PRELIMINARY REPORT ON A DETAILED SURVEY OF PART OF THE MATANUSKA COAL FIELDS.

By G. C. Martin.

INTRODUCTION.

The purpose of this paper is to present briefly the more important practical results of a detailed geologic investigation of the area covered by the Chickaloon special map. This area includes the commercially more important part of the Matanuska coal fields, which is situated in the south-central part of Alaska about 30 miles northeast of the head of Cook Inlet.

The larger geographic and geologic features of the Matanuska Valley are described and all the information then available concerning the coal is given in earlier publications,[1] to which the reader is referred. The contents of this paper are but the summary of and the provisional conclusions from the results of the detailed investigations of 1910, which will subsequently be published in full.

GEOLOGIC OUTLINE.

GENERAL FEATURES.

Among the more important geologic results of this investigation is the acquisition of a considerable amount of new information concerning the local stratigraphic sequence. These facts will be presented in detail in the final report. The following table gives a summary of the geologic succession of the rocks in accordance with the new information:

[1] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, 36 pp. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, 71 pp.

General sequence of rocks in area covered by Chickaloon special map.

Age.	Character of rocks.	Thickness.
Quaternary.	Alluvium, terrace gravels, and moraine.	*Feet.* 0-300+
Pliocene (?).	Lavas, capping Castle Mountain.	800
	Intrusive rocks, mostly basic.	
Miocene (?).	Conglomerate, on Castle Mountain and Wishbone Hill.	3,000
Eocene.	Shale and sandstone, with coal beds.	2,000±
	Arkose, conglomerate, and shale, without known coal.	2,000±
Upper Cretaceous.	Sandstone and shale.	4,500±
Lower Cretaceous (?).	Limestone.	200±
Lower Jurassic.	Volcanic breccias, agglomerates, and tuffs.	1,000±
Early Mesozoic or older.	Granitic rocks.	
Paleozoic.	Gneissic rocks.	

CRYSTALLINE ROCKS BENEATH THE COAL.

The rocks grouped under this heading in this discussion and on the geologic map (Pl. VIII) include the gneissic and granitic rocks, the Lower Jurassic volcanic breccias, agglomerates, and tuffs, and the possibly Lower Cretaceous limestone represented in the general section above. These rocks are grouped together because of the facts that they are all known to be far beneath the coal and that none of them are individually of importance in a discussion of the coal.

Large bodies of gneissic and granitic rocks, which are intimately associated with one another and which have not been separated, occur in the Talkeetna Mountains and are present along most of the northern border of the area represented on the map.

Lower Jurassic volcanic breccias, agglomerates, and tuffs occupy an area east of Kings River along the northern edge of the area shown on the map, and are probably present also in the valley of Coal Creek. These rocks are overlain by a presumably Lower Cretaceous limestone which has been seen only along the northern border of the mapped area east of Kings River.

MESOZOIC SEDIMENTARY ROCKS.

The rocks included under this heading comprise the Upper Cretaceous shales and sandstones of the table on page 129. They apparently have a thickness of at least 4,500 feet. These beds lie beneath the coal-bearing rocks, and consequently the area occupied by them is barren of coal. It should be noted that the character and age of these beds were not recognized in the earlier investigations and that they are included in the areas mapped as Tertiary by Martin[1] and by Paige and Knopf.[2]

TERTIARY ROCKS.

The Tertiary rocks of the Matanuska Valley have been divided into three sedimentary formations and include also volcanic and intrusive rocks.

ARKOSE, CONGLOMERATE, AND SHALE, WITHOUT KNOWN COAL.

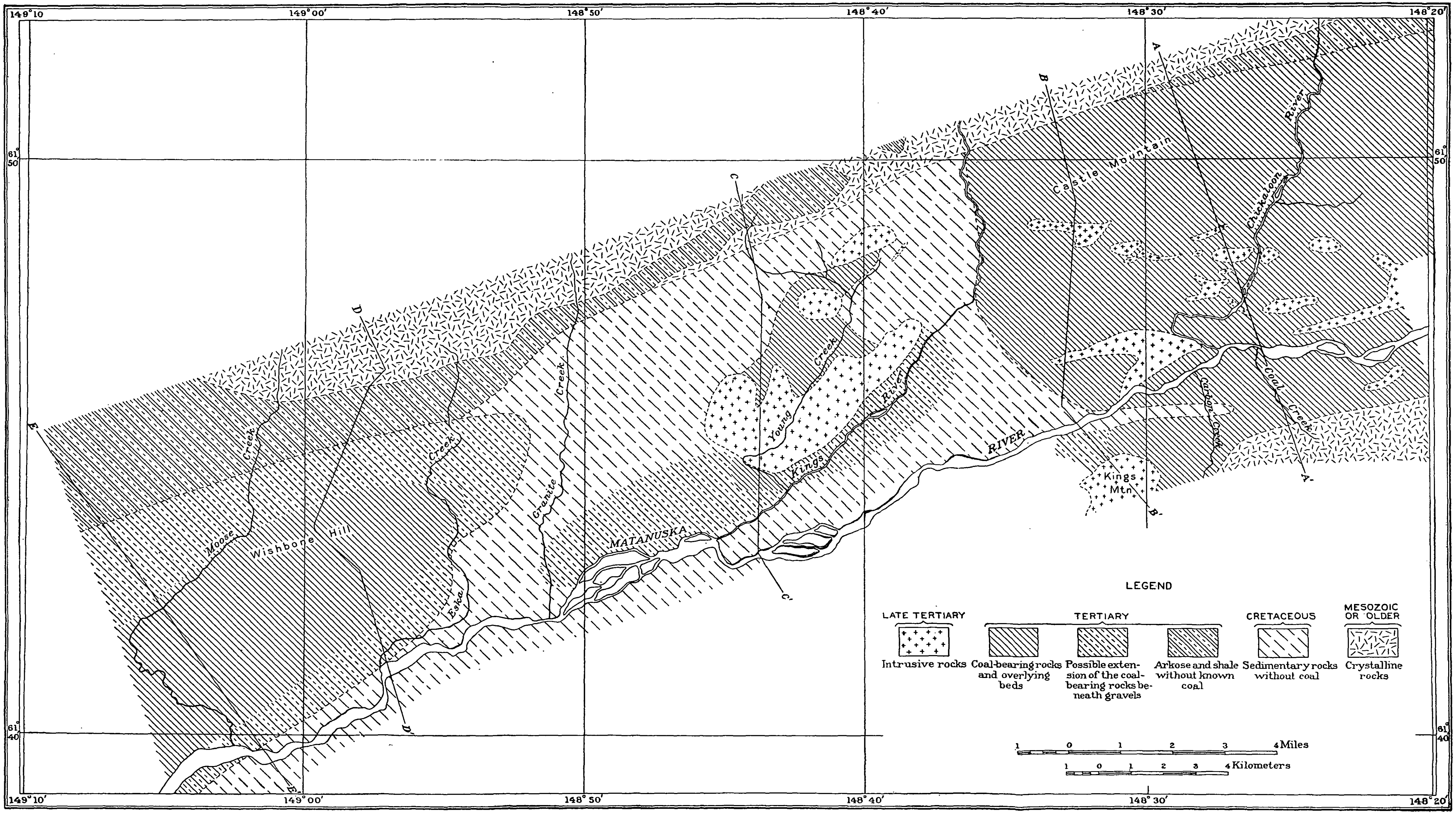
The basal division of the Tertiary consists of beds predominantly arkosic and well indurated, which occupy large areas along the northern border of the Matanuska Valley. These rocks are apparently without coal. They have been separated from the other Tertiary sedimentary beds described below on the basis of their predominantly arkosic character, greater degree of induration, and absence of coal. There is believed to be little doubt that these rocks are for the most part low in the local Tertiary sequence and include the basal beds, although there is a possibility that the assemblage represented on the map includes in part the marginal facies of some beds higher in the Tertiary, as well as higher beds not necessarily marginal but now occurring in structural zones in which they have been deformed to a degree not permitting their separation from the basal or marginal deposits. The thickness of these beds exceeds 2,000 feet.

COAL-BEARING ROCKS.

The coal beds of this district occur in a rather monotonous succession of shales and sandstones. The shales, which predominate over the sandstones in aggregate thickness, are gray to drab, rather soft and inclined to disintegrate on exposure, poorly bedded, and without well-defined joint planes. Most of the beds are rather gritty and vary in grain along the bedding. They contain many nodules and lines of nodules of iron carbonate, some of which form fairly persistent beds. The sandstones are yellowish, rather soft, of diverse grain in the different beds and of varying grain in the same bed, for the

[1] Martin, G. C., Geologic reconnaissance map of the Matanuska Valley: Bull. U. S. Geol. Survey No. 289, 1906, Pl. III.

[2] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance map of the Matanuska and Talkeetna region: Bull. U. S. Geol. Survey No. 327, 1907, Pl. II.



PRELIMINARY GEOLOGIC MAP OF PART OF THE MATANUSKA COAL FIELD.

most part feldspathic, and in general the individual beds are not very persistent. The thickness of the coal-bearing rocks is doubtful, but it appears to be at least 2,000 feet.

Fossil leaves are present in both shales and sandstones and are especially abundant and well preserved in the beds carrying iron carbonate.

The coal beds are numerous. There is no evidence as to their exact position within the formation or as to the persistence of individual beds or groups of beds.

The coal-bearing beds are overlain by conglomerates aggregating about 3,000 feet in thickness. These conglomerates are well exposed in the banks of Moose Creek; on Wishbone Hill, which is between Moose and Eska creeks; and on Castle Mountain and in the hills east of it. Since the coal-bearing rocks underlie the conglomerate, the areas of the conglomerate are included in the coal area as represented on Plate VIII and in the table on page 134, although there is no positive evidence as to whether workable coal is present in these areas.

The conglomerate is overlain unconformably on Castle Mountain by about 800 feet of volcanic rocks.

INTRUSIVE ROCKS.

Several large and many small masses of igneous rock have been intruded into the Tertiary beds in the valleys of Chickaloon and Kings rivers and elsewhere in the eastern part of this region. These intrusives are known in the valleys of Eska and Moose creeks only in the form of very small dikes and sills, except possibly on the northern border of the region. Gabbro, diabase, diorite, and several kinds of porphyritic and fine-grained rocks are known to be represented among these intrusives.

GRAVELS.

The Quaternary deposits of this region are of considerable diversity of character and cover broad areas. They include glacial morainic deposits, gravels laid down by glacial waters, terrace gravels more remotely connected with glacial agencies, and the alluvial deposits on the present flood plains.

The terrace gravels are of wide extent and thoroughly mask the underlying rocks up to an altitude of about 1,000 feet, except where the larger streams have cut gorges through the gravels. These gravels are of extreme importance in a consideration of the coal, because they conceal the underlying rocks over broad areas, thus making it very difficult to estimate the actual areas of coal lands or to determine the details of the stratigraphy and structure. The thickness of these gravels ranges from 300 feet or more down to the vanishing point.

COAL.

STRATIGRAPHIC POSITION AND SECTIONS.

The coal beds of the part of the Matanuska Valley here under discussion are all known to be of Tertiary age and to agree approximately in general stratigraphic position with the coal of the Kenai formation on Cook Inlet. They all occur within the middle local division of the Tertiary rocks as grouped in this report. Their exact position within this division has not been determined, but they seem to be in general distributed throughout the greater part of its thickness. Nothing definite is known concerning the persistence of individual beds or of groups of beds.

Detailed measurements of most of the known coal beds are available in previous publications,[1] to which the reader is referred for such information. The following sections record measurements of exposures which were not seen at the time the earlier work was done and represent practically all of the unpublished information relating to coal sections:

Section of coal bed on east bank of Coal Creek, about 1 mile above Matanuska River.

	Ft.	in.
Gray shale.		
Coal	4	7
Shale		2
Coal		3
Shale		½
Coal		8
Shale		1
Coal		7
Shale		2
Coal	1	7
Shale		1
Coal		11
Carbonaceous shale	2	5
Shale and coal, altered by intrusion		6
Total coal	10	7

Strike N. 67° E.; dip 65° NW.

[1] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska: Bull. U. S. Geol. Survey No. 289, 1906, pp. 18-25. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 43-56.

Section of coal bed on north face of Red Mountain, elevation 3,600 feet (about 4 miles north of mouth of Young or Little Kings Creek or 3.4 miles west of U. S. L. M. No. 1).

	Ft.	in.
Shale with ironstone nodules.		
Coal, exposure obscure and thickness estimated	7	5
Shale		1½
Coal [1]	1	2
Shale		1
Coal [1]		6
Shale		1½
Coal [1]		7
Shale		¾
Coal [1]		4
Shale		½
Coal [1]		2
Shale		¾
Coal [1]	2	
Total coal	12	2

Strike N. 67° E.; dip 54° SE.

Another coal bed at least 5 feet and possibly 10 feet thick is poorly exposed about 30 feet stratigraphically above this, the intervening rocks being shale with ironstone nodules and sandstone. About 30 feet higher another bed of unknown thickness is present, and 50 feet still higher the smut of another bed was seen.

The presence of coal at this locality adds a hitherto apparently unknown coal area to the Matanuska fields.

Section of coal bed on east bank of Moose Creek, 4.1 miles north of its mouth.

	Ft.	in.
Carbonaceous shale with ironstone nodules.		
Carbonaceous shale with seams of bony coal	1	
Coal		7
Bone and shale		1
Coal		10
Bone		2
Coal		9
Shale with coaly streaks	7	
Coal	1	
Shale		1½
Coal		3
Shale		½
Coal	1	5
Bone		1
Coal		10
Nodular shale.		

Strike N. 65° E., dip 80° SE.

[1] Included in sample No. 11382F, p. 138.

COAL AREAS.

EXTENT.

The areal extent of the assemblage of rocks which carry the coal is indicated on the geologic map (Pl. VIII). The map shows also by a separate pattern the areas which may be underlain by these rocks but in which the lack of exposures caused by the presence of gravels on the surface or the indefiniteness of lithologic character of the exposed rocks makes it uncertain whether the coal-bearing rocks are present. These are the areas which may carry coal as distinguished from the areas which are known not to carry coal, represented by other patterns on the map. The areas of the "coal-bearing rocks" can not be assumed to be underlain wholly by beds of coal of workable character and thickness. Moreover, parts of these areas may have no coal under them. The lack of knowledge as to the exact stratigraphic position of the coal beds, the uncertainty as to what stratigraphic part of the "coal-bearing rocks" is represented by the various surface outcrops, and the concealment of the rocks by gravels over broad areas make the precise areal distribution of the coal a problem which can be solved only by drilling or other underground exploration.

The areas of the tracts which it is believed may possibly contain workable coal are indicated in the following tables. The first of these tables shows the areas known to be occupied by the "coal-bearing rocks," as defined above, and by the conglomerates and other beds which overlie them. The second table shows the areas which may also be underlain by these rocks but in which, because of concealment by gravels or because of other lack of definite information, there is a possibility that other formations may be present. These estimates are provisional and may be revised when the field notes are fully worked up.

Areas of supposed coal-bearing rocks.

	Square miles.
Valleys of Chickaloon and Kings rivers	44
South of Matanuska River, between Kings Mountain and eastern edge of area shown on Chickaloon special map	8
Valley of Young Creek	3
Valleys of Moose and Eska creeks	19
	74

Areas of possible extensions of supposed coal-bearing rocks.

	Square miles.
Lower parts of valleys of Kings and Granite creeks	8
Valleys of Moose and Eska creeks	16
	24

STRUCTURAL CONDITIONS.

It is not practicable in this brief report to present an adequate discussion of the structure of this region. This will necessarily be left for the detailed report. The general character of the structure is indicated in the sections on Plate IX. The coal-bearing rocks, like most of the other rocks of this region, have been strongly folded so that steep dips and complex structures are present throughout most of the area. In places there is a continued uniform dip for considerable distances, as is shown in section A–A′, Plate IX, but it is not known whether this condition means simple monoclinal structure or a repetition of parallel fault blocks. At other places there are frequent reversals of dip, but these may be due either to simple folding or to more complex faulting. In each of these cases the lack of definite knowledge concerning the type of structure is due to the absence of recognized characteristic strata from the distribution of which the actual structural details could be inferred.

In two areas within the field the type of structure is known with a fair degree of certainty. These areas are the ones occupied by the conglomerate in the vicinity of Castle Mountain and of Wishbone Hill. Here the clearly defined contacts of the conglomerate with the adjacent rocks, as well as the numerous individual beds of conglomerate, make it possible to determine the actual structural details.

The western end of Castle Mountain (see section B–B′, Pl. IX) is a monoclinal block having a dip of about 6° to 20° NE. The eastern end (shown in section A–A′, Pl. IX) is a syncline having a broad southern limb on which the dips range from 10° to 20° N. and a narrow, sharply upturned northern limb with dips of 60° to 90°. Possibly the northern limb of this syncline is cut off in the western part of the mountains by a fault, or on the other hand the structure may be dominantly monoclinal with local upturning of the strata along the fault in the eastern but not in the western part of the mountain.

Wishbone Hill is in general structurally similar to Castle Mountain. The eastern end (shown in section D–D′, Pl. IX) is a syncline pitching sharply toward the west. The western end is likewise synclinal, but the northern limb of the syncline has been cut by a fault in the western end of the hill and in the valley of Moose Creek, as is shown in section E–E′, Plate IX, so that the conglomerate mass as exposed on Moose Creek shows dominant northward dip and but for a few exposures showing gentle southward dip would appear to be a monoclinal block.

The points of dissimilarity between Castle Mountain and Wishbone Hill are that on Castle Mountain the entire northern edge is bounded by a fault which has brought the arkosic rocks beneath the coal into contact with the conglomerate above the coal, whereas on Wishbone Hill the fault is possibly absent at the east end so that the coal-bearing rocks encircle the end of the conglomerate mass, and at the west end the fault is not of sufficient magnitude to bring more than the coal-bearing rocks into contact with the conglomerate. The syncline at the east end of Castle Mountain pitches toward the east, whereas the one at the east end of Wishbone Hill pitches toward the west.

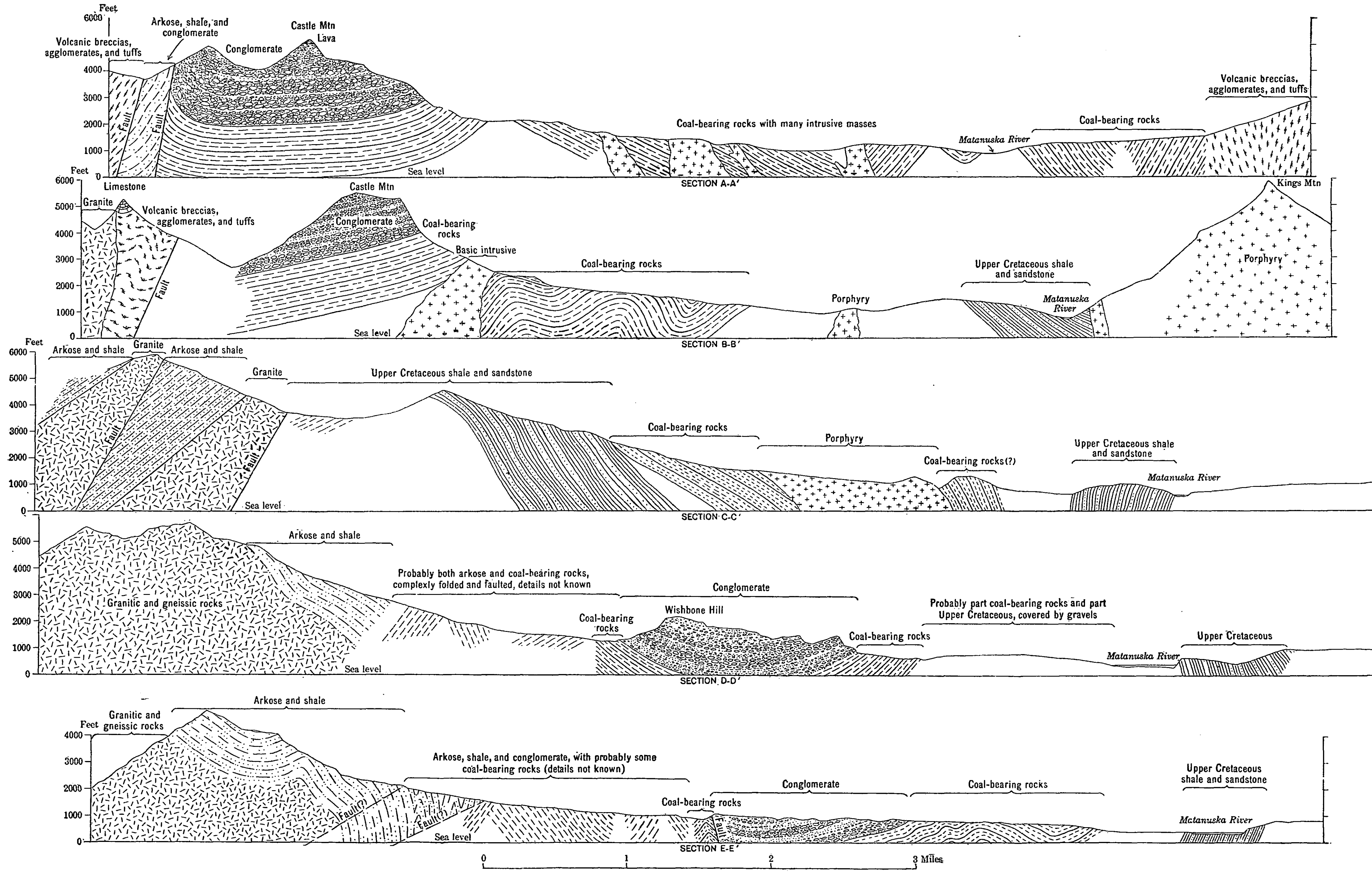
Both Castle Mountain and Wishbone Hill are of fairly simple structure, so that if the coal beds persist beneath the conglomerate, and if the coal-bearing rocks were not folded before the conglomerate was laid down, mining should be simple, at least as far as structural conditions are concerned.

It may perhaps be considered probable that the structures of the entire valley are of the same general type as those known in the areas of the conglomerate. If this is the case, there are probably large areas in which structural conditions will permit the mining of the coal. This condition can not, however, be definitely assumed to exist, and the character of the structure must be regarded as a problem to be solved by underground exploration before the feasibility of mining at a profit the coal of any particular tract can be demonstrated.

EFFECT OF INTRUSIVE ROCKS.

Intrusive rocks are present in abundance and in large masses throughout the greater part of the area of coal-bearing rocks except in the valleys of Moose and Eska creeks, where they are small and are much less numerous than farther east. The areal distribution of the larger of these intrusive masses is indicated on the map (Pl. VIII). Small dikes and sills, not represented on the map, are also present throughout practically all the coal areas. Where the intrusives 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, would not affect the coal seriously, except that the sills show a habit of seeking coal beds for their planes of intrusion. 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, whereas if it is intruded between rock strata, even if only a few feet away from the coal bed, or if it cuts across the coal bed in the form of a dike, its effect on the coal will be slight.

The larger intrusive masses are of much more serious importance than the small dikes and sills, first, because their size is sufficient to reduce the coal areas very 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 beneath the surface of the ground than at the surface. There may also be many intrusive masses which do not outcrop but which are near enough to the surface to be encountered in mining.



STRUCTURE SECTIONS IN THE MATANUSKA VALLEY.

In conclusion, it must be stated that the presence of intrusive rocks in the coal field introduces factors which make an undetermined percentage of the coal areas of very doubtful value. The actual 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 have been intruded into or on the surfaces of coal beds. Where the intrusive mass is in actual 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 even may be possibly improved.

CHARACTER OF THE COAL.

The physical and chemical properties of the coal have been fully discussed in previous publications. This discussion will not be repeated in detail here. It is sufficient to state that the coal on Chickaloon and Kings rivers and on Coal Creek is high-grade bituminous and is probably at least in part coking coal, whereas that in the western end of the district, namely, on Moose, Eska, and Young creeks, is low-grade bituminous and is probably all noncoking coal. The anthracite described in earlier publications [1] is not known within the area here described but lies farther east.

The following table includes characteristic analyses from different parts of the area. The analysis of sample No. 11382F was taken during the investigations here described. The other analyses have been published in Bulletins 289 and 327 and represent samples collected in 1905. All the samples except Nos. 2215 and 2227 are from surface prospects or from outcrops and are consequently somewhat weathered. Samples 2215 and 2227 are from a tunnel at a distance of 43 to 58 feet from the mouth and probably under about 25 or 30 feet of cover.

[1] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska: Bull. U. S. Geol. Survey No. 289, 1906, pp. 18-19, 26-30. Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907, pp. 52-56, 59-62.

Analyses and tests of Matanuska coal (samples as received).

Locality.	Laboratory No.	Thickness in feet.	Loss on air drying.	Proximate.				Ultimate.					Heating value.	
				Moisture.	Volatile combustible.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Chickaloon River, tunnel No. 2[a]	2215	12.3	1.60	2.55	16.66	69.72	11.07	0.57	4.19	76.58	1.37	6.22	7,545	13,581
Chickaloon River, tunnel No. 2, selected sample[b]	2227	5.2	(c)	.99	19.03	75.19	4.79	.60	4.71	83.90	1.48	4.52	8,205	14,769
Coal Creek[d]	2217	5.0	.80	1.97	18.58	75.19	4.26	.50	4.80	82.79	1.79	5.88	8,146	14,663
Kings River[e]	2218	9.9	1.80	2.68	20.69	64.72	11.91	.59	4.68	74.38	.87	5.77	7,422	13,360
Red Mountain[f]	11382F	12.2	6.10	10.57	33.80	50.57	5.06	.23	5.41	65.16	1.13	23.01	6,236	11,225
Eska Creek[g]	2226	2.6	(c)	4.74	34.79	54.06	6.41	.42	5.54	71.06	1.60	14.97	6,985	12,573
Eska Creek[h]	2224	3.3	(c)	5.00	33.90	50.65	10.45	.41	4.77	63.59	1.38	19.40	6,338	11,408
Moose Creek[i]	2225	6.0	(c)	4.75	32.64	50.63	11.98	.38	4.76	64.09	1.09	17.70	6,428	11,570
Moose Creek[j]	2221	11.7	4.60	9.49	33.63	51.71	5.17	.25	5.52	65.85	1.20	22.01	6,445	11,601

[a] Bull. U. S. Geol. Survey No. 289, p. 21, sample No. 2.
[b] Idem, p. 21, sample No. 3.
[c] Not determined.
[d] Idem, p. 20, sample No. 9.
[e] Idem, p. 23, sample No. 13.
[f] This bulletin, p. 133.
[g] Bull. U. S. Geol. Survey No. 289, p. 23, sample No. 18.
[h] Idem, p. 24, sample No. 19.
[i] Idem, p. 25, sample No. 20.
[j] Idem, p. 25, sample No. 21.

A RECONNAISSANCE OF THE WILLOW CREEK GOLD REGION.

By Frank J. Katz.

INTRODUCTION.

Placer prospects were found in the Willow Creek region in 1898. Up to 1906 efforts seem to have been directed mainly to the development of the placers of Grubstake Gulch and Willow Creek. So far as the writer has been able to find out the first quartz-lode location was made in 1906 on the ridge between Willow Creek and Fishhook Creek. This was followed in 1907 by other locations on Fishhook and Willow creeks. In 1908 the field was extended on the west by locations on Craigie Creek, and in 1909 by locations to the north and east of Fishhook Creek, around the head basins of Archangel Creek, and on the mountain between that creek and Little Susitna River. Altogether some 60 claims are being developed and several other prospects have been located.

In September, 1906, Paige and Sargent, of the Geological Survey, visited Willow Creek in the course of a general reconnaissance of the Talkeetna region. Paige's descriptions of the geology and placer mining were published in 1907.[1] In September, 1910, after finishing the season's work with G. C. Martin in the Matanuska coal field, the writer, accompanied by Theodore Chapin, spent four days in the Willow Creek region. The observations made and the information collected by them are embodied in this report.

GEOGRAPHY.

Location and area.—The Willow Creek gold field is included in an area 10 miles square which lies in about longitude 149° 20′ west and latitude 61° 50′ north. It is approximately 20 miles northeast of Knik, a settlement on Knik Arm of Cook Inlet. The field occupies the southwestern part of the Talkeetna Range.

[1] Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna basins, with notes on the placers of the adjacent region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 104-125; Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, 1907.

Topography and drainage.—The region comprises the divide between Little Susitna River and the south fork of Willow Creek and is divisible into a northern and a southern part. The northern part is a high, rough mountain mass, whose 6,000-foot summit is sometimes locally spoken of as "the Pinnacle," from which radiate the headwaters of Willow Creek and the western tributaries of Little Susitna River. The southern portion is a somewhat lower and less rugged ridge, called Bald Mountain, lying between the lower courses of Willow Creek and Little Susitna River.

From the central northern mountain Purches Creek, Craigie Creek, and the creek known as the "head of Willow Creek" flow west, southwest, and south-southwest, respectively, to Willow Creek. Fair Angel Creek and Fishhook Creek head against the same mountain and flow southeast and south, respectively, to Little Susitna River. Little Susitna River flows south along the eastern part of the region to the Matanuska Valley and turns west, following the base of Bald Mountain and receiving from it many small tributaries.

The important streams of the northern part of the district are Archangel Creek, with its branches, and Fishhook Creek, which are tributary to Little Susitna River, and Craigie Creek, the "head of Willow Creek," Grubstake Gulch, and Wet Gulch, tributary to Willow Creek. Archangel Creek is a westerly tributary of Little Susitna River. About 1½ miles above the river it forks. The northern branch is known as Reed Creek and the eastern as Fair Angel Creek. Fair Angel Creek heads in several cirques on the east and northeast side of "the Pinnacle." It is about 2½ miles long and has a southeasterly course. Its basin is U-shaped and from 2,400 feet to 3,400 feet in altitude. Fishhook Creek is south and west of Fair Angel Creek. It flows south about 3 miles from a large compound cirque on the south of "the Pinnacle" and then bends sharply east to Little Susitna River. It occupies a U-shaped basin from 2,000 feet to 4,000 feet high and hangs about 300 feet above Little Susitna River. The "head of Willow Creek" is west of Fishhook Creek and occupies a glacial trough 3,000 to 4,000 feet high and about 2 miles long. It flows southwest to Willow Creek (south fork) proper, which flows west. Craigie Creek has a U-shaped valley west of the head of Willow Creek. Its basin is from 2,500 to 3,500 feet high and about 5½ miles long, directed toward the southwest. It hangs about 400 feet above Willow Creek.

The ridges between these streams are narrow, high, and rugged, with steep, craggy upper slopes. Between the head cirques are very sharp arêtes.

In the southern part of the district the important streams besides Willow Creek and Little Susitna River are those in Grubstake Gulch and Wet Gulch, tributaries of Willow Creek. These gulches are glaciated basins about 3 miles long, heading against the north side of the summit of Bald Mountain. There are four minor streams on the north side and a dozen or more small gulches on the south side of this ridge.

Climate.—There are no recorded observations on the climate of Willow Creek region. It may be said, however, that conditions are in general the same as in the lower Matanuska [1] and Susitna basins, with perhaps a slightly heavier precipitation and shorter summer. In 1910 snow lay on some of the prospects at high altitudes, delaying development work until August.

Water supply.—There is little perennial snow in the district, yet considerable ice persists in the broken rock and talus of the higher mountains. From these sources the streams in the northern part of the region were kept high enough during the dry 1910 season to run such small mills as have been erected. Craigie, Willow, Fishhook, and Fair Angel creeks appear to have during the summer sufficient volume and fall to run prospecting and small development mills for the claims located on them. Large power development is possible at the canyon of Little Susitna River, which is less than 10 miles from the farthest prospect.

For the hydraulic placer mining on Grubstake Gulch the creek has in ordinary years furnished ample water, in rainy years more than could be handled, but in an exceptionally dry season it has failed.

Timber.—In the Willow Creek basin there are no trees above the mouth of Grubstake Gulch and no good spruce above the mouth of Wet Gulch. On Little Susitna River good spruce is about a mile below the mouth of Fishhook Creek. The lumber supply is plentiful and good in the lower parts of the Willow Creek and Little Susitna River valleys. The heads of the streams at the prospects are devoid of alders and willows. The gold-quartz prospects are 4 to 8 miles from building and mine timbers, and even brush for fuel must be hauled or packed at least half that distance.

The Matanuska coal field, which is 25 to 50 miles by trail from the Willow Creek prospects, has furnished forge coal and is a prospective source of fuel for the region. Lignite is reported nearer by, on lower Willow Creek.

Routes.—There are three routes from Knik to the Willow Creek district. One trail which is used only in the winter goes north from Knik around the western end of Bald Mountain to and up Willow Creek. By this route it is about 30 miles to the mouth of Craigie Creek. The old summer trail to Willow Creek takes a northeasterly direction through Cottonwood to Bald Mountain, crosses Bald Mountain at an altitude of 3,400 feet, and goes down Wet Gulch to Willow

[1] Martin, G. C., Reconnaissance of the Matanuska coal field, Alaska, in 1905: Bull. U. S. Geol. Survey No. 289, 1906, pp. 7-8.

Creek. This route is about 26 miles. The third route is a fair wagon road which can be used throughout the year. It leaves the winter trail near Knik and strikes northeasterly across the lowlands to Little Susitna River. It crosses to the west bank and follows up the river to the mouth of Fishhook Creek. The distance is 28 miles. The usual route traveled from Knik to Fishhook Creek in summer follows the old Willow Creek summer trail to the wagon road and then the wagon road. There are trails from Willow Creek at Wet Gulch to and up Craigie Creek, to Grubstake Gulch, and up to the head of Willow Creek. From the head of Willow Creek a trail crosses the divide between Willow and Fishhook creeks through a saddle somewhat lower than 4,000 feet. From the mouth of Fishhook Creek trails lead up Fishhook and to the head of Fair Angel Creek.

GEOLOGY.

The distribution of the rocks, which is shown on the accompanying sketch map (fig. 18), may be summarized as follows:

A line drawn west from the pass between Willow and Fishhook creeks and along the north side of Willow Creek marks the contact of a large area of quartz diorite on the north and mica schists on the south. North of Willow Creek the country rock, which is locally called granite, is light colored, of granitic texture, and composed of feldspar (chiefly plagioclase), quartz, hornblende, and biotite. It is uniform in composition and texture. Quartz diorite is scientifically a more accurate name for the rock than granite. There are a very few basaltic (diabase?) and aplitic dikes of small size cutting the quartz diorite. South of the quartz diorite as far as the summit of Bald Mountain and west of Little Susitna River the rocks are thoroughly foliated mica schists. The schistosity has a prevailingly southward dip. Quartz stringers are commonly seen in these schists. On the south flanks of Bald Mountain and the mountain opposite it east of Little Susitna River are Tertiary arkoses, sandstones, and shales. Along the northern limit of the Tertiary area some of the arkoses, which are sedimentary rocks composed of disintegrated granitic material, so closely resemble the granite or diorite adjacent to them that their differentiation in the field requires considerable care. A narrow tongue of granitic rocks appears to lie along the top of Bald Mountain between the Tertiary sediments and the schists. The Tertiary sediments lie unconformably with southerly dip on the quartz diorite east of Little Susitna River and are probably in like relationship on Bald Mountain. The quartz diorite appears to be intrusive into and largely to surround the schists. A small amount of basalt was noticed on the summit of Bald Mountain west of the head of Wet Gulch.

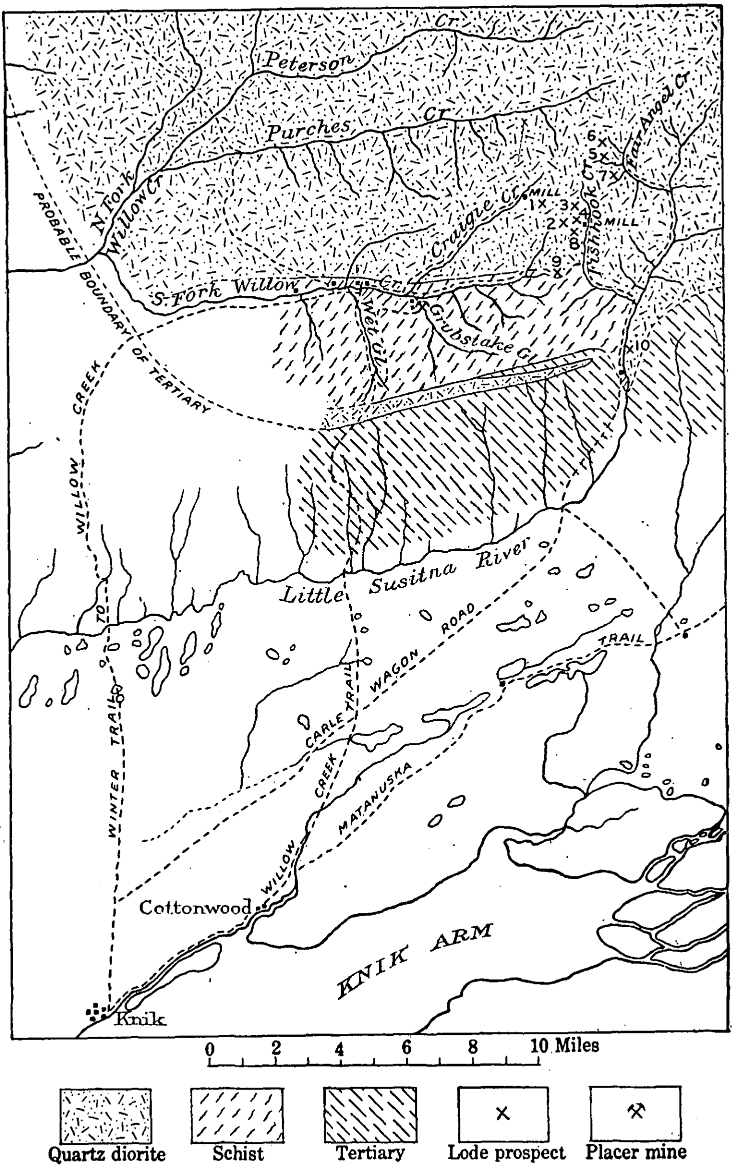


FIGURE 18.—Geologic sketch map of Willow Creek region.

1. Gold Bullion Mining Co.
2. Brooklyn Development Co.
3. Gold Quartz Mining Co.
4. Free Gold Mining Co.
5. Matanuska Gold Mining Co.
6. Conroy & Marrion group.
7. Fiske & Reed group.
8. Bartholf-Isaacs group.
9. Lydell prospect.
10. Miller prospect.

Recent glacial and stream deposits are present in all the valleys. Terraced gravel benches line the lower portions of Willow Creek and Little Susitna River.

MINERAL RESOURCES AND MINING DEVELOPMENT.

INTRODUCTION.

The mineral resources of the Willow Creek region are gold placers and gold-bearing quartz lodes. In 1906 Sidney Paige, of the United States Geological Survey, spent two days on Willow Creek and in its vicinity. Descriptions of the gold placers as then developed have been published in the reports by Paige and Knopf.[1] The gold lodes of the region had not been examined by the Geological Survey prior to the visit upon which the present report is based. Such information as could be gathered from reliable reports of prospectors and others interested in the region was summarized and published by Brooks.[2]

GOLD LODES.

GENERAL DESCRIPTION.

As the writer's time in the Willow Creek region was limited to four days, only the more developed prospects were visited. The following account is therefore incomplete.

The important prospects all lie north of Willow Creek in the area occupied by quartz diorite. In this area there are a few small dikes of diabase and aplite. At one prospect only are dikes (aplite) intimately associated with the ore body. The quartz diorite throughout the region is very much jointed. The most prominent and also the dominant systems of joints, which strike N. 40° W. (dip 20° to 40° SW.) and N. 30° E. and N. 60° W. (nearly vertical),[3] cut the rock into huge rhombohedral blocks that form a striking feature in the topography. At higher altitudes the rock does not decompose and disintegrate. Denudation appears to be largely accomplished by the dislodging of joint blocks. The quartz diorite mountains everywhere in the Willow Creek region and as far back as one can see into the Talkeetna Range are consequently marked by peculiar blocky or tilted steplike forms. Single fissure planes are visibly traceable for long distances. Movements along these planes are here and there indicated by slight crushing and slickensiding and do not appear to be important except in so far as they opened the fissures.

The ore bodies of the region, with the exception to be noted below, are quartz fillings in fissures having as a rule sharply defined walls, there being commonly from a small fraction of an inch to 2 or 3 inches

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[1] Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna basins, with rnotes on the placers of the adjacent region: Bull. U. S. Geol. Survey No. 314, 1907, pp. 116–118; Geologic econnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. U. S. Geol. Survey No. 327, pp. 65–67.

[2] Brooks, A. H., The mining industry in 1909: Bull. U. S. Geol. Survey No. 442, 1910, pp. 35–36.

[3] These directions are approximate only and are referred to the magnetic north, declination 28° 38′ E. at Knik, 1906.

of clayey decomposed diorite along the quartz. Many narrow quartz-cemented breccias of the wall rock have been found along or within the veins. The quartz is white and bluish gray, in many places banded and giving evidence of having been broken and recemented along planes roughly parallel to the walls. The veins lie for the most part along fairly regular plane fissures that are persistent, so far as present developments establish absolutely, through several hundred feet, and some are reported to have been traced for several thousand feet. There are also quartz veins or stringers in irregular, less persistent small fissures which are being prospected. These veins are from 1 or 2 inches to 4 feet in thickness. The smallest one which has been located as a "lode," so far as the writer saw them, is 16 inches thick. With few exceptions within the region proper the veins strike nearly northwest with moderate southwest dip.

There is little visible mineralization in most of the quartz. Much pure-white quartz not only assays high but will yield colors on panning. Considerable quartz with abundant visible gold has been found. Here and there on the veins of all the prospects examined minute and sparsely scattered specks of pyrite and other undetermined minerals were found. Tellurides have been reported by several of the operators. However, in none of the material seen by the writer was the supposed telluride mineral sufficient in amount or in grains large enough to be recognized. The surface material is all very slightly porous and rusty. The Geological Survey has made no assay of these ores. The gold content of these veins, as indicated by mill tests and assays reported by the prospectors and owners, is very high. The superintendent of the Gold Bullion Co.'s plant reports $35,375.54 received from 226 tons. Most of this was free-milling gold. High values are reported in concentrates and tailings. Reports of assays of individual samples from other prospects indicate values between $30 and $40 a ton and higher, and all are free milling. All the material thus far examined is from the surface or from points less than 150 feet from the entrance of the adits.

The foregoing discussion applies to the quartz diorite area where quartz lodes are being developed. In the adjoining schist area, particularly on Grubstake Gulch, are gold placers. Concerning the origin of the placer gold, Knopf and Paige in the reports cited state:

> The origin of the gold may be ascribed with certainty to the abundant quartz stringers in the mica schists. The coarseness and roughness of the gold suggest a near source of supply. * * * The fact that placer gold has not been found in paying quantities where streams have headed in granitic or other crystalline rocks bears out this statement.

Recent developments have thrown no light on this problem. It is still true that there are no paying placers in the area of granitic rocks which contains the quartz lodes of the region, but the valleys of that area are heavily strewn with coarse glacial débris, are farther from timber than Grubstake Gulch and hence are not attractive to the placer miner; furthermore, the prospectors' attention has been concentrated on the lodes. The writer, however, believes that the above quotation ascribes the origin of the placer gold to a source which is not inadequate.

It appears, then, that besides the occurrence of gold in the diorite in veins, large and persistent enough to make workable lodes, gold may also occur in the schist in rather widely distributed small bodies which yield placers.

DESCRIPTION OF THE PROSPECTS.

Craigie Creek.—The Gold Bullion Mining Co. is developing a group of five claims near the summit of the ridge on the south side of Craigie Creek about 5 miles from the mouth of the creek. The lode lies at an altitude of about 4,500 feet, or roughly 1,500 feet above the valley bottom. The mountain slope below the prospect is mantled by glacial débris and talus which contains a great deal of vein quartz in large and small pieces. At and above the prospect there is some talus and the bedrock is considerably disrupted, disturbed, and loosened by weathering (chiefly frost heave). The development work has consisted largely of cleaning out the loosened surface material in order to uncover the lode in firm bedrock. The quartz sorted out in this work has constituted the larger part of the "ore" handled. Through a distance of 3,000 feet several patches of gold-bearing quartz have been encountered. The vein or veins are about 2 feet to 2½ feet thick. Two open cuts and a short adit have been made which show such veins, but all of these were more or less obscured at the time of the visit. A breakdown of the aerial tram had stopped work for about a month and the openings had been permitted to become covered by slide. It seems that the openings are along a single vein or vein zone whose outcrop has an east-west (magnetic) trend and low dip to the south, but this has not been definitely established by the workings.

The ore is quartz in which a little free gold and small specks of sulphides are visible. The quartz is dominantly white but in some places slightly rusty and in others bluish. In some pieces quartz diorite was seen "frozen" to the quartz, but in general both the quartz and the quartz diorite are crushed and seamed parallel to the walls and there is some slickensiding and gouge along the walls.

The Gold Bullion Mining Co. has erected a 2-stamp mill, capacity about 6 tons a day. The mill is run by water power, amply sufficient for five more stamps, which the company intends to install during the winter of 1910–11. A light aerial tram was used to bring the ore down over the high steeper slope of the mountain, below which the ore was dragged in stone boats for about 100 yards by horses. All wood for building, timbering, and fuel must be either dragged or packed by horses from at least 6 miles below the mill.

Willow Creek.—The Brooklyn Development Co. has 11 claims in and around the basin at the head of Willow Creek. Development work has been confined to one of the claims near the summit of the ridge on the east side of the basin. Here there are three small cuts and an adit 150 feet long. The quartz diorite is much broken up by joints striking from N. 40° W. to N. 65° W. with dips southeast from 23° to nearly vertical. Along the fractures the quartz diorite is much crushed and weathered to clay. Quartz lenses and stringers of small size were seen in the fractured quartz diorite shown in the cuts and in the adit. On the dump at the adit larger chunks of quartz indicated that a vein had been cut (probably near the entrance and now covered by timbering so that it was not seen). This quartz is rusty and shows small scattered specks of pyrite and galena(?). It is reported that the adit was started on a vein with low dip which carried it above the adit. At a number of points along the adit the quartz diorite is fractured, crushed, and much decayed. There are small quartz veins in these fractured parts. The reported values are high.

Fishhook Creek.—The Alaska Gold Quartz Mining Co. operates a group of claims, locally known as the Carle prospect, on the Fishhook Creek side of the ridge between Willow and Fishhook creeks about 3½ miles above the mouth of Fishhook Creek. The prospect is on the steep wall of a small cirque several hundred feet above the level of the main valley floor. The prospect is a quartz vein which has been exposed by stripping the débris along the face of the mountain through 300 or 400 feet. An adit has been driven 150 feet on the vein.

The vein strikes approximately N. 52° W. (magnetic) and dips 24° SW. It is not perfectly plane and its thickness is slightly variable but averages about 2 feet. At 147 feet from the entrance the vein is broken by a dip fault of large hade and 4-foot throw.

The quartz is in part banded, white, gray, and dark bluish, carrying scattered minute sulphides (?), and in part very white, massive, and free from visible mineralization. The walls are sharply defined and generally smooth, with a gouge or clay from a small fraction of an inch to 2 and 3 inches thick. Along the borders of the vein are numerous angular fragments of granite, commonly very much decomposed, included within the vein filling.

All parts of this vein are reliably reported to yield free gold by panning.

Besides stripping between 300 and 400 feet along the outcrop and driving an adit 150 feet on the vein, the company has put up, on Fishhook Creek, a small water-power 2-stamp prospecting mill without concentrators and has built a trail over the steep mountain face between the prospect and the mill.

Adjoining the Carle prospect on the south and the Brooklyn Development Co.'s property on the east is the Thomas prospect. This is operated by the Free Gold Mining Co. At about the same altitude as the Carle a vein of quartz has been stripped for 500 feet or so along its outcrop. The vein, which strikes N. 40° W. (magnetic) and dips 36° SW., has been entered by a slope adit. This was partly filled with water, so that only the upper part of the opening could be seen by the writer. The vein is about 16 inches thick and in every way similar in appearance to that on the Carle prospect, of which it may be an extension.

Besides the Carle and the Thomas prospects on Fishhook Creek there are several others which were not visited by the Survey party. Quartz from which gold can be obtained by panning has been found all around the Fishhook basin. On the divide between Fishhook and Fair Angel creeks the Reed & Fiske claims have been located. A large number of open cuts on this property indicate a quartz vein continuous for 300 feet, averaging 4 feet wide. The vein in some places includes a granite breccia and has gouge or clay along the walls. The strike is N. 40° W. (magnetic); the dip 30° SW.

Fair Angel Creek.—The Matanuska Gold Mining Co. has begun work on a group of four claims near the head of Fair Angel Creek. The prospect is near the top of a steep cirque wall and is at an altitude of about 4,500 feet, which is 1,500 feet above the camp in the valley bottom. In the neighborhood of the prospect aplitic dikes were seen in the "granite." The "vein" is an aplitic or pegmatitic dike, in places 9 feet thick, striking N. 60° W. (magnetic) and dipping 52° NE. This rock is a whitish or pinkish quartz-feldspar rock, with a few scattered black minerals, hornblende, and apparently also tourmaline. The dike has been shattered and cemented by quartz, especially along the hanging wall, where there is locally 8 inches of vein quartz. Between this and the granite is a narrow gouge seam. The values appear to be associated with the vein quartz, in which small specks of sulphide minerals are visible. The granite wall is everywhere more or less decayed and is said to carry values.

Two small open cuts were made on the "vein" during 1910. A tunnel was to be driven during the winter of 1910–11.

The Conroy claims adjoin the Matanuska Gold Mining Co.'s property on the north. The prospects lie on a ridge separated from those of the Matanuska Gold Mining Co. by a small cirque. There has been no work done on these claims except a little stripping of loose rock from the vein or veins at several places. At one such place the amount of quartz exposed is small. At another the indicated strike is N. 40° W. (magnetic) and the dip southwest. In attitude of the vein and appearance of the quartz this prospect corresponds with the commoner type of the district and not with the adjoining Matanuska Gold Mining Co.'s prospect, which is exceptional.

Outlying prospects.—Some claims have been located outside of the main quartz diorite area. Among them are the following:

The Lydell claim is in the pass between Willow and Fishhook creeks, on the contact of the quartz diorite and the mica schists. This claim was not visited by the Survey party. However, from reliable sources it was learned that there is a large quartz vein along the contact and a number of smaller quartz stringers in the schist. So far as at present known there are no important mineral values in this prospect.

The Miller claims are in the Little Susitna River valley. One on the east bank is about 2 miles below the mouth of Fishhook Creek. There is here a mass of quartz between 60 and 80 feet thick; the upper wall is brecciated and much-altered quartz diorite(?). The lower wall was not exposed. The trend of the quartz mass appears to be N. 20° W. (magnetic) and it is either vertical or dips about 28° SW. The locator is engaged in crosscutting the quartz. The "ore" is bluish-white fine granular quartz with sparsely scattered pyrite crystals. So far as known the ore carries no gold values. The occurrence is most probably a quartz-filled brecciated fault zone. It is said to be traceable for 3 miles along Little Susitna River.

Mr. Miller has another claim on the west side of Little Susitna River about 3 miles below Fishhook Creek. This was not visited and no satisfactory information about it was obtained.

SUGGESTIONS FOR FURTHER PROSPECTING.

The prospects thus far located around the heads of Craigie, Willow, Fishhook, and Fair Angel creeks are all high on the cirque walls or narrow ridges between cirques. There seem to be two reasons for this restriction in area and altitude. First, the prospecting has been limited to the region nearest to and most readily accessible from the supply point, Knik. Second, the lower slopes and creek basins have been mantled by glacial débris, talus, and moss, which make the surface-examination method of prospecting practiced in the district impossible at lower altitudes. The ridge crests on which the prospects are located have been exhumed by glaciation from considerable depths, and it is probable that the phenomena of fracturing and veining thus exposed are present at lower altitudes also. The wide extent and persistent character of the joint systems, so strikingly apparent in the surrounding mountains of the same country rock, suggest that some of the veins associated with the joints may also have as wide a distribution, both areally and at lower levels, and that at a given locality there may be veins at several elevations. For these reasons, and because the veins are not steeply inclined, prospecting by drilling and sinking shafts appears advisable.

GOLD PLACERS.

The placers are on Grubstake Gulch and on Willow Creek below Grubstake Gulch, both along the creek and on a bench on the south side (left limit) of the creek. Placer gold has been mined in commercial quantities at only one locality within the region—that is, on Grubstake Gulch. Willow Creek proper was staked by M. J. Morris and L. Herndon in 1898, and it is reported that they extracted about $4,000. In 1899 A. Gilbert staked Grubstake Gulch, and in 1900 he sold his interest to O. G. Herning, who manages the property for the Klondike Boston Mining Co., of Boston, Mass. This company also controls ground on Willow Creek and a bench below Grubstake Gulch. W. E. and E. H. Bartholf own most of the other claims on Willow Creek near Wet Gulch and below.

Grubstake Gulch is a glaciated hanging valley tributary to Willow Creek. Near its mouth a rim of bedrock crosses the channel and is cut through by the present stream, which falls precipitously for about 150 feet in a very short distance and enters Willow Creek at low gradient. An excellent dump for hydraulicking is thus afforded. The bedrock is a mica schist penetrated by small veinlets of quartz, both across and parallel to the schistosity. The parallel veinlets or lenses are the more abundant. Some of them have a pegmatitic aspect, but this could not be established in the rusty, weathered field specimens. The schistosity on the gulch has a strike about N. 60° E. (magnetic) and a dip of 40° N. The direction and inclination of the beds across the stream and the dip downstream are especially favorable for the collection of any gold that might have been concentrated from the rocks in the process of erosion.

Mining was begun above the falls. In the years 1904 to 1909, during which hydraulic methods have been in use, 1,200 feet of the creek with an average width of 200 feet and a depth from 2½ to 9 feet and locally (on the terrace on the west side) 12 feet have been worked out. The bedrock slope is about 1 to 24, or flume grade (6 inches to the 12-foot box). About one-third of the gold is coarse and rough, averaging one-tenth inch in diameter; the balance is moderately fine. The gold assays at the mint $16.58 an ounce. Very little black sand is found. In the lowest portion of the pay streak the gold was on a clay above bedrock, but higher up the creek the clay was absent. The greater part of the gold occurs close to or in crevices of the bedrock, but it is not deemed necessary to clean up by hand, the hydraulic giant being relied on to sweep all the gold into the boxes.

The wash, which is confined to the gulch bed—there being no bed-rock bench, although the terraced surface of the gravels is spoken of as a bench—is coarse, ill sorted, and not greatly waterworn. The many large bowlders make it necessary to employ two men in breaking up and removing oversize and add materially to the cost of extraction. Three Hendy giants are installed on the property, two No. 2 and one No. 1. The No. 1 is not ordinarily used. Seven hundred inches of water with a head of 180 feet is brought three-fourths of a mile down the gulch. A 24-inch pipe at the intake dam is reduced to 9 inches at the giant, to which is fitted a 3-inch nozzle. Twelve hundred feet of sluice boxes have been built. These are 27 inches wide, 30 inches deep, with bottom boards 1½ inches thick and side boards 1 inch thick; the frames are 3-inch square timbers. Block riffles are used. The gravel is driven to the boxes by the giants, at least one of which is directed across the creek—that is, parallel to the bedrock crevices. Very little gold is caught below the fourth box, the greater part being retained in the second. Mercury is placed in the third, fourth, and fifth boxes.

During 1910 the Grubstake Gulch operators limited their work to the extension of their pipe line about one-fourth mile and making other preparations for hydraulicking the bench at the mouth of Grubstake Gulch.

A ditch was built a few years ago from Wet Gulch down the south side of Willow Creek for the purpose of exploiting terrace gravels along Willow Creek. This project apparently has been abandoned.

SUMMARY.

The Willow Creek region is an area about 10 miles square some 20 miles northeast of Knik, on Knik Arm of Cook Inlet, Alaska. It includes an area of quartz diorite which is intrusive into and surrounds a belt of mica schist in its southern part and which is overlapped by Tertiary sediments along the south border of the region. The quartz diorite is cut by a few small dikes of diabase and aplite. A regular system of definite and continuous plane joints has broken the quartz diorite into blocks roughly rhombohedral in shape. There are other less regular and persistent joints, and along some of both the regular and the less regular joints there have been movements, but there are no observed faults of large displacement. Quartz filling of the fractures and decomposition of the quartz diorite along the fractures are not restricted to any set of joints, but, so far as this investigation determined, seem to be more extensive along those irregular fractures which are nearly vertical and trend approximately north and south, and along joints which strike approximately northwest (magnetic) and dip 20° to 40° SW. The latter is the most frequent veining and that which is of greatest importance to the region. The important prospects thus far located are on such veins, which are from 16 inches to 4 feet thick, and are demonstrably persistent through distances that warrant development. They carry small amounts of pyrite and other minerals and considerable free gold, much of which is visible in the quartz. So far as developments now show, the ores are free milling and high grade, and it appears not improbable that the mineral-bearing veins may be found over a wider area and at lower altitudes than those now located.