore described collectively under the general group name soda felsite.

All these rocks are more or less altered. The feldspar, where alteration has occurred, has been replaced by calcite, sericite, kaolin, and a yellow-green serpentinous product. Secondary quartz is locally developed along with the calcite. The primary quartz, too, has been altered, much of it being partly replaced by calcite. The original oxides of iron have been developed into limonite and hematite. Both the quartz and the feldspar show pronounced undulatory extinction, indicating that the rocks of this group have suffered a certain amount of dynamic metamorphism in addition to the chemical alteration just noted. So far as observed, however, schistosity or banding has not been developed.

RELATIONS AND AGE

The soda felsite is clearly intrusive. North of Anthracite Ridge it cuts Lower Jurassic rocks, and it has been intruded also along the contact between Lower Jurassic and Upper Cretaceous beds. Moreover, it is itself intruded by diabasic dikes similar to those on the south side of Anthracite Ridge. The felsite dike on the north bank of Matanuska River cuts rocks of Upper Cretaceous age. The relation of the mass at the west end of Anthracite Ridge to the adjoining rocks is obscure.

From the data above given it may reasonably be inferred that the intrusion of these felsitic rocks took place after the Upper Cretaceous beds were laid down and before the intrusion of the basic rocks. The positive evidence available does not warrant any closer estimate of age.

GABBRO, DIABASE, AND BASALT

AREAL DISTRIBUTION

The basic intrusive rocks occur as sills, dikes, and irregular intrusive bodies along the south face of Anthracite Ridge, as trap ridges in the central and western parts of the area, and as sills and dikes scattered throughout the area. Over fifty of the largest masses are shown on the accompanying map, and multitudes of others were seen that are too small to be shown on a map of this scale—for example, the sediments of the Chickaloon formation on lower Chickaloon River, on Coal Creek, and at many other localities are cut at short intervals by dikes and sills that range from a few inches to many feet in thickness. As these bodies of intrusive rock crop out at the surface only on the steep bluffs that border the stream valleys, their known areal extent is small, but they undoubtedly occur in similar abundance in places where their distribution can not be observed because of the cover of gravel and glacial deposits. Probably none of these intrusive masses have an area exceeding 2 square miles, and most of them are much smaller.

PETROGRAPHIC CHARACTER

The basic intrusive rocks consist of gabbro, diabase, and basalt. They are dense dark-gray to black rocks, many of which have greenish tones. The hand specimens show considerable variation in granularity, ranging from coarse-grained gabbros in which the component minerals are clearly visible to fine-grained basalts in which the state of crystallization is not apparent to the unaided eye. In hand specimens of the coarser varieties it is possible to identify feldspar and pyroxene. In general the basalts and finer-grained diabases seem to be more affected by alteration than the gabbros and coarser-grained diabases. It is probable that the mode of occurrence is the most potent factor regulating the degree of alteration shown by the different types.

In thin section it may be seen that there are differences in the fabric or arrangement of the different minerals within the rock. In the more coarsely crystalline varieties these rock-forming minerals approach closely an equidimensional granular habit. With increasing fineness of grain there is a tendency for the feldspar to develop crystals that are smaller and lath shaped, and the pyroxene, though retaining its granular habit, also crystallizes in smaller grains. In this manner arises the intersertal fabric that the basalts possess. The ophitic fabric that is characteristic of the diabases is a special form of the intersertal fabric in which the pyroxene crystallizes in larger individuals, many of which completely inclose feldspar laths. All gradations between these types of mineral arrangement may be found among the basic intrusive rocks. Contact phases are locally somewhat glassy, but as a rule these basic rocks are holocrystalline. Commonly the habit is nonporphyritic, but the phenocrysts that occur are feldspar.

The minerals usually developed are plagioclase, augite, and oxides of iron. The composition of the plagioclase is about that of labradorite, but in some specimens zonal growths occur, and the crystal exhibits a narrow band of more acidic plagioclase. Augite occurs in colorless to light-brown subhedral forms. Oxide of iron, usually magnetite, is a constant though subordinate constituent, developing in subhedral to anhedral equant grains. Apatite is an accessory mineral and occurs in delicate needlelike crystals, which show the imperfect basal cleavage. The usual order of crystallization is magnetite, feldspar, and augite, in the order named; but two specimens showed without doubt that the order of crystallization is sometimes reversed, for in these the augite crystallized first, feldspar next, and magnetite last. The reason for this anomaly, recorded also by others, is not apparent.

Quartz-bearing members of the basic intrusive rocks were noted at several localities. On the south slope of Anthracite Ridge on the first creek west from Purinton Creek, at an altitude of 3,380 feet, a fine-grained quartz-bearing gabbro was found. In this specimen the feldspar was zonally grown and in a section parallel to 010 gave extinction angles ranging from 27° to 0° from the centers of the crystals outward, measured against the 001 cleavage, thus indicating a composition ranging from labradorite in the center to oligoclase on the rim.

At another locality on the west side of Gravel Creek, about 8 miles from the mouth and just a short distance beyond the limits of the area shown on Plate 2, a quartz-bearing basalt was found cutting a mass of quartz diorite. This was a black porphyritic rock, much altered, showing zonal growths in the feldspar phenocrysts.

Just south of the triangulation station on the south end of the easternmost peak on the trap ridge about a mile southeast of Boulder Creek a fine-grained light-colored dike cuts the large intrusive mass that forms the ridge. This dike is also a quartz-bearing rock but differs from the two others mentioned in that it carries more quartz. This rock possesses other abnormal features. The plagioclase appears to be an acidic variety, approaching albite in composition, and is in places intimately intergrown with quartz, giving locally a graphic structure. The pyroxene is a deeply colored green augite, which shows a slight absorption. Magnetite is present in its usual habit and amounts, but apatite is abnormally abundant. This rock is in all probability related genetically to the gabbro mass which it has invaded, and it is regarded by the writer as a differentiated dike rock that was intruded shortly after or possibly before the main gabbro mass had completely solidified. The boundary between the dike rock and the gabbro is not sharp. There is no qualitative rock name that exactly fits this specimen.

Olivine basalts have been noted by Katz [61] among the basic intrusive rocks at two localities in the lower Matanuska Valley, but the writer collected no olivine-bearing rocks in the upper part of the valley. It is probable, however, that they occur in subordinate amounts.

Where alteration has taken place calcite and chloritic material are the secondary products usually developed. Both are derived from the alteration of the feldspar. The augite alters more or less uniformly to a dark-green to yellow dirty-looking chloritic product, in places accompanied by limonite and other secondary minerals. Rarely secondary epidote replaces both plagioclase and augite. The magnetite alters to limonite and hematite. Pyrite occurs in small amount in many of the specimens that have suffered chemical altera-

[61] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 64, 1912.

tion, replacing the primary rock-forming minerals. The apatite needles, so far as observed, have not suffered any alteration. None of the specimens examined show any dynamic metamorphism.

It is believed that the intrusive gabbro, diabase, basalt, and related dike rocks of the Matanuska Valley represent one general period of volcanic activity. There is considerable difference in the appearance of the rocks of this type, but, as pointed out above, this is due largely to differences in the degree of coarseness, in the arrangement of the minerals, and in the order of crystallization. Some slight differences in chemical composition doubtless exist, as is shown by the presence of quartz-bearing varieties, and particularly by the presence of abnormal rock types like the one in the trap ridge southeast of Boulder Creek, described above. But special types are few, and, regarded as a whole, the mineral and chemical composition of these intrusive rocks may be said to be very uniform.

RELATIONS AND AGE

The south face of Anthracite Ridge presents a large number of mappable units of the basic intrusive rocks. The largest of these are the bodies of gabbro that extend from the mass east of Pack Saddle Gulch intermittently westward along the base of the ridge. These are irregular-shaped bodies, usually elongated in a direction corresponding roughly to the general strike of the sedimentary rocks that form the ridge. The smaller intrusive bodies follow more closely the bedding of the stratified rock, and many of them are true sills.

The larger masses of intrusive rock that occur along the base of Anthracite Ridge add a striking topographic feature to the ridge. On account of their hardness and superior resistance to weathering, these rocks form abrupt cliffs at the base of the ridge, over which numerous streams descend as waterfalls. In the intrusion of these larger masses the adjoining sediments have been folded and faulted at many places. The section across the gabbro mass at the base of Anthracite Ridge (fig. 4) illustrates the relation of the gabbro to the stratified rocks. In some places large blocks of shale have been engulfed in the gabbro. In such occurrences the shale has been baked to a hard slabby rock.

Another type of intrusive is shown in Figure 3, which is a section through the large lava mass at the base of Anthracite Ridge, where the second creek west of Cascade Creek cuts through. Here the lava, instead of invading the sedimentary rocks in a large mass, has penetrated upward along the bedding planes. The result is an intricate complex of sills with baked shale and sandstone. On the north side of the complex is a well-defined, steeply dipping fault, and lava has been intruded also along this fault plane.

The trap ridges are irregular-shaped bodies, which form a characteristic part of the topography of the upper Matanuska Valley. Their direction of elongation corresponds roughly to the regional strike of the sedimentary beds. Locally, however, they cut the sedimentary beds that adjoin them. Their general conformity with the structure of the region precludes classing these bodies as dikes, and their size and local transgression of the sediments make them different from true sills. They are probably more or less tabular-shaped laccolithic bodies.

A little patch of basalt just south of the west end of Anthracite Ridge is of questionable origin. The mineral composition conforms equally well with that of the basic intrusive rocks and with the Tertiary volcanic rocks. The rock is quite fresh and appears to be dense, lacking any vesicular or tuffaceous character. This area of basalt seems to be plastered against the side of Anthracite Ridge, with an apparent dip to the west. Whether this is a remnant of a sill or an extrusive rock is uncertain. Probably, however, it does not represent a part of the Tertiary volcanic series.

Small sills and dikes of diabase and basalt are found in many localities in the upper Matanuska field. They most commonly intrude the Tertiary rocks, and in their invasion they have followed particularly the softer beds, such as the shales and coal beds. They are not, however, limited to the Tertiary rocks.

North of Anthracite Ridge basaltic and diabasic dikes cut the Jurassic and Cretaceous rocks, and south of Matanuska River, in the valley of Gravel Creek, just beyond the limits of the area shown on plate 2, a dike of this character cuts quartz diorite in place. As pointed out by Katz,[62] these intrusive rocks are folded and faulted only locally, and the deformation does not compare in extent with that which the Tertiary beds have suffered. Furthermore, the basalt dike intrusive into quartz diorite places the period of intrusion subsequent, at least in part, to the intrusion of the quartz diorite. The study of these rocks in the upper Matanuska field therefore confirms the conclusions reached by Katz in the lower Matanuska field; namely, that the major intrusion was subsequent to the principal deformation that affected the Tertiary beds.

MINERAL RESOURCES

METALLIFEROUS DEPOSITS

No promising metalliferous deposits have been found within the area included in this report. The many intrusive dikes and sills that cut the Mesozoic and Tertiary sediments north of Matanuska

[62] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, p. 67, 1912.

River apparently caused no important metallization of those sediments, and the contact-metamorphic effects from these intrusive rocks extend only a few inches or at most a few feet into the sediments. South of Matanuska River there are extensive areas occupied by more or less metamorphosed volcanic breccias, agglomerates, and tuffs and by rather highly metamorphosed sediments, all of which are cut by large granitic masses. Such a geologic association might well be expected to have produced metalliferous veins, yet within the area here considered no promising veins have been found, and prospecting for placer gold on the many northward-flowing tributaries of Matanuska River has failed to reveal the presence of either gold or other precious metals. West of this area, however, on Carpenter Creek, and on other streams that drain areas of similar rocks, there are quartz veins reported to carry gold, silver, and copper, and some placer gold has been recovered from Metal Creek, a tributary of Knik River that flows southwestward from these same mountains. Further prospecting in the mountains south of Matanuska River and north of Knik River and Knik Glacier therefore seems justified.

An interesting occurrence of copper mineralization on the south slopes of Sheep Mountain, some 16 miles east of the area shown on Plate 2 and just north of Matanuska River, is described by Martin and Mertie.[63] They report that the copper minerals apparently occur in irregular lenticular masses and as disseminated sulphides in the more porous and shattered parts of a series of Lower Jurassic fragmental volcanic rocks and lavas, which are associated with some interbedded shale, sandstone, and chert. Although they saw no ore bodies of commercial size, the occurrence of an area of rather strong mineralization in those rocks indicates the possibility that they may contain valuable lodes in that district or elsewhere. Jurassic volcanic rocks are present throughout this region on both sides of Matanuska River.

COAL

AREAL DISTRIBUTION

Matanuska Valley contains a number of more or less distinct coal-bearing areas. Those in the lower Matanuska Valley have been described elsewhere.[64] The present report deals primarily with the upper Matanuska Valley—the part that lies above Chickaloon—but

[63] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the Upper Matanuska and Nelchina Valleys: U. S. Geol. Survey Bull. 592, pp. 281–282, 1914.

[64] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912; Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–168, 1920; Bull. 714, pp. 197–200, 1921.

for the sake of completeness and in order to correlate the information obtained in the present investigation with that relating to the lower Matanuska Valley,[65] this report and the accompanying geologic map (pl. 2) are made to cover an area extending as far west as Castle Mountain and Kings Mountain, and to include much of the Chickaloon coal field. During the summer of 1924, however, the coal mines at Chickaloon and the development tunnels on Coal Creek were closed and inaccessible, and the descriptions of these coal workings included in this report are based on earlier studies by Martin, Chapin, Hill, and their associates. The other coal fields of the upper Matanuska Valley include two small areas on the south flank of Anthracite Ridge, containing anthracite and some high-grade bituminous coal, and an area on both sides of Matanuska River near the mouth of Gravel Creek—the so-called O'Brien Creek field. A large part of the area east of Chickaloon River, though occupied by beds of the Chickaloon formation, is believed to lie stratigraphically below the coal-bearing beds and to contain no workable coal. Plate 2 shows the areas occupied by the Chickaloon formation, which carries all the coal, but by no means all those areas are to be considered coal land. The Chickaloon in this district is generally covered by a layer of glacial till and gravel sufficiently thick to conceal the rocks, and exposures are largely confined to the banks of a few sharply intrenched streams and to the steeply sloping south face of Anthracite Ridge. It has therefore been impossible to trace the outcrops of the coal beds with sufficient definiteness to delimit sharply the coal-bearing areas from those that contain no workable coal.

Without doubt the largest area of coal land in this district (pl. 2) is contained in the Chickaloon field. The principal surface outcrops of the coal beds occur on the north bank of Chickaloon River at the town of Chickaloon, and it is there that most of the development work has been done. At Chickaloon the rocks dip steeply northward and strike nearly due east. In that vicinity all the known coal beds are on the north side of Chickaloon River, and no coal outcrops have been found south of Chickaloon, except in the Coal Creek area, south of Matanuska River. East of the town of Chickaloon the coal-bearing formations pass beneath the gravel-covered benches and are generally concealed, but from such exposures as were found and from the trend of the sill-like intrusive masses, it seems probable that the strike of the coal beds is northeastward from Chickaloon and that all the known coal-bearing beds lie north of a line drawn from Chickaloon through the intrusive ridge just south of Rush Lake. Except for the coal outcrops high on the flanks of Anthracite Ridge and a

[65] U. S. Geol. Survey Bull. 500, pl. 5, 1912.

single exposure on the north bank of Matanuska River just above the mouth of Packsaddle Creek, where two thin coal beds crop out, no coal beds are known in the area north of Matanuska River and east of the Chickaloon basin.

South of Matanuska River there are two distinct areas in the region here discussed that contain considerable coal. One is on Coal Creek, about 2 miles southeast of the town of Chickaloon, and the other is the so-called O'Brien Creek area, at the eastern edge of the Matanuska field. At both of these localities the exposures of the coal formation are of small extent, and there is a general cover of surficial gravel, so that it is impossible, from a surface examination only, to outline the coal-bearing areas or to work out the details of structure in the coal formation. At both places, however, there has been much deformation with steep tilting or folding, and at both the coal beds are cut by pronounced faults. It is believed that only a moderate quantity of coal is available in each of these areas. A third patch of the Chickaloon formation occurs 1 to 2 miles south of Matanuska River, opposite the mouth of Cascade Creek. In this patch, which has an area of about 1¼ square miles, some thin coaly seams were noted, but no coal beds of commercial size. This area of the Chickaloon formation lies in high, rugged mountains; and even if coal beds of commercial size exist there, which is doubtful, its topographic position precludes exploitation until the more favorably located fields are exhausted.

STRATIGRAPHIC OCCURRENCE

The coal beds of the upper Matanuska Valley, like those of the lower valley, are all of Tertiary age and occupy the same general stratigraphic position as the coal of the Kenai formation of the Cook Inlet-Susitna lowland. All, except possibly those in the vicinity of O'Brien Creek (pl. 2), occur in the Chickaloon formation, which is the middle local division of the Tertiary rocks as described in the report on the geology of the lower Matanuska Valley,[66] and the commercially important coal beds apparently all occur in about the middle portion of the formation, though their exact position in the section is not known. The coal beds south of Matanuska River, on Coal and O'Brien Creeks, have not been correlated with the section north of the river, as the structure is complicated by faulting, but it seems likely that at these localities also the coal beds occupy the middle portion of the Chickaloon formation. Mining and prospecting have shown that the coal beds pinch and swell from place to place, and the character of the coal beds as well as of the sand and shale members of the formation may vary greatly within short dis-

[66] Martin, G. C., and Katz, F. J., op. cit.

tances, so that the greatest difficulty has been met in attempting to correlate one section of the Chickaloon with another some distance away. This characteristic of the formation greatly increases the cost of developing a coal mine and renders uncertain estimates of the amount of coal in a given block of ground made in advance of underground exploration.

CHARACTER OF THE COAL

PHYSICAL PROPERTIES

The upper Matanuska Valley contains high-rank bituminous coal and some anthracite. In the lower Matanuska Valley the coals are low-rank bituminous, and still farther west, in the Susitna Basin, there are many deposits of lignite. All these coals, however, are of approximately the same age. The character of the coal is apparently the direct result of the metamorphism which it and the containing sedimentary beds have undergone. In the Susitna Basin and the Cook Inlet region the coal-bearing beds are little folded and deformed, and the coal is lignitic. In ascending Matanuska Valley the deformation becomes more intense and the coals become of progressively higher grade, through low-rank bituminous at Moose and Eska Creeks to high-rank bituminous at Chickaloon and Coal Creek. In the upper valley, too, intrusive dikes and sills in the coal measures are more abundant, and they may have played some part in improving the quality of the coal. Very close folding, faulting, and intrusion by igneous rocks on the south slope of Anthracite Ridge, near the head of Purinton Creek, have resulted in the development there of a small area of anthracite. This coal, which is of excellent grade, is exposed at many places, and at one place a bed of anthracite nearly 40 feet thick crops out. It is hard, firm, little fractured for surface coal, and has a high luster. As is shown by the analyses of surface samples (p. 84), it contains from 81 to nearly 86 per cent of fixed carbon and only 0.3 to 0.6 per cent of sulphur. The coal beds appear to lie in synclinal basins, and the upper parts of the folds have been largely removed by erosion. These beds no doubt contain considerable excellent anthracite, but whether it occurs in beds sufficiently large and continuous to justify the expense of mining is uncertain in view of the complex structure of the coal and the cost of building a railroad to it. Very little prospecting has been done on the anthracite beds, and whether they include workable bodies of coal can be proved only by extensive exploration, both on the surface and underground.

The high-rank bituminous coal of Chickaloon and Coal Creek is fragile and soft, like all coal of this variety, and the beds show the effects of having been severely crushed. The friability of the coal is so great that it crushes rather badly on shipment, but this is not so great a detriment as might at first seem, because many of the beds contain so many impurities that the coal from them needs to be washed to lower the ash content. Certain of the coals from Coal Creek, when properly cleaned, are said to be excellent for blacksmithing and for foundry uses.

The low-rank bituminous coal of the lower Matanuska Valley is on the border line between bituminous coal and black lignite. It is harder than the high-rank bituminous coal. Many of these beds, too, have been crushed, and it will probably not be possible to obtain from them a large proportion of lump coal. This coal possesses no coking properties but makes a satisfactory fuel for locomotive or stationary boilers. It is not so good for this purpose as the higher-rank coal but is less expensive to mine. Even when the high-rank Chickaloon coals are again put on the market, they will be most valuable for making coke, for smithing, and for naval coal, and will thus command a higher price, leaving some, at least, of the low-price market for the poorer coal. Each of the various kinds of coal should therefore command its own special market and should be to some extent noncompetitive.

COAL BEDS

The following pages contain measured sections of all the coal exposures that were accessible in the upper Matanuska Valley. Most of these sections were measured by Martin and Mertie in 1913,[67] but as no development work has since been done on them, the descriptions are still adequate. The results of mining at Chickaloon and at Coal Creek have been published elsewhere, but there is here included a tabulation of the coal sections at Chickaloon, as compiled by Chapin.[68] (See pl. 14.) The measurements given below were all made at natural exposures, there being no prospect openings or tunnels. No attempt has been made to correlate the beds, as the complex structure and the fact that none of the beds can be traced from point to point make correlation impossible. The sections in the Matanuska Valley proper are arranged in order from northwest to southeast.

1. Creek flowing northwest into Boulder Creek from near the west end of Anthracite Ridge, altitude 3,700 feet. Coal blossom (bed concealed) near outcrop of dark shale. Strike N. 68° W., dip 63° SW.

2. South face of Anthracite Ridge, 2 miles east of its west end, altitude

[67] Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina Valleys: U. S. Geol. Survey Bull. 592, pp. 273–299, 1914.

[68] Chapin, Theodore, Mining developments in the Matanuska coal fields: U. S. Geol. Survey Bull. 712, pl. 5, 1920.

3,900 feet. Coal blossom. No exposure obtainable.

3. Creek bed 1.2 miles S. 52° W. from 6,280-foot peak at head of Purinton Creek, altitude 3,350 to 3,500 feet.

	Ft.	in.
Crumpled shale	85±	
Coal	1	1
Shale		6
Sandstone	21	
Shale	25	
Coal	1	
Shale	25	
Sandstone	18	
Shale	18	
Sandstone	36	
Shale	3	
Coal		8
Shale	12	
Sandstone	24	

Strike N. 62° W., dip 45° S.

4. West Fork of Purinton Creek, altitude 4,200 feet.

	Ft.	in.
Intrusive rock (diabase).		
Shale roof.		
Coal		6
Diabase sill		6
Shale		3
Coal with much shale	1	6
Shale		1
Very carbonaceous shale and coal		5
Shale.		

Strike N. 88° E., dip 43° S.

5. West Fork of Purinton Creek, altitude 4,100 feet. Apparently two beds of coal, each 5½ or 6 feet thick, 2 or 3 feet apart, but more probably one bed repeated by surface slipping. Strike N. 65° W., dip 30° SW.

6. West Fork of Purinton Creek, altitude 3,900 feet. Coal, 40± feet. Neither roof nor floor of this coal bed could be found. The coal is apparently cut off at each end of the exposure across what appears to be the bedding. This is the exposure which has previously been described[a] as a 38-foot bed of anthracite. It should probably be regarded as a swollen pocket lying in a closely folded overturned syncline and probably cut by a fault. An exposure of shale in the creek 15 or 20 feet below the coal gave three readings on the bedding, as follows: Strike N. 72° E., dip 11° NW.; strike N. 76° W., dip 12° NE.; strike N. 73° E., dip 21° NW.

7. West Fork of Purinton Creek, altitude 3,880 feet.

	Ft.	in.
Shale roof.		
Coal	1	
Shale with some coal		5
Coal	3	1
Shale	1	4
Coal	1	3
Shale with some coal		6
Shale	2	3
Shale with some coal	1	
Shale	2	4
Coal	1	6
Black shale	1	4
Gray shale	12±	
Shale with some coal		6
Black shale	1	8
Coal	1	10
Shale		8
Coal with a little shale	1	4
Gray fissile shale floor.		

Strike N. 87° W., dip 55° S.

8. East bank of East Fork of Purinton Creek, about 570 feet upstream from section 9.

	Feet
Shale and sandstone much folded.	
Coal with some shale	7±
Covered	6
Coal with some shale	4±
Shale and sandstone, much folded.	

9. East Fork of Purinton Creek, altitude 3,480 to 3,560 feet.

	Ft.	in.
Diabase.		
Shale, baked	12	
Sandstone	10	
Shale, with coal blossoms	47	
Coal	2	7
Shale floor.		

Strike N. 80° W., dip 55° S.

[a] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, p. 18, 1906.

The section given below was measured by Martin[70] in 1905 on the East Fork of Purinton Creek or on the next creek east of it, on the south slope of Anthracite Ridge.

Flaggy sandstone.	Feet
Coal and shale	3
Coal	7
Shale	4
Coal	1
Shale	3
Coal	2
Shale	2
Coal	7

Strike N. 89° E., dip 55° SE.

10. Creek bed 1.3 miles S. 24° E. from 6,280-foot peak at head of Purinton Creek, altitude 3,850 to 3,950 feet.

	Ft.	in.
Diabase sill	19	
Shale	4	
Coal	1	1
Partly shale, partly covered	21	
Coal		8
Shale	15	
Coal		10
Shale with thin sills	23	
Coal	2	
Shale partly covered	27	

Strike N. 86° E., dip 44° N.

11. Creek bed 2.9 miles S. 55° E. from 6,280-foot peak at head of Purinton Creek, altitude 3,880 to 3,895 feet.

	Ft.	in.
Shale with coal blossoms	50	
Coal	3	5
Shale	24	
Coal	2	2
Shale	21	

Strike N. 82° W., dip 20° N.

12. Creek bed 2.9 miles S. 54° E. from 6,280-foot peak at head of Purinton Creek, altitude 3,830 to 3,850 feet.

Shale roof.	Ft.	in.
Coal	1	2
Shale	3	8
Coal		9
Shale	2	2
Coal	3	2
Shale	1	1
Coal		7
Shale floor.		

Strike N. 82° W., dip 20° N.

The two following sections described by Paige and Knopf[71] were measured by Knopf on either this creek or the next one east of it:

Anthracite Ridge, altitude 3,100 feet.

	Ft.	in.
Diabase	50±	
Sandstone and shale	10±	
Coal and shale	6	
Coal		2
Shale		1
Coal		10
Shale	2	
Sandstone	7	

Strike N. 70° W. (magnetic), dip 40° S.

Anthracite Ridge, altitude 3,600 feet.

Sandstone.	Ft.	in.
Coal	2	6
Coal and shale		4
Coal		6
Coal and ferruginous clay		2
Coal		10
Shale		6
Coal		4
Shale	12	
Coal	1	3
Shale	5	
Sandstone	1	
Shale	1	6
Clay ironstone nodules		6
Shale	1	6
Clay ironstone nodules		6
Highly carbonaceous shale	5	
Coal	1	5
Shale	9	
Sandstone	4	
Shale	15	
Coal		10
Shale	4	
Coal	2	2
Shale	4	
Coal		10
Shale	2	6
Coal and shale		6
Shale footwall.		

Strike N. 80° E. (magnetic), dip 34° S.

[70] Martin, G. C., op. cit., p. 19.

[71] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 55–56, 1907.

13. West bank of Muddy Creek, altitude 3,700 feet.

	Ft.	in.
Sandstone	20	
Carbonaceous shale, locally coal		6
Coal	1	7
Shale	3	
Coal	1	1
Carbonaceous shale		6
Shale with flattened ironstone nodules	3	
Coal	1	2
Shale		10
Ferruginous sandstone	1	2
Drab shale	1	7
Carbonaceous shale, locally coal		4
Coal		4
Carbonaceous shale, locally coal		6
Shale floor.		

Strike N. 32° W., dip 45° W.

14. East bank of Muddy Creek, altitude, 3,690 feet.

	Ft.	in.
Shale roof.		
Coal	1	2
Shale	6	
Sandstone	4	
Shale	7	
Coal	1	7
Shale parting		2
Coal	1	10
Shale	8	
Sandstone	5	
Shale	3	
Coal	1	1
Shale	6	
Coal	1	7
Covered.		

Strike N. 65° E., dip 45° S.

15. Bed of Muddy Creek, altitude 3,340 to 3,415 feet.

	Feet
Diabase sill	100
Carbonaceous shales containing 6 to 12 coal seams ranging in thickness from 1 inch to 18 inches. Badly crushed and sheared	22
Sandstone, thin bedded, and shale	28

Strike N. 8° E., dip 25° W.

16. Crest of spur between Muddy Creek and Packsaddle Gulch, altitude 4,400 feet.

	Feet
Covered.	
Coal	11+
Covered.	

Strike approximately east, dip 90°±.

17. Ridge east of Muddy Creek, altitude 3,900 feet. Coal blossom over a considerable area, and a poor exposure of 2 feet of dirty coal.

18. West slope of upper Muddy Creek Valley, altitude 3,450 feet. Coal blossom. No good exposures.

19. Spur west of Muddy Creek, altitude 3,360 feet. Coal blossom. No exposures.

20. North bank of Matanuska River, half a mile above Gravel Creek.

	Ft.	in.
Fissile gray shale.		
Coal, clean	1	4
Coal, somewhat shaly		9
Fissile gray shale.		

Strike N. 49° E., dip 30° NW.

The entire exposure at this point consists of about 200 feet of shale and sandstone, with several carbonaceous zones 10 to 40 feet thick, in some of which there are coal beds several inches thick. The coal bed described above is near the base of the section and extends along the face of the bluff for a considerable distance, in which it shows no indication of lenticularity.

21. Gulch 0.3 mile west of O'Brien Creek, altitude 1,800 feet.

	Ft.	in.
Black shale with some coal.		
Gray sandy shale	8	4
Black shale		7
Coal		7
Gray nodular shale	3	3
Coal	2	
Gray shale, much stained by iron		10
Coal		9
Shale		2
Coal		4
Shale with a little coal	2	
Ironstone band		9
Coal		7
Gray nodular shale	3	5
Coal		9
Shale		2
Coal	1	3

	Ft.	in.
Concealed	8	
Coal and some shale	6	
Concealed.		

Strike N. 78° E., dip 40° S.

22. O'Brien Creek, altitude 1,500 feet.

Gray shale under clay.	Ft.	in.
Coal		½
Shale		1
Coal	4	1
Shale with some coal	1	9
Coal	1	6
Coaly shale		10
Coal	2	6
Shale with ironstone concretions	6	
Shale and coal	4	7
Coal		2
Shale		1½
Coal	1	5
Shale		2½
Coal		11
Shale		½
Coal		1½
Shale		½
Coal	2	
Coal and shale, squeezed	1	6
Coal	2	8
Coal and shale		9
Shale	1	2
Coal	1	3
Coaly shale		10
Gray shale with ironstone concretions	13	6
Gray shale	31	
Gray shale with ironstone concretions	3	
Sandstone with some interbedded shale	14	10
Shale, somewhat sandy	15	

Strike N. 70° W., dip 87° SW.

23. O'Brien Creek about 100 yards farther upstream. Coal with many thin partings, 25 feet. This bed is apparently below No. 22.

24. Near top of west bank of O'Brien Creek, a short distance above No. 23. Large coal outcrop, which apparently consists of the bed represented in No. 23 folded back upon itself in an overturned syncline.

25. Gulch one-third mile east of O'Brien Creek, altitude 1,800 feet.

Shale roof.	Ft.	in.
Coal	3	9
Coal and some shale	2	
Concealed.		

Rocks dipping gently northeast.

26. Gulch one-third mile east of O'Brien Creek, altitude 1,900 feet.

Sandy gray shale roof.	Ft.	in.
Coal		8
Shale with some coal	2	
Sandy shale.		
Concealed.		

Rocks dipping about 20° NE.

27. About 1½ miles up the creek which enters Gravel Creek from the west 2¼ miles above its mouth, altitude 2,100 feet.

Covered.	Ft.	in.
Coal, impure, sheared	1	7
Shale		7
Coal, impure, sheared	1	2
Covered.		

Dip 75° S.

The rocks at this locality can not with certainty be assigned to the Chickaloon formation, which includes all the other known coal beds in the main valley of the Matanuska. The coal at this locality may represent either a local coal-bearing bed in the pre-Chickaloon strata, or a small block of the Chickaloon formation folded or faulted into the mass of rocks which are otherwise barren of coal.

STEAMING, COKING, AND BY-PRODUCT QUALITIES

Few tests have been made to determine the coking qualities of the Matanuska coals. It is generally understood that the coal mined in 1924 on Eska and Moose Creeks is noncoking, and that the coals at Chickaloon and Coal Creek are coking coals. The following statements on the coking and by-product qualities of coals from Chickaloon are quoted from a report by Chapin.[72]

In 1914, 586 tons of coal from the Chickaloon mine was submitted to an exhaustive test by the Navy Department. This test, made on the U. S. S. *Maryland*, included use of coal as follows:

1. An uninterrupted period of 7 days in port.
2. A test at sea for 24 hours with not more than three-fourths boiler power, and at a speed of 15 knots.
3. A test at sea for 4 hours under full boiler power at speed of 20 knots.
4. A test at sea of 40 hours at speed of 10 knots.

The Navy Department also submitted the coal to laboratory tests and to full analyses. As a result of these tests the board appointed to pass on the coal reported[73] that "the sample of Matanuska coal tested is suitable in every respect for use in the naval service."

A field test of the coking qualities of the Chickaloon coal was made in 1905 by Martin,[74] who says:

"The resulting coke was hard and firm and had a good ring and a good texture. The test indicated that by proper treatment a coke of satisfactory grade can be produced. No further tests have been made by members of the Geological Survey. The analyses indicate, however, that the high-grade bituminous coal on Chickaloon and Kings Rivers and on Coal Creek is probably, at least in part, coking coal, and that the coal in the west end of the district, on Moose, Eska, and Young Creeks, is low-grade bituminous and is probably all noncoking."

In 1918 a coking test on 6 tons of washed Chickaloon coal was made by the Bureau of Mines at the Wilkeson coking plant of the Wilkeson Coal & Coke Co., under the direction of George W. Evans. The analyses of the coal used for the test and of the resulting coke given below are taken from an informal report to the Alaskan Engineering Commission.

Analyses of Chickaloon coal used in coking test at Wilkeson coking plant and of resulting coke

	Moisture	Volatile combustible	Fixed carbon	Ash	Sulphur
Coal	1.0	22.52	65.87	10.61	0.49
Coke	.55	.70	85.45	13.30	.57

The coke is reported by Mr. Evans to be of good appearance, and a foundry test made on about 3 tons of it by the Puget Sound Iron & Steel Works, of Tacoma, Wash., was satisfactory and indicates its suitability for foundry purposes.

The following report was made by F. W. Speer, jr., on a sample of coal taken from bed 8 at Chickaloon, submitted by the Bureau of Mines to the laboratory of H. Koppers Co., Mellon Institute, Pittsburgh, Pa.:

Proximate analysis:

Volatile matter	21.14
Fixed carbon	72.37

[72] Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 138–139, 1920.

[73] Sixty-fourth Cong., 1st sess., S. Doc. 26, p. 9, 1915.

[74] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 92, 1912.

Proximate analysis—Continued.	
Ash	6.49
Sulphur	.57
Distillation:	
Water	3.077
Carbon dioxide	.787
Hydrogen sulphide	.088
Composition of gas (calculated to oxygen-free basis):	
C_nH_m	2.6
CO	4.9
H	60.4
CH_4	29.8
N_2	2.3
Ratio: $\frac{\text{Fixed } NH_3}{\text{Total } NH_3}$	.033
Specific gravity of gas	.30
British thermal units in gas per pound of coal	2,979
Practical yields per net ton:	
Tar ... gallons	4.4
Sulphate ... pounds	20
Gas at 15° C., 760 mm. Hg ... cubic feet	10,850
Coke ... per cent of coal	81.3
Light oil (estimated to contain 55 per cent benzol and 12 per cent toluol) ... gallons	1.9

"This is a coking coal similar in quality to Pocahontas. It would probably produce a similar coke, but the exact character of the coke can only be determined by making an oven test. Such coal usually requires mixing with some high-volatile coal in order to avoid trouble due to expanding and sticking."

The possibility of the utilization of the Matanuska coals for their by-products should be investigated when sufficient coal reserves are developed. A ton of bituminous coal will produce, in round numbers, 10,000 cubic feet of gas, three-quarters of a ton of smokeless fuel, 20 pounds or more of ammonium sulphate, 2 gallons of light oil, and from 4 to 9 gallons of tar. The carbon residue when briquetted furnishes a fuel approaching hard coal in value, and both it and the gas might be used for industrial and domestic purposes. Recoverable by-products that would find a local market are tar for road dressing, ammonium sulphate for fertilizer, and benzol for motor oil. Other by-products are toluol, essential in the manufacture of high explosives, dyes, and chemicals.

CHEMICAL ANALYSES

Many analyses of Matanuska coals have been published from time to time in the bulletins of the Geological Survey [75] and the Bureau of Mines,[76] and there are many analyses still unpublished. The following table gives analyses of coals from Chickaloon, Coal Creek, and Anthracite Ridge. A few analyses of samples from Eska and Moose Creeks, in the lower Matanuska Valley, and from the Nenana lignite field are also given for comparison, as all those coals are in direct competition among themselves for the markets made available by the Alaska Railroad.

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[75] U. S. Geol. Survey Bull. 500, pp. 90–92, 1912; Bull. 712, p. 137, 1920.
[76] Bur. Mines Bull. 123, pp. 24–28, 1918; Bull. 193, pp. 19–21, 1922.

Proximate analyses of coals from the Matanuska Valley and other fields in central Alaska

No. of sample	Locality	Laboratory No.	As received: Moisture	Air dried			Sulphur	Calorific value	
				Volatile matter	Fixed carbon	Ash		Calories	British thermal units
	Chickaloon:								
1	Tunnel 2	2227		19.6	74.6	4.9	0.6	8,260	
2	United States Navy Alaska Coal Commission tunnel B, lower No. 5 bed, crosscut connecting tunnels 2 and B	18148	1.96	19.56	70.89	9.55	.58	7,861	14,150
3	Same, upper 2 feet of 3-foot section of No. 6 bed	18143	1.89	20.87	76.06	3.07	.69	8,440	15,192
4	Same, No. 9 bed, face of tunnel	18150	2.64	18.5	60.96	20.54	.55	6,757	12,163
5	Same, fines from "Big Vein"	18042	2.21	21.22	70.49	8.29	.44	7,955	14,319
6	United States Navy Alaska Coal Commission tunnel D, E bed, near face	18046	2.6	22.05	66.82	11.13	1.51	7,618	13,712
7	United States Navy Alaska Coal Commission tunnel 3, No. 3 bed, 1 left gangway, 52 feet from mouth	18095	2.72	20.63	73.59	5.78	.69	8,151	14,672
	Coal Creek:								
8	United States Navy Alaska Coal Commission tunnel A, on west side of Coal Creek, No. 8 bed, face of 1 gangway, 50 feet from its mouth	18104	1.71	21.49	73.33	5.18	.47	8,271	14,888
9	Same, prospect drift 2, No. 4 bed, 43 feet from mouth	18096	2.35	20.83	65.73	13.44	.62	7,503	13,505
10	Same, 2-foot 4-inch cut of clean bright coal at bottom of bed	18102	2.03	22.05	71.12	6.83	.58	8,123	14,621
11	Same, bed 3, at 3,925 feet altitude	A3538	4.0	8.7	82.8	6.4	.5	7,594	13,670
	Anthracite Ridge:								
12	Outcrop on West Fork of Purinton Creek, at 4,240 feet altitude	A3539	3.2	8.1	85.8	4.2	.3	7,750	13,950
13	Same, bed 4, at 3,925 feet altitude	A3540	4.7	9.2	81.4	6.3	.6	7,372	13,270
	Eska, sec. 16, T. 19 N., R. 3 E.:								
14	David mine, David bed, 2 chute, 75 feet from mine mouth	28733	4.9	43.69	50.52	5.79	.55	7,614	13,705
15	Same, Maitland mine, Maitland bed, 2 chute or plane; represents 2 feet 10 inches of coal	28736	5.06	44.25	48.13	7.62	.46	7,464	13,435
16	Same, Emery mine, Emery bed, 1 chute, 60 feet from mine mouth	28735	5.43	41.38	48.36	10.26	.35	7,268	13,083
	Moose Creek:								
17	Premier mine, near top of chute at counter, about 250 feet below collar	A1962	5.8	40.0	50.7	6.5	.3	7,217	12,990
18	Same, Le Roy permit, Howard & Jesson mine, 390 feet from portal south	A1963	5.5	40.6	46.9	9.8	.2	6,839	12,310
19	Same, 400 feet from portal south	A1964	5.3	39.0	42.9	15.4	.2	6,239	11,230
20	Same, 415 feet from portal south	A1965	5.8	36.9	40.6	19.5	1.1	6,056	10,900
	Nenana field, Healy Creek:								
21	Roth mine	A1390	12.9	42.8	41.0	8.0	.3	6,250	11,250
22	Same, outcrop 1 mile above mouth of creek	26368	21.5	53.27	39.2	7.5	.3	6,073	10,931
23	Lignite Creek, SW. ¼ SE. ¼ sec. 30, T. 11 S., R. 6 W., B bed, outcrop from cliff on north bank of Lignite Creek; slightly weathered	26362	20.6	48.48	37.82	13.30	.24	5,644	10,159

1. Analyses by F. M. Stanton, U. S. Geological Survey coal-testing plant, St. Louis, Mo.
2-10. Analyses by U. S. Bureau of Mines, Bull. 123, pp. 24-28, 1918.
11-13, 17, 18, 20, 21. Analyses by U. S. Bureau of Mines (unpublished).
14-16, 22, 23. Analyses by U. S. Bureau of Mines, Bull. 193, pp. 19-21, 1922.

MINING CONDITIONS

The possibility of mining the Matanuska coal at a profit depends on a variety of factors, some of which are geologic and are discussed below, while others, such as the cost of labor and supplies, purchase or leasing charges, transportation, and markets, are economic and do not belong strictly within the province of this report.

The geologic factors that affect the possibility of mining include the character of the coal, such as its composition, heating power, firmness, smoking, and clinkering qualities, and coking or other special properties; the character of the coal beds, such as their thickness, persistence, freedom from partings and binders, and the nature of the roof and floor; the attitude of the coal beds, including their depth below the surface, steepness, and structural regularity; and the presence of extraneous detriments, such as intrusive rocks, water, gas, and dust.

A large number of these factors are variable within the field, either regionally or from bed to bed. These must be considered in detail, both locally and by beds, in connection with each proposed mining project, and they can not be the subject of a general discussion here. Others of these factors have already been considered in the preceding pages, so far as the available information permitted. There remain, however, several factors concerning which it is possible and desirable to present brief general discussions.

EFFECTS OF FOLDING AND FAULTING

Throughout the greater part of the Matanuska Valley the structural details are not known, but there are indications that complex structure is general. The steep dips and complex folding and faulting introduce serious problems in mining, as has been demonstrated at Chickaloon and at Coal Creek. There are probably large areas in which the structural conditions will make the mining of the coal difficult and expensive, and in some parts of the Anthracite Ridge and O'Brien Creek areas it may be practically impossible. In other areas the structure is probably simple enough to permit the mining of the coal, but it will probably be found that where the structure is simple the coal is of low grade.

The exposures on the north bank of the Matanuska from a point 1 mile above to a point 4 miles below the mouth of Gravel Creek show gently dipping regular beds. No large coal beds have yet been found there, but if coal exists in commercial quantities there should be no difficulty in mining it.

The hill north of Boulder Creek and immediately east of Chickaloon River is composed of gently dipping Eska conglomerate. If the coal beds persist beneath the conglomerate and if the coal-bearing rocks were not folded before the conglomerate was laid down, mining should not be difficult, at least so far as structural conditions are concerned. It should be remembered, however, that the vertical distance from the Eska conglomerate to the workable coal is not known and that the coal at this point may be at a prohibitive depth or under a prohibitive load.

Careful investigation of each tract should be made before the development of mines is attempted. In this way only can the feasibility of mining at a profit the coal of any particular tract be assured.

EFFECTS OF INTRUSIVE ROCKS

Intrusive rocks are abundant throughout the area of coal outcrops in the upper Matanuska Valley. The masses are large and numerous along the south front of Anthracite Ridge in the area of both the anthracite and the low-grade bituminous coal. The areal distribution of the larger of these intrusive masses is indicated on the map (pl. 2). Small dikes and sills, not represented on the map, are also present throughout practically all the coal areas. Where the intrusive rocks cut the coal beds the coal is rendered worthless for a distance of a few inches from the contact. The small dikes and sills, on account of the short distance to which their effect extends, do not affect the coal seriously, except that the sills show a habit of intruding the planes of the coal beds. It is clear that if a sill is intruded into a coal bed for a long distance a large amount of worthless coal will result; but if it is intruded between rock strata, even if only a few feet away from a coal bed, or if it cuts across the coal bed in the form of a dike, its effect on the coal will be slight.

A serious uncertainty is introduced into the engineering task of laying out a plan for economic mining by the possibility that extensive masses of hard intrusive rock may be encountered along the line of projected gangways and counters, not only replacing expected coal but necessitating either expensive removal or else a rearrangement of the mine plan. Such conditions have actually been met at Chickaloon and are to be expected elsewhere. They have a decided effect upon the cost per ton of the coal produced.

The larger intrusive masses are of much more serious importance than the small dikes and sills, first, because their size is of itself sufficient to reduce the coal areas considerably, and second, because each of them is likely to have sent off many apophyses in the form of sills in or along the surfaces of coal beds. The dimensions of these masses are, moreover, probably greater underground than at the surface. There may be also many intrusive masses that do not crop out but are near enough to the surface to be encountered in mining.

In conclusion, it must be stated that the presence of intrusive rocks in the coal field introduces factors that make an undetermined percentage of the coal areas of very doubtful value. The size and distribution of these intrusive masses beneath the surface, as well as at the surface in the areas of scanty outcrops, can not be determined without underground exploration. The effect of the smaller intrusive masses on the coal depends on the extent to which these masses have been intruded into or along the surfaces of coal beds. Where the intrusive mass is in contact with the coal the coal is worthless, but where it is a few feet away the quality of the coal is probably unimpaired or may possibly even be improved.

UNDERGROUND WATER AND GAS

In any large mines that may be opened in this region it will be necessary from almost the beginning of mining to pump or hoist mine water. It is not believed possible to open any large mines having natural drainage, but the amount of underground water encountered will probably not be great unless the mines are opened on the outcrop. Precipitation in this region is so slight that large amounts of water can get into the mines only from the streams; therefore if ordinary precautions are taken to prevent streams from breaking into the mine openings the workings ought to be fairly dry.

The heavy cover of gravel that exists at the lower altitudes throughout most of the Matanuska Valley may be a source of danger from water. Unless the depth of the gravel at different points and the shape of the underlying rock floor are determined by drilling the mine workings may break through the surface of the rock into the gravels. As the gravels in some places probably carry large amounts of water serious accidents might thus result.

Gas will probably be a serious problem in local mining from the very start. Experience in the tunnels at Chickaloon and at Coal Creek indicates that these coal beds will yield large amounts of dangerous gases. This condition necessitates adequate ventilation systems and the rigid enforcement of regulations in regard to open lights and the kind of explosives to be used in the areas that prove to yield explosive gases.

CHICKALOON AND COAL CREEK MINES

The only localities in the upper Matanuska Valley at which serious attempts have been made to mine coal are at Chickaloon and on Coal Creek, about 2 miles southeast of Chickaloon, on the south side of Matanuska River. The mines at Chickaloon were not operated in 1924, at the time the latest field work for this report was done, and the workings were inaccessible. The very brief reference here given to these mines is therefore not the result of original work for this report but is taken from the published statements of G. C.

Martin[77] and Theodore Chapin,[78] of the Geological Survey, and from the unpublished reports of Sumner S. Smith, supervisor of coal mining, of the Bureau of Mines, and of Capt. W. P. T. Hill, of the Navy Alaska Coal Commission. The report of Captain Hill includes carefully plotted geologic sections of all the workings of the Government-operated mines on Chickaloon and Coal Creeks up to the time these mines were closed, in the spring of 1922.

A plan and profile of the underground workings at the Chickaloon mine are given in Plate 15. Columnar sections of the strata penetrated by the tunnels are shown in Plate 14. A large amount of information was acquired by the opening of these mines, so that the underground character and structure of the coal beds in that vicinity are now known with some accuracy. A source of high-grade coal was needed, but in spite of a large expenditure of funds for the development of a source of such coal at Chickaloon, this mine could not be operated at a profit in competition with the lower-grade but more cheaply mined coals of the lower Matanuska Valley. The great deterrents to economical mining at Chickaloon were numerous faults and squeezes, irregular dip of the coal beds, and the presence of intrusive dikes that locally cut out the coal. All these things increase the cost of mining. There can be no question that there is a large tonnage of high-grade coal at Chickaloon. At a sufficiently high selling price it can be mined profitably. It so happens that the present market, which is confined largely to the needs of the Alaska Railroad and to the small industries and domestic requirements along the railroad, is more concerned with price than with quality and can be satisfactorily supplied with the more cheaply mined but poorer coals found in the lower Matanuska Valley and in the Nenana lignite field. Should an insistent demand arise for high-grade coal, such as steaming coal for the Navy or coking coal for metallurgical work, this coal will be mined, and the demand is likely to come when cheap fuel oil is no longer available on the Pacific seaboard.

At the same time that the Chickaloon mine was in operation an exploration and development campaign was carried on by the Navy Alaska Coal Commission on Coal Creek, about 2 miles southeast of Chickaloon, on the south side of Matanuska River. Several hundred feet of tunnels and airways were driven eastward from the bank of Coal Creek to explore the underground condition and character of the coal beds, and numerous diamond-drill holes and prospect pits were sunk on the high bench east of the creek to determine the extent of the coals in that direction. Although this work con-

[77] Martin, G. C., Geologic problems at the Matanuska coal mines: U. S. Geol. Survey Bull. 692, pp. 279–280, 1919.

[78] Chapin, Theodore, Mining developments in the Matanuska coal field: U. S. Geol. Survey Bull. 712, pp. 131–167, 1920; U. S. Geol. Survey Bull. 714, pp. 197–199, 1921.

COAL BEDS AND FOLDED COAL-BEARING ROCKS IN SOUTH FACE OF ANTHRACITE RIDGE

vinced those in charge that the Coal Creek area contains a few hundred thousand tons of high-grade bituminous coal, nevertheless here, as at Chickaloon, mining is complicated by numerous dikes and sills and by faults. As a consequence, mining costs at that time were too high to permit marketing this coal in competition with coal from Moose and Eska Creeks, farther west, and the mine was closed in 1922. Since 1922 some prospecting has been continued by private individuals on the extension of these same coal beds west of Coal Creek, opposite the Government workings, and a small tonnage of blacksmith coal has been produced.

CONCLUSIONS

There is no prospect that large-scale mining operations in the upper Matanuska Valley will be resumed in the near future on the bituminous coals either at Chickaloon or at Coal Creek. The present inactivity in this area must, however, not be taken to indicate that the upper Matanuska Valley does not contain valuable reserves of high-rank coal. The extensive explorations of the Navy Alaska Coal Commission at Chickaloon and at Coal Creek have proved beyond doubt that such reserves exist. The temporary cessation of mining is due solely to the fact that more cheaply mined coals, of somewhat poorer quality but nevertheless satisfactory for railroad and local industrial uses, are found in the lower Matanuska Valley. There is not sufficient demand for high-quality steaming and coking coal on the Pacific coast to insure profitable mining of these high-rank coals at this time. The abundant and cheap crude oil from the California oil fields at present holds the market for the high-quality fuel used by the Navy and merchant marine, as well as in many industries. For these uses the Matanuska coking coals can not compete with fuel oil at present prices. Many qualified judges believe that the abundant supply of cheap fuel oil on the Pacific coast can not last over any great stretch of years, and that with diminishing production of oil, or with expanding markets for oil, its cost will rise to a point where coal, even at a cost greater than that now ruling, can find a market. When that time comes there will be a renewal of interest in the coking coals of Alaska, and a stimulation of activity may come even sooner, if special demands for high-quality coal should develop that could not be supplied by fuel oil. In this connection mention should be made of possible competition from Australian coals, though the influence that foreign coals may have upon the development of the Alaskan coal fields can not yet be estimated.

It is pertinent to summarize here some of the factors that tend to increase mining costs in the upper Matanuska field. Mining at

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Chickaloon and underground exploration at Coal Creek have shown that the coal beds are only moderately persistent along the strike, pinching and swelling within short distances. Faults are common, and some are of large displacement. Dikes and sills intrude the coal measures and cause local deterioration of the coal or cut it out entirely. Most of the coal beds contain impurities, and the coal should be crushed and washed to reduce the ash content to a reasonable figure. Although many of the coal beds crop out at the surface, most of them dip at steep angles, and no localities have yet been found at which extensive workings can be developed above the outcrop so as to take advantage of the slope for natural drainage. It will therefore be necessary at most places to sink shafts, hoist the coal, and drain the mines by pumping.

The anthracite beds of Anthracite Ridge have not yet been explored sufficiently to justify any prediction about the possibilities of opening successful anthracite mines. The known area of anthracite is small, and it lies high on the slope of a mountain ridge, 2,700 to 3,000 feet above the level of Matanuska River and about 12 miles east of the terminus of the Chickaloon branch of the Alaska Railroad. Practically no development work has been done on this coal. From the natural surface exposures the structure of the coal beds is seen to be highly complex, with close folding and faulting (pl. 16) and with numerous large and small intrusive masses cutting the coal-bearing series (pl. 10, *B*). Apparently the coal lies in synclinal basins, most of the upper parts of the folds having been removed by erosion. The presence of workable bodies of anthracite coal can be proved only by extensive exploration, both on the surface and underground.

In spite of the above-enumerated factors that tend to increase the cost of mining, the important fact should be borne in mind that the coals of the upper Matanuska Valley are of unusually good quality, and, with the possible exception of coals from the Bering River field, are probably unequaled by any other coals on the Pacific slope of North America. They have a great advantage over any competitive coals in the length of haul necessary to land them at Pacific coast ports, and it may be confidently predicted that in time they will prove to be the source of a needed supply of high-grade fuel.

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