THE NIXON FORK COUNTRY

By John S. Brown

INTRODUCTION

FIELD WORK

Nixon Fork, from which the region here described is named, is a river that unites with the Takotna a few miles above McGrath, where the Takotna joins the Kuskokwim. In addition to the Nixon Fork basin the region includes a considerable area that drains directly to North Fork of Kuskokwim River and a large part of the upper Nowitna basin, tributary to the Yukon, as shown in Figure 4. This region previously constituted an unsurveyed wedge of land lying between surveyed areas. As the region was known to contain some valuable mineral deposits it was thought desirable to fill this break, and in 1924 a United States Geological Survey party, in charge of R. H. Sargent, topographic engineer, was sent into the region to cover as much of it as possible. The writer accompanied this party as geologist. Four other men were taken as assistants and camp hands. The party used 16 pack horses and 6 saddle horses. Field work began on July 4 and ended the last of August. Owing to nearly continuous rain with heavy fogs after July 20, progress was slow.

GEOGRAPHY

Routes of travel.—The Nixon Fork country is remote from any large ports or mining centers. In winter it is reached from almost any direction by dog team, but the principal route, the one used by the mail service, runs from Nenana by way of Lake Minchumina down the valley of the North Fork of the Kuskokwim. Almost all outside freight comes in summer by ocean steamer to Bethel and thence is carried by river boats up the Kuskokwim to McGrath or Berry's Landing (Medfra post office), but service is irregular and uncertain. There is some summer travel between the Kuskokwim and the Yukon by way of Ophir and Iditarod and also by Lake Minchumina and the Kantishna to Nenana, but any of these routes involves many miles of foot travel.

The Alaska Treadwell Gold Mining Co. for a few years maintained a wagon road between Berry's Landing and its mines, about 12 miles to the north, but this road is now unused and scarcely

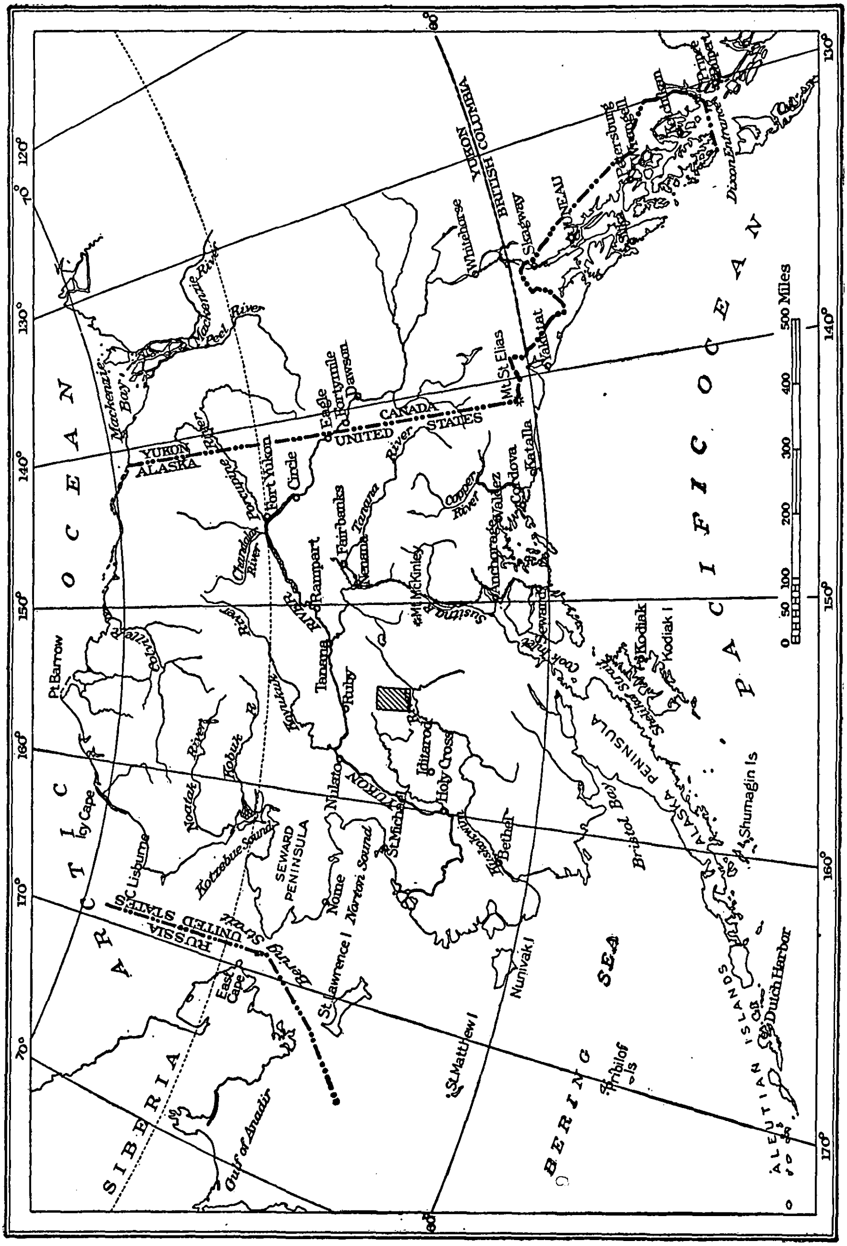

FIGURE 4.—Index map showing location of the Nixon Fork country (shaded rectangle)

passable in summer. There are no other roads in the region except the winter trails of trappers and prospectors, a few of which have been blazed and lightly bridged at bad crossings. In summer poling boats may be used for considerable distances on Nixon Fork, Nowitna River, Susulatna River, locally called Agate Fork, and possibly a few other streams.

The Survey party entered the region from Ruby, on the Yukon, using the Government road that is maintained in good condition to Long and is being gradually extended toward Poorman. The return was made by the same route.

Inhabitants.—At present there are no natives and very few permanent inhabitants in the Nixon Fork country. In 1924 there were about 20 white men at the Nixon Fork mines, possibly half as many more scattered over the rest of the region, and one or two families at Berry's Landing. A few trappers occupy isolated cabins here and there in winter.

Climate.—As a rule the rivers run free of ice in May and freeze in October, and this period represents the growing season. Frosts may occur during every month of the year. In summer the temperature rises above 80° F. and in winter it falls to 60° below zero. The annual precipitation probably averages about 20 inches but is erratic from year to year. Slow and long-continued rains with much fog seem to be the rule in July and August, at least along the higher ranges, but months of fair weather are common at other seasons.

Vegetation.—The vegetation is subarctic. The greater part of the region is at least thinly forested, although numerous peaks and ridges rise above timber line, which ranges from 1,000 to 2,000 feet above sea level. Most of the forest is composed of small spruce less than 6 inches in diameter, of little value except for fuel but indispensable for this purpose to trapper, prospector, and miner. Small patches of larger spruce, some of the trees 2 feet in diameter and useful for lumber, grow in favored places near the big streams or on southern slopes. The aspen, commonly called cottonwood, and the birch also form local patches of forest and reach diameters of more than a foot. Tamarack grows sparingly with the spruce. Alder is common is many places, dominating the upper fringe of forest near timber line. Willows of several species form thickets along the streams.

Small brush, berries, flowers, and grasses grow profusely in the long summer days. Blueberry and cranberry usually are abundant. Wild roses, bluebells, fireweed, and other flowers in turn brighten the landscape. Several species of grass make valuable forage; the best is the wild redtop that is usually found on the flood plains of the larger streams and here and there on hill sides, especially in thin birch forests. Upland grasses in the spruce timber are also valuable. Grass was the sole subsistence of the horses of the Survey party. As a rule it is available from early in June until about the middle of September.

Mosses of numerous kinds are present almost everywhere, growing with other vegetation and also mounting well above timber line, although commonly replaced at higher altitudes by the lichens or "caribou moss."

Many of the peaks of the higher ranges, especially of the limestone ranges, seem almost entirely devoid of vegetation.

Animal life.—Game is moderately plentiful in much of the region and includes the black bear, moose, caribou, and small animals, such as rabbits, grouse, and ptarmigan. Beaver are abundant, and their numerous dams create swampy areas that are a great nuisance in crossing the smaller streams. Grayling is the only common fish and inhabits only favored parts of certain streams.

Topography.—In the basin of Nowitna River most of the interstream areas are of moderate altitude and have a rolling surface, but farther southeast, on either flank of Nixon Fork, the region is dominated by irregular groups of rugged mountains which for considerable distances rise more than 3,000 feet and in some places more than 4,000 feet above sea level. Along the larger streams broad alluvial flats scarred by oxbows and meanders are common.

Geographic names.—In an area so thinly inhabited many features, even notable ones, bear no names, or the names that have been used are unobtainable. Again, the prospectors of one period use a set of names which are forgotten or ignored by their successors, who apply new names to the same features. The large river formerly mapped as the Susulatna is now more generally known as Agate Fork. Duplication of well-worn names is excessive. Thus many small areas have several streams called "Flat Creek" and "Bonanza Creek." So far as possible names in local usage have been adopted; for other features names have been invented as convenient handles for description. The Sunshine Mountains in particular bear no local name, although Mertie and Harrington[1] have referred to them casually as the Nixon Fork Mountains, a name that seems ill chosen because it is not now in use and because the name Nixon Fork is more closely identified with the mining district in a different mountain range.

ACKNOWLEDGMENTS

The Geological Survey party is deeply indebted for hospitality and assistance to many citizens from Ruby to Poorman and at the Nixon Fork mines. J. B. Mertie, jr., of the Survey, made the determinative study of thin sections of the rocks from the Nixon Fork country and has assisted the writer in their interpretation. He has also carefully criticized the report as a whole.

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[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, p. 28, 1924.

AREAL GEOLOGY

PREVIOUS WORK

The United States Geological Survey has published several reports that deal mainly with the geology of regions adjacent to the Nixon Fork country. Of these reports the bulletins by Eakin [2] and by Mertie and Harrington [3] are most detailed. A brief report by Martin covers the Nixon Fork mining district.[4] Spurr's account of his traverse down Kuskokwim River in 1898 is also still of value.[5] A few other papers of incidental interest are mentioned in their appropriate connections.

GEOLOGIC MAP

The accompanying geologic map (pl. 5) shows the distribution of the different subdivisions of rocks within the area and gives their ages and relations as well as could be determined.

METAMORPHIC ROCKS

Metamorphic rocks of unknown age but chiefly pre-Ordovician constitute the oldest recognized subdivision in the region. They occur mainly in a large area between Nowitna and Sulukna Rivers, where they are seemingly continuous with similar rocks to the northeast mapped by Eakin.[6] They are also correlated in a general way with the metamorphic rocks to the northwest described by Mertie and Harrington.[7] The description is based mainly on observations in a small area northwest of Nowitna River and in the basins of Bridge and Harding Creeks.

The metamorphic rocks embrace a great variety of schistose rocks, many of which must originally have been sandstone, shale, and limestone. Others, however, are greenstones and gneissoid diorites of igneous origin. The sedimentary rocks now constitute quartzite, quartz-sericite schist, slaty schist or phyllite, mica schist, at places garnetiferous, and yellow to white recrystallized limestone. Quartz-sericite schist and phyllite are very common. Greenstone, or green schist rich in chlorite and green hornblende, is fairly common, and gneissoid hornblende diorite is well developed. The greenstone prob-

[2] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

[3] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, 1924.

[4] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

[5] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

[6] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

[7] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, 1924.

ably represents basic lava flows and the hornblende diorite was doubtless intrusive. Quartz veins injected along the cleavage are abundant in these rocks at most places. No evidence of extensive mineralization was found related to these veins.

The structure of the metamorphic rocks is very complex. The cleavage trends north and south rather than east and west but varies greatly both in strike and dip. True bedding is evident in few places. The erratic distribution of different rock types suggests complex folding, probably accompanied by faulting and complicated by unconformity.

Limestone beds seem as a rule not to exceed a few hundred feet in thickness. Some small limestone masses show true bedding. These are very likely later Paleozoic rocks infolded into the schists, but no fossils were found in them.

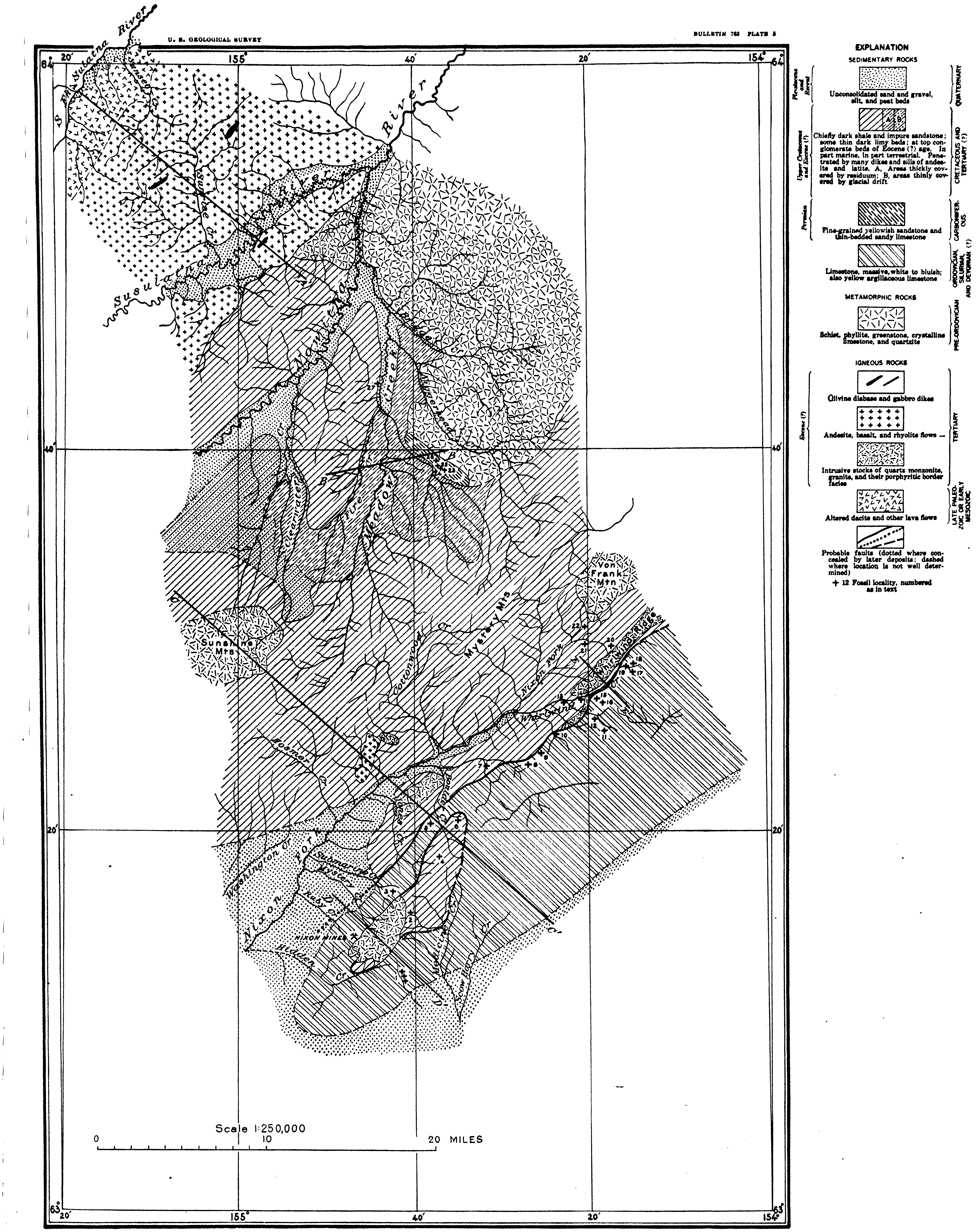
The oldest sedimentary rocks overlying this complex group within the region are of Ordovician age. The Ordovician limestones show much less metamorphism than the schists, a fact which suggests that they are younger, although in Alaska this criterion must be used with great caution. Evidence from other areas also indicates that the schist series is mainly pre-Ordovician.

PALEOZOIC LIMESTONE

Limestone forms the greater part of the ranges that lie between Nixon Fork and the North Fork of the Kuskokwim. Several types of limestone are common. One is dull white or gray on weathered surfaces, blue-gray on a fresh fracture, and commonly seamed by many calcite veinlets. The beds usually range from 2 to 6 inches in thickness, but a few very massive beds 20 to 200 feet thick are found, at some places forming huge ridges crossing hills and valleys. This massive type is well developed just south of upper Whirlwind Creek and less so near the Nixon mines. It forms the most rugged of the limestone peaks. At places it is highly fossiliferous, and most of the collections listed were obtained from rocks of this type.

Another type of limestone is very thin bedded, the layers ranging from one-eighth inch to 1 inch in thickness. It is conspicuously buff or yellow on weathered surfaces but dark blue or black inside. Outside it commonly looks sandy, and cross-bedding is suggested. Shaly layers and blue-black chert were noted in this limestone. Small worm trails are abundant, but no fossils of diagnostic value were found. Its topographic forms are of subdued character. Near the head of Canyon Creek it forms a lowland.

A third and very common type of limestone is almost dead white on weathered surfaces, has a sandy or granular texture, and is white to gray in the interior. It seems to be moderately thin bedded, but bedding is visible in but few places, as the surface slumps readily.



GEOLOGIC SKETCH MAP OF THE NIXON FORK COUNTRY

78644°—26. (Face p. 102.)

Only molds of fossils of no determinative value were found. The peaks and ridges formed by this third type of limestone are intermediate in ruggedness between those formed by the first two types.

The structure of the limestone is complex. Nearly everywhere the beds are sharply folded, although the details could not be determined in the time available. The area around the Nixon Fork mines is believed to be irregularly anticlinal. Steep or vertical dips are not uncommon. The major trend of folding is to the north of east along the general elongation of the ranges. Observation along the northern border, however, showed variable dips locally, and on Whirlwind Creek at the two observed localities the limestone is overturned near the Cretaceous contact and dips about 80° SE. The writer believes that the limestone has been thrust forward along a great fault over beds of Upper Cretaceous age.

The thickness of the limestone series is unknown but must be at least 5,000 to 7,000 feet and may be much more.

Sharp-crested divides, cliffed peaks and slopes, and in the higher mountains great barren areas wholly devoid of vegetation make the limestone ranges the most picturesque feature of this region. On many ridges vegetation occupies the southward-facing slopes but terminates abruptly at the crest. Grass is scarce and forage very hard to find over much of the limestone country.

Many stream beds in the limestone are paved with loose cobbles and traversed by dry flood channels, as much of the drainage both here and on the slopes is subterranean. Typical sink-hole topography, however, is lacking, although there are a few sinks.

Fossils from these limestones, some in place and some from float, were obtained at numerous localities, as numbered on Plate 5. These collections were examined by Edwin Kirk, of the United States Geological Survey, who has made the following determinations. Key numbers are those given on Plate 5. Numbers in parentheses are those of the Geological Survey locality records. N. B. indicates the number in the author's notebooks.

1 (1963, 1964, 1965). N. B. 75a, 75b, 75c. Collected along a mile or more of road about halfway between the monzonite contact and the flats from boulders washed bare in roadbed and creek. About midway of this distance some of the species can be found poorly preserved in a parent ledge. Beds estimated to be at least in part from 1,500 to 2,500 feet stratigraphically above the base of the limestone.

Silurian: Pentameroid brachiopod.

In part Silurian, in part possibly Devonian:

Favosites sp.
Alveolites sp.
Favosites sp. (same as No. 9).
Cyathophyllum sp.

3 (1962). N. B. 69. From loose blocky talus of broken moss-covered ledges on north slope of ridge east of Submarine Creek and about 1½ miles north

of Strand Peak. Beds estimated to be not over 500 feet above the adjacent shale and porphyry, nearly in place.

Probably same as No. 8 and probably Ordovician:

Leperditia sp.

Zygospira sp.

5 (1966). N. B. 88. Just south of Boulder Creek near northern contact of limestone. Slump, nearly in place.

Ordovician (Richmond): Liospira sp.

7 (1960). N. B. 63. Limestone float in creek bed a mile or more from contact.

Ordovician (Richmond):

Cyrtolites? sp.

Lophospira sp.

8 (1959). N. B. 62. Crest of the first (northern) limestone ridge. In place.

Probably Ordovician (compare No. 3): Leperditia sp.

9 (1958). N. B. 61. From loose material thrown out of a prospect pit. Very near northern border of limestone.

Silurian or possibly Devonian: Favosites sp.

10 (1957). N. B. 60. Limestone float in a small creek bed.

Probably Silurian but might be Devonian: Sieberella sp.

11 (1955). N. B. 55. In place. Thin-bedded limestone.

Age indeterminable: Annelid trails.

12 (1954). N. B. 54. Float, bed of Canyon Creek.

Age doubtful: Poorly preserved corals and crinoid stems.

14 (1953). N. B. 51. Limestone float, bed of Whirlwind Creek.

Probably Silurian: Favosites sp.

15 (1953). N. B. 51. Hillside float between 14 and 16.

Ordovician: Poorly preserved cephalopod and Hormotoma sp.

16 (1952). N. B. 50. From subsidiary peak north of impressive high peak (station 39). Crest of anticline. Virtually in place.

Silurian or possibly Devonian:

Stromatopora sp.

Favosites sp.

Cladopora sp.

17 (1950). N. B. 46.

Ordovician (Richmond): Liospira? sp.

18 (1951). N. B. 47.

Ordovician (Richmond):

Paleophyllum sp.

Halysites sp.

Paleofavosites sp.

Calapoecia canadensis Billings.

Liospira sp.

Hormotoma sp.

Illaenus sp.

19 (1949). N. B. 48. Localities 17–19 are close together and all represent very massive beds described on page 102, about half a mile south of Whirlwind Creek. Nos. 17 and 18 represent material substantially in place in massive reefs; No. 19, stream float below and between these two localities.

Ordovician (Richmond):

Stromatopora sp.

Favosites sp.

Columnaria sp.

Halysites sp.

With reference to No. 19 Mr. Kirk states that the greater part is Ordovician, but that one or two specimens may be Silurian.

It seems from these determinations that the limestones constitute a terrane which comprises sections of both Ordovician and Silurian beds and possibly Devonian. The separation of these systems is a problem for further study, but one which the general features of the region indicate might well be done.

These limestones seem to be at least in part the same as those to the northeast described by Eakin,[8] for the indications are that the rocks are continuous through the areas, and similar fossils (Richmond) have been found in them. The writer also suspects that they are closely related to the limestone of the Takotna ("Tachatna") "series"[9] to the southwest, which has been considered Middle Devonian.

PERMIAN ROCKS

A small area of Permian rocks was found along the crest of the low, elongate, asymmetric ridge west of Harding Creek. This discovery is interesting because Permian rocks are not known in the adjoining areas. The exposures were studied only for about a mile along a group of small knobs that occupy the summit of this ridge. The lower portion of the beds, in the southern part of the area seems to consist entirely of brown to yellowish sandstone, generally weathered soft and porous, containing a few poorly preserved fossils. This sandstone seems at one place to rest on green chloritic schist. The thickness of sandstone here probably does not exceed a few hundred feet.

On a group of several small knobs midway of the exposures the sandstone grades into thin-bedded, impure yellowish sandy limestone, which is exposed in place dipping gently southwestward. Certain beds are abundantly fossiliferous.

Farther north, and therefore seemingly beneath these beds, is a band about 1,000 feet wide of very thinly laminated black slate, whose cleavage strikes N. 60° W. and dips 45° SW. This slate separates the first sandy and limy beds from a little ridge on which similar but more indurated sandy and quartzitic rock is found, at one place in a small, rather massively jointed cliff. The slump from this exposure is partly dense quartzite, partly leached porous sandstone. The sandstone phase is full of poor fossil molds rather similar to those farther south. This sandstone is succeeded to the northwest by blocky semimetamorphic dark crystalline limestone, which is assumed to belong to the metamorphic complex.

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[8] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, 1918.

[9] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 31–264, 1900.

The Permian beds probably continue at least 2 or 3 miles to the southeast and very likely some distance to the northwest. Certain thin-bedded limestones and siliceous limestones only mildly metamorphosed just south of the head of the north fork of Bridge Creek may perhaps also belong to this series. The Permian beds are doubtless overlain unconformably by the Upper Cretaceous beds if the two series are anywhere in contact.

George H. Girty, of the United States Geological Survey, reports on these fossils as follows:

23 (5456). N. B. 32. Small knob showing low bluff of sandy limestone at Survey station 28. The most southerly collection.

Stenopora aff. carbonaria.
Chonetes aff. C. ostiolatus.
Chonetes sp.
Productus aff. P. mammatus.
Productus n. sp.
Marginifera aagardi?
Pustula aff. P. montpelierensis.
Pustula n. sp.
Pustula sp.
Pustula sp.
Aulosteges? sp.
Camarophoria margaritovi?
Rhyncopora aff. R. nikitina.
Spiriferella arctica.
Spirifer aff. S. nikitina.
Spirifer aff. S. triplicatus.
Martinia aff. M. triquetra.
Squamularia sp.
Aviculopecten n. sp.
Aviculopecten sp.
Euchondria? sp.
Pseudomonotis? sp.
Griffithides.

24 (5455). N. B. 31. Small knob similar to No. 23 and about 300 feet to the northwest.

Batostomella? sp.
Chonetes sp.
Productus aff. P. mammatus.
Marginifera aff. M. splendens.
Marginifera aagardi.
Rhyncopora sp.
Camarophoria aff. C. crumena.
Spirifer aff. S. triplicatus.
Squamularia sp.
Aviculopecten n. sp.
Euchondria? sp.
Pleurotomaria sp.
Griffithides sp.

25 (5454). N. B. 30. Very thin limestone beds on little ridge 400 feet northwest of No. 24.

Fistulipora sp.
Stenopora sp.
Rhombopora sp.
Spirifer aff. S. triplicatus.

26 (5453). N. B. 29. Talus just west of small cliffy exposure of massively jointed quartzite. About a quarter of a mile northwest of station 29 and perhaps half a mile north of No. 23.

Marginifera aagardi.
Phanerotrema? sp.

These four collections all contain the same fauna, though that from lot 25 is almost too meager for satisfactory interpretation. The fauna is obviously that which has been identified in Alaska as Permian (Artinskian) and which is best known from exposures on

Kuiu Island and on Yukon River opposite the mouth of Nation River.

A smaller collection of the same fauna was obtained by A. G. Maddren, of the Geological Survey, a few hundred miles to the southwest, on Kuskokwim River at about longitude 160° W. This is the nearest known occurrence of Permian beds. The beds there, according to unpublished information, consist of 50 feet of limestone overlain by several hundred feet of tuffs and volcanic rocks. The upper part of the limestone is tuffaceous and contains the fossils. No similar tuffaceous rocks were noted in the Nixon Fork country.

UPPER CRETACEOUS AND EOCENE (?) ROCKS

Rocks of Upper Cretaceous and perhaps in part of Eocene age cover extensive tracts in the heart of the area and are particularly well exposed along the Nixon Fork-Nowitna divide, where they form the Mystery Mountains and the border about the Sunshine Mountains. Here they are well exposed along numerous creeks and canyons but have been strongly affected by the abundant intrusions. In the tongues of land between Nowitna River and Meadow Creek to the south and Agate Fork to the north they are present in more normal condition but much less satisfactorily exposed. On the west they are continuous directly or beneath alluvial flats with similar rocks that have been mapped over wide areas by Mertie and Harrington.[10] On the east they are cut off over most of their extent by the schists and metamorphic rocks but continue an undetermined distance eastward in the region at the head of Nixon Fork and Sulukna River, although they were not recognized by Eakin[11] in the Cosna-Nowitna area. If present there they must occur in only small areas and must be much modified by metamorphism.

The Upper Cretaceous rocks are of highly variable character but consist dominantly of dark, more or less slaty shale and of impure grayish arkosic sandstone or graywacke, with gradations between the two. Thin beds of impure dark limestone as much as 2 feet thick are not uncommon, and impure chert is interbedded with the slate on lower Whirlwind Creek. Pebbly or conglomeratic sandstone is fairly common, and thick beds of very coarse conglomerate occur in the upper part of the series in the general region of Hosmer Creek. This part of the section, if any, is believed to be of Eocene age.

The thickness of the Upper Cretaceous and Eocene (?) rocks is unknown but must be at least 5,000 feet and possibly considerably more. On the south slopes of the Mystery Mountains opposite the head of Cottonwood Creek an unbroken section about 1,500 feet

[10] Mertie, J. B., jr., and Harrington, G. L., op. cit.
[11] Eakin, H. M., op. cit.

thick was examined. Possibly 10 per cent of this thickness is made up of intrusive matter in the form of sills. The beds grade from slaty sandstone at the lowest exposures into coarse arkosic sandstone and pebbly beds above. These rocks are thin bedded, well indurated, and cross-bedded and contain imperfect plant markings. Thin sections show the sandstone to contain a little quartz, more feldspar, and abundant fragments of a dark lava, with a little slate. Similar arkosic sandstone or graywacke is abundant south of Nixon Fork from Whirlwind Creek to Jones Creek and occurs also, mainly as loose fragments, on nearly all the ridges northwest of Meadow Creek. A thin section from station 20 consists dominantly of quartz but contains much dark chert, some feldspar, and traces of slate or schist, with considerable secondary carbonate.

The conglomerate occurs in thick beds forming very prominent ridges between Cottonwood and Hosmer Creeks. The pebbles are as much as 6 inches in diameter, are very perfectly rounded, and consist of dark micaceous quartzite, varicolored chert, and vein quartz in the relative order of decreasing abundance named. Some of the conglomerate beds are a few hundred feet thick.

The shale as a rule is black and fissile, and at many places it is impossible to determine true bedding, owing to the secondary cleavage and jointing. Small nodules of pyrite and large calcareous concretions are common in some exposures.

Included with these rocks in the region of fossil station 20 is a small area of much shattered grayish chert, which may possibly be a remnant of an older series of chert and argillite described by Mertie and Harrington.[12]

Around the Sunshine Mountains, in the Mystery Range, at Von Frank Mountain and about the monzonite at the Nixon Fork mines, the Upper Cretaceous rocks, especially the shale, have been strongly indurated by the intrusive igneous rocks which cut them everywhere as bosses, sills, and dikes. Near the larger intrusive masses the shale is changed to a dense black structureless rock which forms coarse talus blocks, many of them several feet in diameter, called locally "block slate." In a general way metamorphism is notably gradational and is much more severe in the southern part of the Upper Cretaceous area than in the area northwest of Meadow Creek, where igneous rocks are absent and folding is less intense. Veining in the slate is fairly common, quartz veins being abundant south of the Sunshine Mountains and calcite veins fairly common near Meadow Creek.

Structurally the rocks occupy a series of open folds closely related to the intrusive rocks, as described on page 114–120. They must rest

[12] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 22–23.

unconformably on the metamorphic rocks, fragments of which they contain in some places, and doubtless they are also unconformable with the Permian beds. With the Paleozoic limestones they seem to be in fault contact throughout the Nixon Fork area, as described on pages 120–123.

The rare limy beds in the series very commonly yield imperfect fossils, usually broken fragments of *Inoceramus*. Collections obtained at several localities described as follows have been examined by T. W. Stanton, of the United States Geological Survey, who reports on them as follows:

6 (12564). N. B. 64. Slopes east of head of east fork of Boulder Creek and about 1½ miles southwest of Survey station 46.

Fragments of small undetermined pelecypods, one of which has angular ribs. Presumably from the same Mesozoic formation as lots 13, 22, and 27.

13 (12563). N. B. 53. Low bluffs on south bank of Whirlwind Creek just below mouth of Canyon Creek.

Inoceramus sp.

Fragments of shell like those in lots 22 and 27.

22 (12562). N. B. 41. Headwaters of Nixon Fork, about 3 miles southwest of Von Frank Peak.

Inoceramus sp. Fragments of shell. Belemnites or Belemnitella sp. The fossils are like those in lot 27.

27 (12561). N. B. 23. Bluff on northwest bank of Meadow Creek about 10 miles above its mouth and about 2 miles below mouth of Fire Creek.

Rhynchonella? sp. Fragmentary imprints.

Inoceramus sp. Numerous fragments of a rather large, thick-shelled species.

Belemnites or Belemnitella sp. Several fragments and cross sections of a slender species.

The thick fibrous shell and the apparently large size of the *Inoceramus* in this lot suggest Upper Cretaceous age. On the other hand, belemnites are common in the Lower Cretaceous and especially in the Jurassic, whereas belemnoids of any kind are very rarely if ever present in the Upper Cretaceous of Alaska. The horizon is not older than Middle Jurassic and not younger than Cretaceous. I think it most likely Upper Cretaceous, but additional species or better preserved specimens, or both, must be obtained before it will be possible to make a more definite age determination. Previous collections from presumably the same formation in this region have been no better than this one.

All the collections are fragmentary, but the last (No. 27) is best.

In addition to the above collections four others of indeterminate character were obtained from what appear to be the same (Upper Cretaceous) beds, as follows:

2 (1948b). N. B. 68. About 1½ miles east of Strand Peak, Survey station 47.

4 (1961). N. B. 66. Divide at head of Jones and Boulder creeks.

Fragment of a bivalve; indeterminable.

20 (1948a). N. B. 44. Slope of Whirlwind Ridge near porphyry contact, about 1½ miles northeast of summit.

21 (1948). N. B. 43. South bank Flat Creek, about 1 mile north of No. 20. Algae. Age indeterminable.

Mr. Stanton says that lots 2 and 20 "may well come from the same formation," but they contain nothing positively determinable. The greater part of the shales and sandstones are evidently of Upper Cretaceous age. The higher conglomeratic beds, from evidence obtained in other areas, probably range into the Eocene, although no fossils were obtained from them.

The topography of the Upper Cretaceous rocks differs in different areas. They form very bold jagged and asymmetric peaks on the borders of the Sunshine Mountains, in the Mystery Range, and on Von Frank Mountain, where the shale is so indurated as to be very resistant. At other places there is a succession of curved asymmetric ridges of sandstone or of intrusive sheets, harder than the shale. Northwest of Meadow Creek a very low, subdued rolling topography is the rule. Most of the area of outcrop is well wooded.

UNCONSOLIDATED SAND AND GRAVEL DEPOSITS

Flat lowlands underlain by unconsolidated gravel, sand, and silt are extensive along the larger streams. The "flats" along the North Fork of the Kuskokwim and the lower part of Nixon Fork are several miles in width. Others are generally less than a mile wide.

Information about these deposits is meager, as they are in few places well exposed, and the Survey party traversed none of the larger flats or stream courses. Spurr has described very well the exposures in bluffs along the Kuskokwim.[13] They consist of yellow silt, blue clay, and local layers of peat and of buried logs. There seems to be imperfect terracing in the deposits, and small terraces were noted on some streams, such as Whirlwind Creek.

Fossil bones of extinct Pleistocene mammals are found in these deposits, very often during placer mining. C. W. Gilmore, in 1907, ascended Nowitna River for about 180 miles by water and collected bones of *Elephas primigenius*, *Bison*, *Equus* (horse), *Ursus* (bear), *Alce* (moose), and *Castor* (beaver) on the gravel bars, which had been uncovered by erosion from the stratified silts.[14] Shells of invertebrate land animals are also common in the silt at many places.

In addition to the true alluvium there are large areas of residuum consisting of a mantle of decayed vegetation, soil, and ground ice,

[13] Spurr, J. E., op. cit., p. 122.

[14] Gilmore, C. W., Smithsonian exploration in Alaska in 1907 in search of Pleistocene fossil vertebrates: Smithsonian Misc. Coll., vol. 51, No. 1807, p. 23, 1908.

generally less than 50 feet thick. Most of these areas are not shown on Plate 5. The most extensive area is southeast of the strip of alluvium along Meadow Creek and on the low saddles connecting with Nowitna River. Most of this area is probably underlain by soft Upper Cretaceous shale.

The alluvium and residuum exhibit a number of peculiar topographic forms which are due mainly to the subarctic climate. These forms include small benches, probably formed by creep and the action of landslides and lakes or muskegs on slopes or even hilltops, possibly due, at least partly, to irregular thawing of ground ice. Only along the largest streams are features of normal stream erosion, such as oxbows and gravel bars, to be found.

Nearly all the higher portion of the Sunshine Mountains was rather severely glaciated in Pleistocene time. The north slopes were most strongly affected, and the area occupied by slate on the southeast seems to have escaped. Characteristic U-profiles can be seen on many valleys, as at the head of Clearwater Creek; high benches and hanging valleys are common along minor streams; imperfect cirques are numerous, and one very beautiful example has a lake several hundred feet long and a great steep granite cliff behind. Morainal deposits are common, and at the north and west the ice seems to have spread out in a sheet that rode indiscriminately over ridges and valleys, smoothing off much of the area into flat spurs of gentle slope covered with thin ground moraine. This moraine consists mainly of fine fragments of slate but includes a few large boulders of granite and spotted slate even several miles from their nearest possible source. The area of glacial deposits, as shown on the map (pl. 5), occupies mainly the slopes between Clearwater Creek and Nowitna River.

Glacial deposits probably occur in similar development on the north and west slopes of Von Frank Mountain but were not examined. Cirquelike forms were seen from a distance, and broad flat spurs, probably covered with moraines, were noted at the base of the mountains. Slight glaciation may also have occurred in the Mystery Range on the north, which was not examined. Even the highest peaks of limestone show no sign of glaciation, and in general the glaciers seem to have been restricted in this region to areas in which the highest peaks reach 4,000 feet or more in altitude.

IGNEOUS ROCKS

EXTRUSIVE FLOWS AND TUFFS

Extrusive igneous rocks occur mainly in the narrow northern part of the Nixon Fork country (pl. 5) a short distance south of Agate Fork. The rocks of this belt extend into the region on both sides, where they occupy large areas and have been described by Mertie and Harrington,[15] who separate them into two groups of different age.

OLDER EXTRUSIVE ROCKS

The older volcanic series occupies only a very narrow strip of the Nixon Fork country just south of the South Fork of Sulatna River. The writer had little opportunity to study this area, but his observations accord with those of Mertie and Harrington.[16] These authors classify the rocks as soda rhyolite and oligoclase dacite. They are fine-grained volcanic lavas, porphyritic in thin section but thoroughly impregnated with secondary chalcedonic silica. Imperfect feldspar laths and magnetite dust are abundant, and flow structure is suggested.

In the field the rocks are red, brown, or green, very commonly green in the interior. They break persistently along minute, invisible joint planes, which show black stains of iron or manganese. Amygdaloidal beds containing almond-shaped cavities filled with calcite or chalcedony or both are common.

Mertie and Harrington found that these rocks were interbedded with cherty and gritty rocks that they considered doubtfully to be of Mesozoic age but older than Upper Cretaceous. The structure of the series is complex, owing to folding and faulting.

YOUNGER EXTRUSIVE ROCKS

Mertie and Harrington[17] classify the younger extrusive rocks as pyroxene andesite and basalt. The series as studied by the writer fits this description fairly well but seems also to contain a large amount of material of rhyolitic appearance, some of it distinctly quartz-bearing. In this respect it accords more closely with the volcanic series in the Cosna-Nowitna area described by Eakin.[18] In the thin sections examined by Mertie and Harrington and in those from the Nixon Fork country the feldspar of the andesite is chiefly labradorite, partly oligoclase. The labradorite forms striking phenocrysts and also small laths in an oligoclase matrix. Some sections contain a dark-brown glassy matrix, more or less devitrified. Augite and magnetite are common. The basalt closely resembles the andesite but is darker, contains no oligoclase, and may contain olivine. The more acidic lavas seem to consist mainly of oligoclase, with orthoclase phenocrysts and with quartz phenocrysts also common in some sections. They should be classed as rhyolite.

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[15] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 55 et seq., 1924.

[16] Idem, pp. 60–62.

[17] Idem, pp. 62–66.

[18] Eakin, H. M., The Cosna-Nowitna region, Alaska: U. S. Geol. Survey Bull. 667, pp. 33–34, 1918.

In the field the more basaltic types are black and may be either dense and vitreous or scoriaceous. Some of the cavities seem to have contained fillings of calcite or chalcedony. These rocks are clearly interbedded in the andesite but form only a small part of the series. Separate flows probably in few places exceed 50 feet in thickness.

The most abundant and best exposed lava, where found in place, is rather solid and blocky. Steeply dipping joints are more pronounced than the obscure flow banding. Weathered faces generally are brown or reddish, and fresh surfaces are commonly dark green. The prominent feldspar phenocrysts in many places give the rock a spotted appearance. This rock ranges from andesite to basalt.

The rhyolite was not found in place but yields abundant float blocks at many localities and forms almost the whole of Stone Mountain (Survey station 14). It is generally white, except for abundant brown iron stains. Striking flow structures are common. Many of the fragments are platy. The rocks seem to be interbedded with the andesite and basalt.

Tuffs either are not abundant in the series or else are very poorly exposed. A thin bed was noted about 6 miles southwest of the junction of Agate Fork and Nowitna River. It forms a narrow band about 800 feet long and 12 feet wide, offset 20 feet at the northeast end by faulting. The rock is porous and light colored and seems to correspond in composition to the rhyolite. The largest fragments are about an inch across.

Some portions of the lava contain abundant cavity fillings of chalcedonic quartz, locally called agates. These agates are very resistant and have become so concentrated on the gravel bars of Agate Fork as to give the name to that stream. They range in diameter from a quarter of an inch to 6 inches. As a rule there is an outer shell of chalcedony and a drusy center lined with quartz crystals. Impressions of calcite rhombohedrons indicate that this mineral was commonly present but has been broken or dissolved away. Some of the agates are of good quality and might have a slight value as cut stones.

The main source of the agates is uncertain. They were found sparingly on weathered knobs of andesite and basalt, and a piece of andesitic matrix full of small specimens was found on a bar. Mertie and Harrington[19] mention a locality where fillings at most 3 inches in diameter were so abundant as to make the rocks resemble superficially a conglomerate. Some such locality must be the principal source of this material.

The structure of the lavas is rarely visible, but it was seen at several places along the ridge at the western border of the area

[19] Mertie, J. B., jr., and Harrington, G. L., op. cit., p. 62.

mapped. Here the dip is uniformly southeast at angles of 5° to 20°, flattening toward the northwest. The strike is N. 30°–50° E. Dips of 20°–50° SE. were noted in a bluff northeast of the main western tributary of Sunrise Creek. Southeast of Agate Fork, on the other hand, the few observed dips are all fairly steep to the northwest and the strike is about N. 55° E. It therefore seems that the structure from northwest to southeast is synclinal.

The observations along the ridge at the western border indicate that the total thickness of the lavas must be at least 3,000 feet, unless there is unsuspected repetition by faulting.

Very little was learned concerning the relations of the lavas to the other formations, but nothing was found that did not fit with the conclusions of Mertie and Harrington, who believed that they rested unconformably above the older lavas to the north and more or less conformably above the Upper Cretaceous and Eocene (?) beds. Their age is interpreted as Eocene or post-Eocene.

In addition to the main body of these volcanic rocks a small area of similar andesitic lavas was found between Cottonwood and Hosmer Creeks. These lavas seem to overlie the conglomerate and sandstones of probable Eocene age in the trough of a deep syncline and are presumably of about the same age as those just described.

INTRUSIVE ROCKS

BASIC ROCKS

Several small bodies of basic intrusive rocks are found within the region. Three of these bodies are within the large area of younger extrusive rocks in the northern part of the region (pl. 5). One locality is on the ridge south of the head of Sunrise Creek, and specimens of similar rock were brought to the writer by Ray Russell, assistant to Mr. Sargent, from a locality about 5 miles to the southwest. The rocks are diabasic and in thin section are seen to consist of labradorite feldspar, olivine, and augite, probably titaniferous, all abundant, with a green incrusting, radiate product of alteration, probably serpentine, replacing the olivine and feldspar. They may be classified as olivine diabase. At both localities the rock is found only in abundant dark glistening boulders, the largest of them 3 feet in diameter, rather well rounded by weathering. The areas of occurrence are a few hundred feet long and elongated from northeast to southwest.

A very similar rock occurs in much the same way on the slopes just south of Agate Fork on the first bluffs below Sunrise Creek. This rock, however, is fully crystalline and seems to be a gabbro. This gabbro and the diabase are believed to form dikes or plugs cutting the volcanic rocks.

On the divide east of Mint Creek on the crest of the Sunshine Mountains a dike of basic andesite cuts the granite. It consists of zoned plagioclase of intermediate character in a matrix of devitrified brown glass full of small crystals of magnetite. Secondary carbonate, serpentine, and zeolites are present.

Considerable float of green basic rocks was noted on Whirlwind Creek, but its source was not determined.

Martin[20] describes a basic dike of pyroxenite cutting the limestone on the southeast border of the monzonite at the Nixon Fork mines.

The basic rocks of the Nixon Fork country resemble closely those in the Ruby-Kuskokwim region described by Mertie and Harrington.[21] Those authors state, however, that the basic rocks are older than the monzonite and are cut by it, whereas at the only localities in the Nixon Fork country where they have been definitely recognized the basic rocks cut granite. The basic rocks associated with the lavas probably cut them but are very closely related to them both in age and composition.

ACIDIC ROCKS

Acidic intrusive rocks of the general type called granite by prospectors form a number of irregular stocks and bosses within and bordering the drainage basin of Nixon Fork. Some of these rocks are true granite, and others are more properly classified as quartz monzonite. Associated with the larger intrusive bodies are a multitude of smaller closely related bodies forming dikes and sills, mainly in the Upper Cretaceous shale and sandstone. As the larger intrusive bodies are genetically related to the gold and other mineral deposits in this and adjacent areas, it seems advisable to describe each of the occurrences in some detail.

GRANITE AND QUARTZ MONZONITE

Sunshine Mountains.—The Sunshine Mountains contain a simple core of granite surrounded by a rim of slate, which represents the indurated Upper Cretaceous shale. The highest peaks, on the east and southeast, are composed of slate, but granite forms numerous peaks of nearly equal height in the central and more northerly and westerly areas. These features correspond closely to the descriptions of Mertie and Harrington.[22]

The granite is a gray rock generally of rather coarse and even grain but over considerable areas distinctly a granite porphyry. The granite porphyry, however, seems not to be a border phase.

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[20] Martin, G. C., op. cit., p. 161.
[21] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 66–69.
[22] Idem, p. 28.

In thin section dusty orthoclase and large quartz grains are seen to be the chief minerals. Soda orthoclase and acidic plagioclase are subordinate. Green and brown biotite is fairly common, and unimportant accessories, chiefly magnetite and apatite, are present. The rock is a typical granite.

Small porphyritic dikes closely related to the granite in composition are common near the contact in the slate and probably within the granite itself. Small quartz veins occur in the granite but are not abundant. A basic andesite dike was noted at one place, and float of dark fine-grained rocks at several places indicates that related dikes may be fairly common.

The granite forms an irregularly rounded stock whose walls are inclined at angles of 45° to 90°. As a rule this dip is steeper than the bedding of the surrounding slate, which, nevertheless, is sharply domed. The slate is so much metamorphosed that bedding is commonly destroyed and a steeply inclined jointing imposed upon it. Much of it also is spotted with specks composed chiefly of biotite and muscovite.

The topography of the granite has been produced largely by glaciation (p. 111). Sharp arêtes and cirque forms are common. Many jointed and pointed pinnacles of granite, locally called monument rocks, occur along the divides. Below the ridge crests are great slopes covered with coarse blocky talus, and morainal débris of granite covers most of the lower slopes and valley bottoms.

Von Frank Mountain.—The mountain locally called Von Frank is formed of a rock resembling granite but more properly called quartz monzonite. It has the texture and appearance of granite but is darker gray, the feldspars are orthoclase and plagioclase, the latter near oligoclase, in about equal amounts, and both hornblende and augite are present in addition to quartz and biotite. The writer studied this rock only at its most southwesterly exposure and in hand specimens brought by Mr. Sargent from the summit of Von Frank Mountain. It seems to be an intrusive rock of rather uniform character cut by a few small quartz veins.

The extent of the quartz monzonite is unknown, but it probably constitutes the bulk of the higher peaks in the vicinity and may very likely be connected around the head of Nixon Fork with the similar monzonite of Whirwind Ridge.

The slate that borders the intrusive is much indurated and blocky, like that of the Sunshine Mountains, and forms numerous sharp subsidiary peaks. The structure seems to be complex, unlike that of the simple Sunshine Mountain dome.

Topographically the vicinity of Von Frank Mountain is the most rugged area in the Nixon Fork country. Glaciation has probably assisted in carving its features, particularly on the northern slopes.

Whirlwind Ridge.—Quartz monzonite, seemingly identical in appearance and mineralogy with that of Von Frank Mountain, forms the crest and higher parts of the ridge just north of upper Whirlwind Creek. A notable feature of this intrusive mass is the presence, especially on the northwest, of a thick border of porphyry that seems to be of the same composition as the diorite and at places grades into it, though elsewhere the two seem rather sharply defined. The border probably has a maximum thickness of a few hundred feet and represents the quickly chilled outer margin of the intrusive mass. On the west end of the ridge at some places it completely arches over the crystalline monzonite and conceals it. It is likely that on the east the monzonite connects with that of Von Frank Mountain.

The western part of the ridge is only moderately rugged. In many places the porphyry border stands up in sharp peaks on the spurs. To the east the crest of the ridge breaks up into numerous rather sharp conical peaks.

At the two places examined the monzonite is separated from the limestone to the south by a thin band of slate and sandstone, but at other places it may invade the limestone. The contact seems to be steeply inclined on the south and more gently inclined on the north. The surrounding Upper Cretaceous beds seem to be domed irregularly by the intrusive. They are but little affected by metamorphism.

Canyon Creek.—A narrow strip of granite extends across Canyon Creek along the contact between the Paleozoic limestone and the Upper Cretaceous slate and sandstone. The granite is well exposed in a bluff on Whirlwind Creek, where there has been some desultory prospecting. Elsewhere it was found only as float but abundant enough to mark its occurrence fairly well. It seems to cross Whirlwind Creek but was not examined farther in that direction, so that its relation to the quartz monzonite is unknown.

The rock is a pink granite rich in coarse-grained quartz. Pink alkali feldspar is abundant, much of it weathered badly to sericite, carbonate, and kaolin, and altered plagioclase is present. The rock contains green biotite, green hornblende, and a little tourmaline. The occurrence of the tourmaline is rather unusual. The rock is best classified as a granite.

Careful search at several places failed to reveal the nature of the contact between the granite and the adjacent limestone and shale. The granite probably forms an irregular dikelike mass intruded along the great fault that separates the limestone from the Upper Cretaceous rocks. There is no evidence of notable metamorphism in the adjacent formations.

The granite has a subdued topographic expression and occupies low cols along the interstream ridges between the rugged limestone mountains on one hand and the broken hills of slate and sandstone on the other.

Boulder Creek and Jones Creek.—South of Nixon Fork, extending from Boulder Creek probably as far as Jones Creek, occurs a mass of porphyry which almost certainly represents the top of a granite mass not yet eroded deeply enough to expose the fully crystalline phase. Good exposures of the porphyry in place are found on the smooth slopes west of Boulder Creek. It is either massive or sheeted by close parallel joints. Weathered fragments are yellow or brown, are very resistant, and yield abundant boulders in the creek bed. The porphyry here is very full of dark inclusions of the Upper Cretaceous shale which it invaded. These inclusions are only slightly indurated.

The porphyry as seen in thin section consists of orthoclase phenocrysts, rounded, resorbed quartz grains, and a matrix of fine feldspar rods and quartz. Farther southwest, along a rounded barren ridge, only float is visible. This float is increasingly crystalline toward the center of the mass, and much of it contains coarse flakes of biotite in addition to large phenocrysts of quartz and feldspar.

The sandstones on the southeast dip 20°–30° SE. Elsewhere the structure was not determined. The porphyry doubtless represents the top of an elongated dome.

Area near lower Cottonwood Creek.—An intrusive rock of intermediate composition, probably related to the quartz monzonite, occurs in a small area about 3 miles northwest of the mouth of Cottonwood Creek. It is known only from specimens collected by Mr. Sargent. This rock is darker than typical monzonite and consists of plagioclase, orthoclase, quartz, and accessories, such as augite, biotite, apatite, and magnetite. It is therefore a granodiorite. Probably it is related to the rock in the small area of extrusive rocks near by.

Nixon Fork mines.—The quartz monzonite area at the Nixon Fork mines is described under the heading "Economic geology" (p. 124) in connection with the ore deposits that are so closely related to it.

Crooked Creek.—The area on Crooked Creek also is treated under the heading "Economic geology" on page 139.

DIKES AND SILLS

Innumerable porphyritic dikes and sills cut the Upper Cretaceous sandstone and slate in the general vicinity of the larger intrusive bodies. None of these dikes and sills are shown on the map (pl. 5), although at many places they form the most conspicuous, if not the most extensive portion of the bedrock. Although many of the large intrusive masses lie close to the limestone and even intrude the limestone at the Nixon Fork mines, similar dikes and sills are almost unknown in the limestone. A few dikes cut the limestone at the Nixon Fork mines, but none whatever were seen elsewhere. This seems to indicate that the limestone was peculiarly resistant to injection, whereas the shale and sandstone were peculiarly susceptible.

Sills appear to be more numerous than dikes. Some of them exceed 100 feet in thickness. The thickest dike observed was about 50 feet thick. The best exposures are found in bluffs along streams, such as Nixon Fork and Whirlwind Creek, but fair exposures can be found on many ridges above timber line.

The sills are notably porphyritic. The usual phenocrysts are feldspar; phenocrysts of biotite and quartz are less common. In thin sections of rock from upper Nixon Fork the feldspar is seen to be plagioclase and the accessories to be hornblende, biotite, and magnetite, with traces usually of quartz. This mineral composition corresponds closely to that of the neighboring quartz monzonite, and the rock probably should be called andesite. The sills south of Sunshine Mountains are much richer in large quartz phenocrysts and also contain orthoclase. They are classified as rhyolite or quartz latite porphyry. In most of the sections examined there is intense alteration in the form of replacement by carbonate minerals and to a less extent by sericite, chlorite, and quartz. Some sections seem to contain nearly 50 per cent of calcium carbonate and would approach limestone in chemical composition.

A platy structure is well developed in most of the sills. The plates average 1 to 2 inches in thickness and seem invariably to be parallel to the walls, thus giving a clue to the structure.

The dike rocks of the upper Nixon Fork differ from the sills only in minor features. Generally they are denser, finer grained, and of darker color and lack the sheeting peculiar to the sills. They include types which should probably be classified as dacite porphyry, vogesite, and quartz latite, but all the sections examined contain large amounts of secondary carbonate minerals with some silica replacing both matrix and phenocrysts and seemingly destroying the original ferromagnesian minerals. Pyrite of later introduction than the original minerals is present in some sections.

Dikes near the Sunshine Mountains are of virtually the same composition as the granite (p. 116) and include rhyolite porphyry and soda rhyolite porphyry.

The intrusion of the dikes and sills as a rule metamorphosed the adjacent sedimentary rocks but little if at all. Near the Sunshine Mountains, however, many of the dikes show narrow borders an inch or so in width of altered green slate, spotted with muscovite, biotite, and chlorite, and impregnated with silica. A large dike on Nixon Fork just below Cottonwood Creek has caused extensive slickensiding and some graphitization of the intruded shale.

Many of the dikes and sills are conspicuous topographically, as they are resistant and form long asymmetric ridges, sharp conical peaks, and broken cliffed slopes in the shale areas.

AGE OF ACIDIC INTRUSIVE ROCKS

The bosses, dikes, and sills of acidic intrusive rock cut rocks of Upper Cretaceous and in part perhaps of Eocene age and are believed to be either Eocene or earliest Oligocene. They are undoubtedly closely related to the later extrusive lavas and probably are of nearly contemporaneous formation.

CONTACT BETWEEN PALEOZOIC AND UPPER CRETACEOUS BEDS

The contact between the thick Paleozoic limestone and the Upper Cretaceous beds south of Nixon Fork is of unusual interest. The fossils indicate that the beds are widely separated in age. Such a break must mean either unconformity or faulting. Owing to the heavy cover of residuum and talus the contact was not found definitely exposed, although its zone was examined at numerous places over a distance of more than 20 miles. Several lines of indirect evidence, however, have a bearing on its interpretation.

Topographically the limestone rises abruptly in rugged ranges above a subdued lowland of broken ridges. The contact zone is occupied nearly everywhere by short valleys etched out on the shale at the foot of the limestone ridges, the main drainage being transverse to the contact. Low cols and saddles mark the spurs along the contact. These features and the character of the fragments of the Upper Cretaceous rocks indicate that in most places the softer and finer-grained beds of the Upper Cretaceous lie nearest the limestone.

Ordinarily, where clastic beds like those of the Upper Cretaceous in this region rest unconformably on other rocks, fragments of the underlying formation are found in them, especially in the basal beds near the contact. Not a single fragment of limestone was found in the Upper Cretaceous beds, however, either in the field or in thin sections. These beds consist mainly of fragments of igneous and metamorphic rocks (p. 107).

If the contact is unconformable the Upper Cretaceous beds should overlie the limestone. Although the relations were not positively determined the evidence points rather to the opposite conclusion, that the limestone at present overlies the Upper Cretaceous beds. Near fossil stations 17, 18, and 19 and also near stations 15 and 16 the massive limestone is arched into broken anticlines, which within a few hundred feet of the contact are overturned and dip 75–80° SE. (See fig. 5.) At most other places the dips are variable but steep in diverse directions. The Upper Cretaceous beds near the contact seem to dip rather uniformly to the southeast, as if passing beneath the limestone. Near the junction of Canyon and Whirlwind Creeks the dips over a large area are 15°–45° SE. Near fossil station 7 and near Boulder Creek the dips are monoclinal to the southeast for long distances near the contact.

The inclosed area of Upper Cretaceous beds near the Nixon Fork mines is especially significant. Here the shale and sandstone form a lowland, cut through on the southwest by the monzonite mass, surrounded on all sides by a rugged rim of limestone. The limestone of this rim seems to dip away from the shale as described on page 126, indicating anticlinal structure. This area of Upper Cretaceous beds might be explained in the following ways:

1. As a graben dropped by a rather complicated oval system of normal faults. Such a fault system would be unusual and the location of a graben on an anticline rather anomalous.

2. As an infolded remnant resting unconformably on the limestone. The deposit must then occupy a basinlike area eroded in the limestone. The absence of fragments of limestone and the presence of igneous and metamorphic material in the Upper Cretaceous beds are scarcely explainable on this hypothesis.

One other line of evidence is suggestive. The Upper Cretaceous beds nearly everywhere north of the limestone area are cut by innumerable intrusive dikes and sills. Not a single dike or sill was observed in the adjacent limestone near the contact. Only at the Nixon Fork mines, where a major monzonite mass itself invades limestone, are a very few dikes present in that formation. If the limestone underlies the Upper Cretaceous beds unconformably and presumably at no great depth, along the contact, then these small intrusive masses must have risen up through it, and their absence in the limestone, where it is exposed, is most remarkable.

All the features of this contact, it is believed, may be satisfactorily explained as a result of thrust faulting. Under this interpretation the limestone has been thrust upward and to the northwest, overriding the Upper Cretaceous beds along a front of at least 30 miles and for a maximum distance of at least 6 or 7 miles. Its position seemingly above the shale is thus readily explained, and so also is the absence of fragments of limestone in the Upper Cretaceous beds. The dip of the Upper Cretaceous beds beneath the limestone is natural, and the dikes and sills may be considered as rising

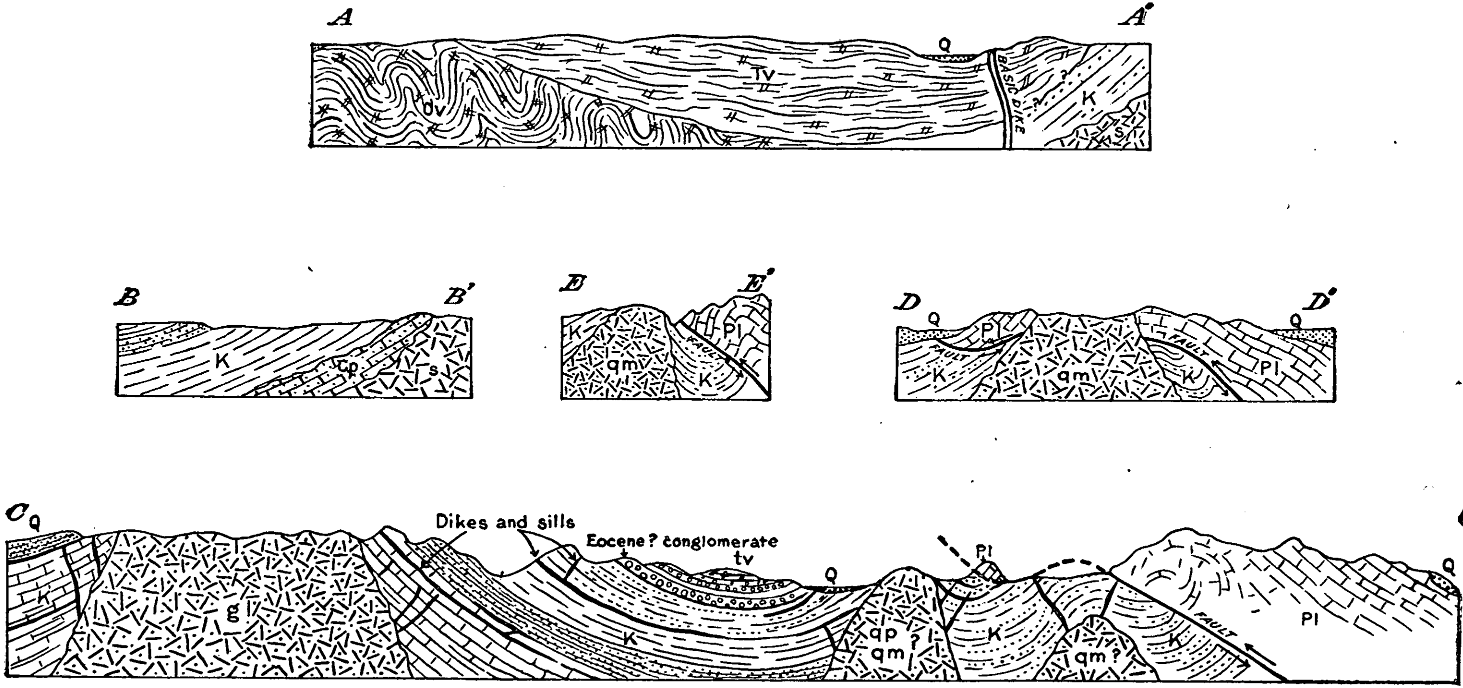


FIGURE 5.—Structure sections in the Nixon Fork country. (See locations on pl. 5.) Q, Quaternary; K, Upper Cretaceous; Cp, Permian; Pl, Paleozoic limestone; qm, quartz monzonite; qp, quartz porphyry; g, granite; s, schist; Ty, Tertiary volcanic rocks; ov, older volcanic rocks

through the yielding thin-bedded shale and as being checked by the massive limestone above. The area of Upper Cretaceous beds at the Nixon Fork mines thus occupies naturally the crest of a breached fold domed by an intrusive mass which penetrated barely through the shale into the overlying limestone. This interpretation is illustrated in Figure 5.

Certain minor features may seem to be not fully in accord with this interpretation. The main contact on the northwest is rather straighter than might be expected of a thrust fault, although at places it is sinuous. Moreover, no outliers of limestone were found to the northwest beyond the border of the main mass. Both these facts may well be explained as a result of later folding, which has caused the thrust plane to dip steeply to the southeast along this front.

One other explanation is possible. The main northwestern contact might be a normal fault and the area of Upper Cretaceous beds at the Nixon Fork mines might be a graben, as previously mentioned (p. 121). On this assumption, however, the shale should dip away from rather than toward the limestone, owing to drag. Also, the occurrence of the intrusive mass of the Nixon Fork mines at the center of a graben would be anomalous.

The evidence in favor of thrust faulting is strong but not conclusive, and the field should be searched for other facts. If the thrust hypothesis is correct, then the fault is of later age than the Upper Cretaceous beds involved but earlier than the quartz monzonite at the Nixon Fork mines, which cuts through it into the overlying limestone, and also earlier than much of the folding which accompanied the intrusion of the larger igneous masses, approximately in Eocene time. The overthrust would belong therefore to an early stage in those violent dynamic disturbances which took place during or immediately after the Eocene epoch.

ECONOMIC GEOLOGY

MINES NEAR NIXON FORK

The only notable mining operations in the Nixon Fork country have been in a small area bordering the monzonite mass in the southwestern part of the great limestone range south of Nixon Fork. A brief description of this region by Martin[28] was published in 1921. The present description is more complete, although only a few days were available for the examination and several of these were almost continuously rainy. Furthermore, the underground workings had been closed down and were mostly inaccessible, so

[28] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, pp. 149–161, 1921.

that little could be seen of the actual occurrence of the ore. On the other hand, the people living in the district assisted the Survey party freely in every possible way. The writer is much indebted to all those who were so uniformly courteous and helpful, particularly to Mr. E. M. Whalen, joint owner and operator of the principal developed mine.

INTRUSIVE QUARTZ MONZONITE AND PORPHYRY

The most striking geologic feature of the mining district is a small elongated body of quartz monzonite and associated porphyry, very similar in composition and occurrence to the other larger intrusive masses (pp. 115–118). Its area and relations are shown in Plate 6. It differs from most of the other intrusive masses mainly in that at places it cuts the Ordovician and Silurian limestone as well as the Upper Cretaceous slate and in that the mineralization accompanying the intrusion was more extensive than elsewhere.

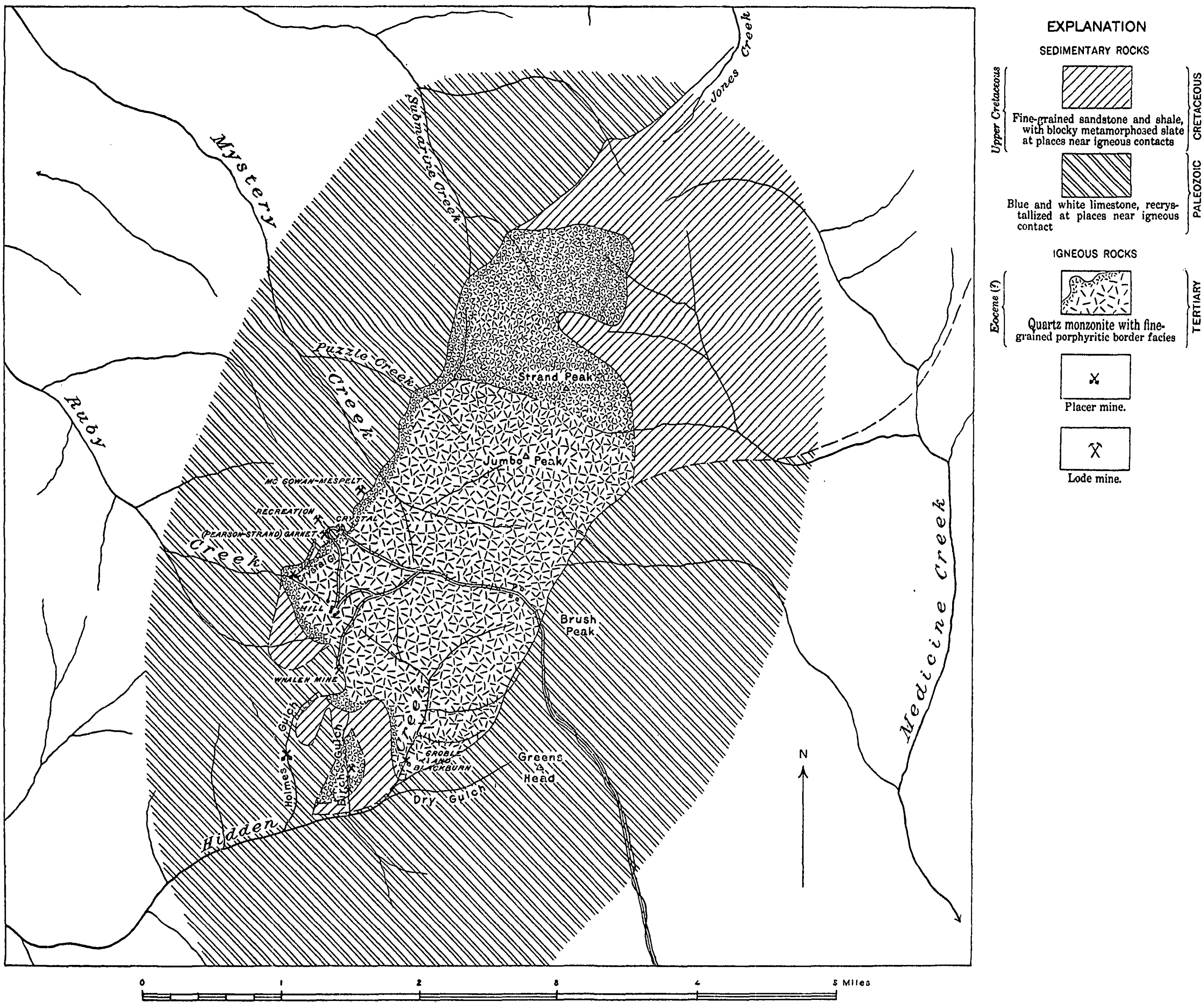
The monzonite is of rather variable appearance. It closely resembles granite, but as a rule it is rather darker than true granite. Thin sections show both orthoclase and plagioclase feldspars, quartz, brown biotite, green hornblende, and minor accessories, such as apatite, iron oxides, and pyroxene. The monzonite is exposed in a few low ridges, as those near the Whalen shaft and west of Brushy Peak, and in numerous road cuts and prospect pits. It also forms two small cliffed masses on Jumbo Peak. Between the Whalen shaft and the Pearson-Strand claims the monzonite contains many dark xenolithic patches, which probably represent incompletely absorbed inclusions of shale.

Porphyry closely related in composition to the quartz monzonite occurs in the area in two ways—as a chilled border phase and as dikes. The porphyry border partly encircles the monzonite, separating it from the intruded rocks. It probably is not more than 100 to 200 feet thick at many places. The outcrop is usually only a few hundred feet in width, but at the northeast it broadens into a wide nose, forming the whole of Strand Peak and completely arching over the monzonite beneath. There the porphyry contains abundant inclusions of the overlying intruded Upper Cretaceous shale.

The porphyry dikes cut both the limestone and slate and probably the monzonite as well, for porphyry float is abundant in road cuts and prospect pits within the monzonite. Pearson and Strand state that they have followed a dike from monzonite into limestone in prospecting.

Martin [24] also describes a basic dike cutting the limestone.

[24] Martin, G. C., op. cit., p. 157.



GEOLOGIC SKETCH MAP OF THE VICINITY OF THE NIXON FORK MINES

In part from geologic maps prepared by Livingston Wernecke of Alaska Treadwell Gold Mining Co.

UPPER CRETACEOUS (?) SLATE AND SHALE

Shaly rocks cover a large area to the northeast of the monzonite and near the intrusive mass have been metamorphosed into small patches of slate. The fossil collections from these rocks are poor, but in conjunction with the lithology they indicate almost unmistakably that the rocks belong to the Upper Cretaceous series as described on pages 107–110. Southwest of the monzonite the slate occurs only as float in the placer mines and ditches. Blocky pieces a foot through are abundant at the Groble & Blackburn placer.

PALEOZOIC LIMESTONE

The limestone surrounding the monzonite and slate belongs to the Paleozoic limestone formation and resembles most closely the thicker-bedded phase described on page 102. The beds in this locality, however, range from 3 to 12 inches in thickness as a rule. On a fresh fracture the rock is gray-blue, and it is commonly called the "blue lime." It is seamed by a great many small veinlets of pure white calcite.

Traces of fossils are found at many places, but good material is generally obtained only in float. Collections Nos. 1 and 3 are the only ones obtained near the mining district. Fossils similar to those in No. 3 can be found sparingly in places on Submarine Creek, and traces of fossils were also seen on Brushy Peak. Fossils are reported also from other localities not visited. Collections Nos. 1 and 3 indicate that the rock is of middle Paleozoic age, probably in part Ordovician and in part Silurian.

The thickness of limestone about the borders of the intrusive mass was not determined, but probably it is more than 2,000 feet, although less than the thickness of limestone farther east.

At most points near the intrusive mass the limestone has been mildly metamorphosed. On the southeast border of the monzonite the chief effect is recrystallization, accompanied by a yellow color and some silicification. On the northwest border metamorphism has been more pronounced in certain irregular patches a few hundred feet in length or breadth. These effects are described later in connection with the associated mineralization. Where slate intervenes between the limestone and the monzonite metamorphism is scarcely noticeable in the limestone.

The topography of the limestone is much bolder than that of the shale and monzonite. It forms an imperfect rim of steep or cliffy slopes encircling the lower and more rolling hills of monzonite and shale. This rim, however, is trenched by the gorges of many small outward-flowing streams. The limestone contact, whether with monzonite or shale or porphyry, usually occupies cols on the interstream ridges.

STRUCTURE

The structure of the region was not well worked out, but the sedimentary rocks are believed to form an irregular anticline arched up by the intrusion of the monzonite mass. South of the monzonite mass the asymmetry of ridges strongly suggests dominant southward dips, and definite southward dips were observed on Brushy Peak, although associated with dips in other directions. Along Submarine Creek, north of the intrusive mass, dips of 20°–40° NW. were seen clearly in good exposures for a distance of a mile or more. The structure of the slate and shale could not be made out at any place.

The upper surface of the monzonite and the associated porphyry mass almost certainly was dome shaped, and the borders dip beneath the sedimentary beds at an angle steeper than that of the bedding. The straightness of the contact and the virtual absence of the porphyry border on the south suggest that the dip there is very steep, whereas on the north it is probably much less, the porphyry border being well defined at most places and the contact irregularly sinuous. This relation, however, is probably due in part to faulting. The great extent of shale and porphyry on the northeast compared to that on the southwest also suggests that the anticline plunges much more steeply on the southwest. This interpretation, as stated on page 103, is based on the assumption, not fully proved, that the limestone is overthrust on the shale by faulting, as shown in Plate 6. This assumption is based partly on the fact that the limestone along its contact with the shale stands high above it topographically and appears to dip away from it, and that the monzonite and porphyry, coming from below, appear to have invaded the shale at many places without having encountered the limestone. The shale, moreover, as discussed on pages 107–110, shows none of the features that would be expected on the interpretation that it overlies the limestone.

The structural relations are undoubtedly complicated by normal faulting later than the supposed thrust faulting, the folding, and the intrusion of the monzonite mass. A partial examination of the underground workings at the Whalen shaft showed many small slips and shear zones, and in a prospect pit near by recrystallized limestone is clearly in fault contact with monzonite (p. 129). Normal faulting, however, can not be mainly responsible for the outlines of the intrusive mass, because the contact effects about its border are continuous and the thin border of porphyry is very persistent. Extensive faulting would cause these thin zones to be cut out and would bring the monzonite into contact with unaltered sediments at many places.

Erosion does not seem to have cut very deeply into the monzonite mass, and it is unlikely that the highest point of the intrusive mass ever stood much more than 1,000 feet above its present surface.

ORE DEPOSITS

HISTORICAL NOTES

Martin summarizes the history of the discovery and development of this district prior to 1920 as follows:[25]

> For several years a few small placer mines have been worked on Ruby and Hidden creeks, which are tributary to Nixon Fork from the south. In the course of this placer mining it was found that the gold became more abundant as it was followed up the creeks, but that above certain points it was no longer found. Shafts sunk into the bedrock at the limits of the placer gold revealed rich gold-bearing lodes lying on or near a monzonite-limestone contact. Further prospecting at this contact revealed the presence of other gold lodes. Shafts were sunk early in 1919 on two of the more promising of these lodes, and from one of them several hundred tons of high-grade ore was mined in the winter of 1919–20. This ore was sledded to Kuskokwim River, and in the summer of 1920 it was shipped to the Tacoma smelter. In the meantime prospectors had traced the contact of the monzonite boss near the margin of which the known lodes lie, had staked claims along probably the entire contact, over much, if not all, of the monzonite area, and over part of the surrounding limestone, and had dug many trenches and pits along the contact and at other places, revealing the presence of many ore bodies of different sizes and richness. Many of the more promising claims, including the one from which ore had been shipped, passed into the control of the Alaska Treadwell Gold Mining Co. and associated interests early in 1920. During the summer of 1920 the Alaska Treadwell Co. was actively engaged in prospecting its holdings, and prospecting was being continued on a smaller scale on some of the other claims.

The operating company was the Treadwell Yukon Co. (Ltd.), owned and controlled by the Alaska Treadwell Gold Mining Co. and locally called the Treadwell Co. From 1920 until late in 1923 this company actively prospected and developed some of the more promising properties, particularly three groups of claims—those of Whalen & Griffin, Pearson & Strand, and McGowan & Mespelt. The original and principal property was that of Whalen & Griffin. Considerable work was done also on the Pearson-Strand property but little on the third group of claims.

In 1921 a 10-stamp mill was erected, and this mill is stated to have produced $114,024 in gold during four months of operation in 1922.[26] The mill was also operated in 1923. The total output is reported locally and unofficially as about $235,000. This gold came chiefly from the Whalen mine and some of it from the Pear-

[25] Martin, G. C., Gold lodes in the upper Kuskokwim region: U. S. Geol. Survey Bull. 722, p. 149, 1921.

[26] Weed, W. H., Mines Handbook, vol. 16, p. 175, 1925.

son-Strand claims. The operations are generally admitted to have been at a loss.

During this time the company maintained a camp of 20 or 30 men and kept the 12 miles of wagon road to Berrys Landing in passable condition.

The best ore in sight at the Whalen mine had by this time been nearly exhausted, and no promising new ore bodies had been located. Accordingly, the company decided to abandon the venture, and the claims reverted to their original owners. The mill still belonged to the Treadwell Yukon Co. (Ltd.). There was still some good ore at the Whalen shaft, much of it broken but not milled, owing to a fire which had destroyed the engine house. The mine and mill were therefore leased to an association of four men, including E. M. Whalen, one of the owners, and these four, assisted by several hired men, milled the remaining ore in 1924. It was generally reported in August that the clean-up for the season would run about $80,000. After this the mine was to be virtually abandoned, although Mr. Whalen expected to do some further prospecting underground.

Pearson & Strand were actively prospecting in 1924, but the McGowan & Mespelt claims were idle.

In addition to the lode claims several small placers had been operated continuously, yielding a few thousand dollars yearly. From 1920 to 1924 the region had been pretty thoroughly prospected both for lodes and for placer gold.

LODES

WHALEN MINE

The Whalen mine is on a low knob at the head of Holmes Gulch, in an altered portion of the Paleozoic limestone or "blue lime." The limestone forms an irregular narrow tongue or possibly even an isolated "island," although the ridge to the west was not examined to determine this relation. The topography suggests that slate may intervene along the saddle between this limestone and the main front farther west.

The altered limestone is less than 200 feet from exposures of fully crystalline quartz monzonite, and it seems likely that the porphyry border usually present around the monzonite has been cut out at the surface by faulting. In a prospect shaft 300 feet about N. 20° E. from the main shaft the contact is very clearly a fault between limestone and monzonite. The fault trends almost toward the shaft. Contrary to expectation monzonite forms the hanging wall, as the fault dips about 80° SE. The drag also suggests that monzonite had dropped against limestone, possibly as the result of some later reversed movement along a previously normal fault by which limestone must have been dropped against monzonite, cutting out the porphyry border.

Mr. Whalen conducted the writer down the shaft to the 100-foot level, where the ice prevented further descent. The shaft is inclined about 80°, away from the monzonite contact. Down to the 100-foot level it penetrates altered limestone. A drift trending N. 15° E. also penetrates limestone for about 50 feet, where there is a fault contact with much altered porphyry, in which the drift extends 25 feet. This fault trends nearly east, and dips steeply. The opposite drift to the southwest is in limestone for 50 feet, as far as it was accessible. So also is a short crosscut to the south. Jointing, slickensiding, gouge, and brecciation show evidence of movement with intense shearing.

Much of the altered limestone is a white or gray rock, recrystallized but not otherwise greatly modified. Mixed through this rock in irregular streaks or bands are masses of darker rock that is much more severely altered. This darker rock consists of typical contact-metamorphic silicates, such as zoisite, pyroxenes, garnet, and similar minerals, together with a great deal of fine-grained quartz, which replaces the original limestone. These masses in many places are closely associated with irregular knots and blebs of much modified intrusive matter, doubtless originally monzonitic.

The ore occurred in irregular masses and ore shoots not confined to any definite vein or structure. It has been almost wholly oxidized to the bottom of the workings, but enough of primary ore remains to indicate that it consisted mainly of pyritic sulphides, especially pyrite and chalcopyrite, with free gold, the gold being the chief portion of value. The sulphides have altered to limonite, malachite, and black earthy oxides of copper, and the ratio of copper to iron is rather high. The circulating ground water which assisted in this oxidation has modified considerably the original distribution of the copper and carried it into shear zones where no ore was originally present. For this reason the gold does not follow strictly the distribution of the copper minerals, although in general the richest gold-bearing material corresponds to the material that has the higher content of copper. The amount of copper is small, probably not more than 1 or 2 per cent for any considerable tonnage of ore.

The metals were irregularly distributed, but considerable good ore running $70 and more to the ton was extracted. Martin [27] stated that in 1920 a crosscut on the 40-foot level showed 32 feet of ore, reported to average $68 a ton in gold. The "clean-up" ore being

[27] Martin, G. C., op. cit., p. 160.

milled in 1924 was estimated by the operators to run about $56 a ton.

In addition to gold, the ore carried from 1 to 3 ounces of silver to the ton. The richest ore was restricted definitely to the upper part of the workings, above the 100-foot level, and was mined out above this level until the surface caved into a large "glory hole." One or two pockets of ore, smaller and not so rich, were found between the 100 and 200 foot levels but nothing of great value.

Two main significant facts can be gleaned from the description of this mine. First, the ore forms a fairly typical contact-metamorphic deposit; second, its richness near the surface was almost certainly due in a considerable measure to enrichment. As the other deposits in this district are of much the same character the bearing of these facts on the future possibilities of the mines will be discussed collectively elsewhere (pp. 139–140).

The ore was hauled to the mill, half a mile away, on an easy downhill grade, in wagons. After passing through the stamps it was treated by amalgamation. Tables were used, however, to concentrate the pyritic and cupriferous minerals, which carried most of the gold. It is said that this treatment left $7 to $8 in gold to the ton in the slimes. These slimes at first were ponded, but later for lack of convenient space no effort was made to save them for possible further treatment.

PEARSON-STRAND CLAIMS

The Pearson-Strand claims lie just south of the divide between Ruby and Mystery Creeks, at the head of a small ravine called Crystal Gulch. The limestone here forms an irregular salient, topping the ridge and presumably overlying the sloping surface of the monzonite. The prospects are in more or less altered limestone at and near the contact. The underground workings were not examined, and the structural relations are not clear, but there is no definite evidence of faulting. The porphyry border of the monzonite seems to be present here or near by. The shape of the salient of limestone also suggests that it overlies the monzonite without much disturbance, so that faulting was probably of less consequence than at the Whalen mine.

Four main openings have been used in prospecting these claims. The Keen shaft and Crystal shaft have been abandoned for some years, and the following descriptions by Martin[28] are quoted:

> The Keen shaft is on the wagon road near the head of Crystal Gulch, about 1,000 feet east of the western border of the monzonite. It is said to have revealed a vein 4 feet wide, and material from this vein on the dump shows

[28] Martin, G. C., op. cit., pp. 159–160.

quartz with much yellow stain containing numerous small flakes of a grayish mineral with metallic luster (probably arsenopyrite) and a few small cubes of pyrite.

The Crystal shaft is near the head of Crystal Gulch, a tributary of Ruby Creek. It is in the monzonite not far from the limestone. The shaft was begun in January, 1919, and was sunk in the winter of 1919–20 to a depth of 65 feet. The workings, which were inaccessible at the time of the writer's visit, were made for the purpose of mining whatever ore could then be shipped at a profit. It is said that the ore body thus mined was a lens 10 by 20 by 65 feet in dimensions and that there was "6 feet of sulphides in the bottom of the shaft." The ore is unoxidized and, as shown by specimens on the dump, consists of chalcopyrite, pyrite, and bornite in a gangue of calcite, siderite, and a zeolite, probably scolecite.

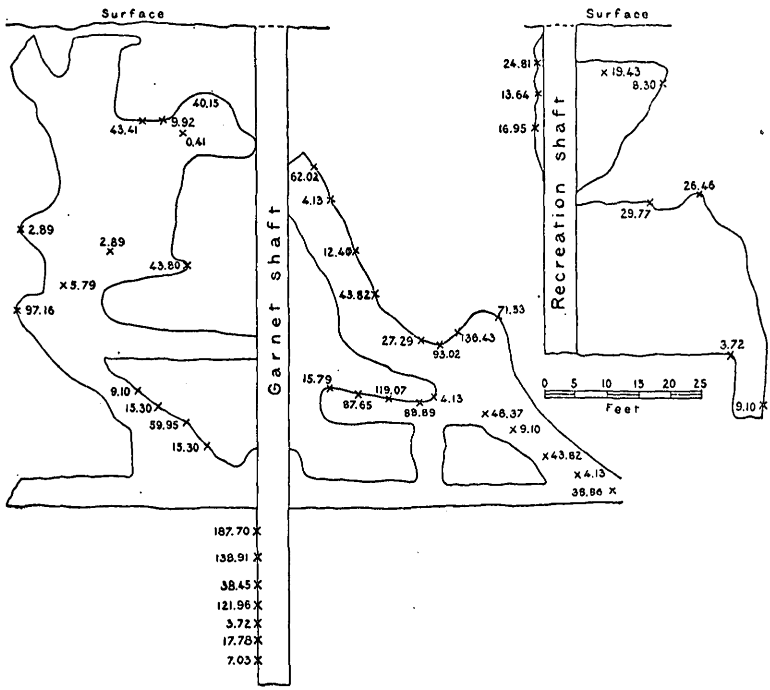


FIGURE 6.—Assay plan of Garnet and Recreation shafts. Figures indicate assay value in dollars to the ton

The Garnet shaft is south of the wagon road near the head of Crystal Gulch. It is in limestone, about 100 feet from the outcrop of the monzonite, but masses of monzonite show in the lower workings. The shaft was 76 feet deep when visited, and there was about 70 feet of drift. At the surface the ore is the full width of the shaft which does not show the walls. At the bottom of the shaft the vein is not more than 4 feet wide. The ore, which is thoroughly oxidized, consists of chloritic material, iron ores, and quartz with many thin films and small masses of malachite and azurite.

The Garnet shaft was the principal scene of the Treadwell Co.'s later explorations on this property. The shaft was sunk to 270 feet, and a winze was driven 40 feet deeper. The lower workings were in monzonite with little or no ore. In the upper part of the workings some very rich ore was found, mixed in spotty fashion with much lean material, as is well illustrated in the assay plan (fig. 6). Some of this ore was hauled to the mill and treated. The ore was at least partly unoxidized, as pyrite and chalcopyrite show in the dump material.

Near the Garnet shaft and the near-by Crystal shaft there is a considerable body of dense red garnet rock, which represents limestone very intensely altered and replaced. Martin[29] described the Recreation shaft as being

in the limestone about 600 feet west of the margin of the monzonite. A shaft 50 feet deep with a drift 35 feet long exposes a vein having a maximum thickness of 6 feet. The vein has been traced by surface cuts for about 200 feet. The ore is thoroughly oxidized and shows in thin section iron oxides and hydroxides, quartz, chlorite, which is in part spherulitic, malachite, probably some azurite, and a little apatite. The specimens show much dark-green and some blue stain, probably derived from copper minerals. No sulphides or metallic minerals were seen.

This shaft also was used by the Treadwell Co. and deepened to about 100 feet. The assay plan (fig. 6) indicates something of the distribution and amount of the valuable metals. A little of this ore also was milled.

The ore on the dump, as stated by Martin, consists mainly of oxides and carbonates of copper but contains also unaltered cores of chalcopyrite and bornite. The associated rock seems to be simply silicified limestone and lacks the contact minerals common at other places.

During 1924 Pearson & Strand sunk three shafts 25 to 40 feet in depth and did some little drifting in ground 150 to 300 feet south of the Recreation shaft. They found a loose capping of decomposed limestone containing very rich ore. Probably about 100 tons of this material was on the dump. It consisted of rich copper carbonate and oxide with some secondary chalcocite and abundant visible traces of free gold. It is stated that the value of some of this ore will run into hundreds of dollars a ton. As a whole, however, it probably averages between $50 and $100 a ton.

The character of this ore and the assay plans of the Garnet and Recreation shafts show clearly that enrichment has been active here as at the Whalen mine, and the surface ore will doubtless prove to be considerably richer than that below.

The Treadwell officials claimed that this ore responded to treatment much less satisfactorily than that of the Whalen mine. Unverified reports say that the recovery was not more than 50 per cent of the value. The greater amount of unaltered sulphides present in the ore doubtless explains its more refractory nature. These sul-

[29] Martin, G. C., op. cit., p. 160.

phides probably remain because there has been less fracturing and crushing since the ore formed, and leaching has been less thorough. Some other treatment than simple amalgamation will probably be required for the recovery of the gold in this ore.

The presence of porphyry dikes cutting the limestone at these prospects should be noted. The porphyry float shows at the surface, and Pearson & Strand state that in prospecting they have traced two dikes, each 30 or 40 feet wide, from the vicinity of the Recreation shaft southward across Crystal Gulch and beyond Ruby Creek. Some of the ore in the limestone may follow in general the location of such dikes.

M'GOWAN-MESPELT CLAIMS

The McGowan-Mespelt property, often called the Southern Cross, lies on the slopes leading to Mystery Creek, several hundred feet from the Pearson-Strand claims and in a similar position along the limestone-monzonite contact. Nothing was being done at these claims in 1924, the owners were absent, and for lack of time the claims were not visited. The following deseriptions from Martin[30] apply to this property.

> The Garnet trench is on the contact between the monzonite and limestone, south of Mystery Creek and near the northeast corner of the Southern Cross claim. The ore consists chiefly of garnet containing many thin films and small masses of malachite and azurite. The thin section shows, in addition to garnet, augite, a little sericitized plagioclase, apatite, epidote, and chloritic material.
>
> The Twin shafts are near the center of the Southern Cross claim. They are in an oxidized zone on the contact of a fine-grained porphyry dike intrusive into limestone. The ore was so much decomposed that no microscopic study or determination of the constituent minerals was possible. It is said to carry about $10 worth of gold per ton.

The writer later met Mr. Charles Mespelt, one of the owners, who said that the upper 30 feet of the ore in a 50-foot shaft, sampled and assayed by Mr. Bullard, of the Treadwell Co., averaged $90 to the ton in gold. The material from a 20-foot shaft and 6-foot drift in rotten porphyry along the contact averaged $20 a ton. It is plain that the prospect resembles closely those already described.

GENERAL FEATURES OF THE PRINCIPAL LODES

The ores of the three lode claims above described, which constitute the only notable claims in the district, are of the type commonly called contact or contact-metamorphic deposits, such as are formed typically around the borders of an igneous intrusive mass, especially in limestone wall rock. The ores were deposited from rising

[30] Martin, G. C., op. cit., pp. 160–161.

solutions given off from the monzonite as it cooled and crystallized. These solutions were fairly hot. They contained gold and copper and carried much silica and other common substances. On reaching the limestone they found a favorable place to deposit their heavy mineral content, and they penetrated along any convenient fractures, bedding planes, or cavities, irregularly replacing the limestone, altering it to quartz and silicates, and depositing copper and gold.

Such ore bodies are usually irregularly distributed more or less along the contact but in places even several hundred feet from it. They occur in localized ore shoots or bunches, and the valuable material is generally spotty. Most of the ore bodies seem to have been rather small, generally less than 100 feet in lateral or vertical extent, and other ore bodies that may be discovered will probably be of similar dimensions.

ENRICHMENT

Enrichment is the process by which the ore near the surface has been modified so that its valuable content runs much higher than that of the material below. It has come about chiefly in three ways. First, the limestone is easily broken down and washed away; the gold, which is heavier, tends to remain behind and become concentrated in the soil and loose rock where the ore body was exposed. Some gold, however, has also been carried down the gulches to form placer deposits. Second, the limestone is much more soluble than the gold, and it has been dissolved, decomposed, and carried away in solution, leaving behind a loose mantle of soil and rock containing most of the original metallic matter. Third, gold and especially copper are themselves somewhat soluble and tend to be dissolved and carried downward by ground water. When they come into contact with unaltered sulphides they are reprecipitated on the sulphides, thus enriching the original deposit. The oxidized nature of the ore bears abundant witness to the effectiveness of these processes of enrichment, especially in the upper 100 feet. It is not likely that unusually rich ore running more than \$50 or \$100 to the ton will be discovered below this depth. Oxidation has also been effective in freeing the gold from its association with the copper sulphides and rendering it free milling. Ore discovered below 100 or 200 feet in depth will probably be largely unaltered sulphide and not as suitable for amalgamation as that above.

PROSPECTING

Contact-metamorphic ore bodies are not necessarily confined strictly to the contact of the igneous mass. Even the Treadwell Co., in the writer's opinion, stuck rather too closely to the immediate vicinity of the contact in exploring the ore bodies. Surface outcrops show that ore may occur several hundred feet from the monzonite. In the vicinity of known ore bodies, therefore, surface prospecting anywhere in the limestone is justified, and underground it is fully as desirable to drive crosscuts away from the contact as toward it, at least for distances of a few hundred feet. The vicinity of dikes that cut the limestone near the monzonite is probably an especially favorable place for prospecting.

GROSHONG CLAIMS

H. Y. Groshong and a partner own four lode claims lying above two placer claims on Birch Gulch. The lode claims so far have yielded only placer gold, which is fairly coarse and little worn and evidently not far removed from its original source. There seems to be no copper with the gold. Mr. Groshong has spent several years sinking many pits in endeavoring to discover the source of this gold. He believes it to be connected with a porphyry dike that is supposed to cut the slate bedrock in the vicinity. Porphyry boulders are abundant, but whether or not they come from a dike or merely from the chilled border of the monzonite is uncertain. The occurrence of porphyry bedrock in the placer below might suggest that this is the outer shell of the intrusive monzonite. Dikes, however, may occur anywhere.

A tongue or perhaps an isolated mass of limestone projects into the slate here and seems to be faulted against slate or mixed slate and porphyry on the southeast. The rock is blue limestone, much veined by calcite and strongly recrystallized.

OTHER LODE PROSPECTS

Martin[31] describes the Matthews & Blackburn prospect, "in the valley of Hidden Creek near the south end of the area of monzonite. Only a shallow excavation had been made * * * and no well-defined ore body exposed. The prospect is situated on the outcrop of a basic dike intrusive into limestone, near the margin of the main mass of monzonite." The dike is the one mentioned on page 161. The writer did not visit this prospect, which never amounted to anything. Only stains of copper and a little gold were found, it is said, all the gold within the monzonite.

The margin of the intrusive mass and much of its surface as well have been pretty thoroughly and rather intelligently prospected by shallow pits and trenches in search of outcrops of mineralized rock. The porphyry knob at Strand Peak in particular is covered by pits, trenches, shallow shafts, and tunnels. The porphyry contains abun-

[31] Martin, G. C., op. cit., p. 161.

dant streaks and masses of shale and rusty iron stains suggesting mineralization, but it is said that scarcely a trace of gold was found.

Even in the limestone away from the contact with the monzonite and in the shale area to the northeast many pits have been dug, but none of them ever yielded anything encouraging.

PLACERS

GENERAL FEATURES

Placers were discovered before the lodes, and prospecting for placer gold has gone on almost continuously. Only four workable deposits, all of small size and low grade, have been found. All are unfavorably situated for obtaining water. No streams of any consequence flow through the area, and the placers are mainly near the heads of small creeks that are dry except for brief periods early in spring and after the heavy summer rains. These conditions make operations difficult in ground which, under more favorable conditions, would have yielded profits for a short time.

HIDDEN CREEK

F. E. Matthews, of Berrys Landing, owns the largest placer in the district. This property was operated in 1924 by Charles Groble and Lewis Blackburn. Martin[32] in 1920 reported that "the pay gravel is said to be 75 to 125 feet wide, and it has been shoveled in to a depth of about 4 feet." Operations since then have been extensive, and a large area of ground has been worked out.

The covering over bedrock is 10 or 12 feet deep. The upper 3 or 4 feet consists of muck, which is removed by ground-sluicing. The lower part is composed of coarse gravel, boulders, and sand with little silt. A drag-line scraper is used to remove the boulders, which range from 1 to 3 feet in diameter. They consist chiefly of three kinds of material—blocks of dense slate with rectangular sides, rough blocks of yellow porphyry, and rounded boulders of monzonite. The bedrock is rotten monzonite, although slate tops the ridge to the northwest and limestone lies near by on the southeast. The stream appears to have trenched down into the intrusive rock beneath the overlying sediments. The monzonite makes an excellent floor, easily worked and cleaned.

All the gold occurs near bedrock and is said to run about 50 cents to the square foot. About $14,000 is said to have been cleaned up in 1923, and rather less was expected in 1924.

Native bismuth is rather abundant in the black sand recovered with gold at this placer and occurs also in the other placers of the

[32] Martin, G. C., op. cit., p. 161.

district. The writer saw one nugget of bismuth an inch in diameter. The source of this material is unknown, and little if any search has been made for it.

BIRCH GULCH

Mr. Groshong, whose lode claims are described on page 135, has two placer claims lower down on the same gulch, which he had leased in 1924 to two men, who had just completed a ditch more than a mile long and expected to take out a little gold late in the season. The porphyry bedrock is said to lie about 24 feet below the surface. Very large boulders occur in the poorly sorted overburden. The pay probably is narrow and patchy, for the gulch is a very irregular steep channel, usually dry. The placer gold found just above on the lode claims is coarse and little worn.

HOLMES GULCH

A placer property on Holmes Gulch, owned by E. M. Whalen, the owner of the Whalen mine, has produced gold for several years and was being worked by Jensen & Matson in 1924. In tracing gold up this gulch the lodes at the Whalen mine were discovered.

The stream channel from the Whalen mine down to the placer, a distance of about three-quarters of a mile, seems to be mainly or wholly in limestone, although the float on the slopes just to the southeast is composed of slate and porphyry. The placer bedrock is limestone, partly blue and cavernous and partly what the operators call a "yellow sandy lime." This yellow rock may be a slightly altered and recrystallized phase of the blue limestone, and suggests that the monzonite is near the surface. The surface of the blue limestone is very rough and hard to clean; the yellow rock is much easier cleaned.

The gravel is 9 or 10 feet in depth and contains but little muck. It is very coarse and hard to handle. The coarsest boulders are porphyry. Fine-grained boulders of monzonite are present, and limestone boulders are abundant. Some of these boulders bear copper stains, indicating that they probably come from the lodes near the Whalen mine. Some of the gold itself contains fragments of silicified limestone stained with copper. Some of the coarse gold bears square and rectangular impressions, evidently those of pyrite crystals among which it was deposited. It seems fairly certain that the Whalen lodes have furnished most if not all of this placer gold.

The black sand recovered with the gold consists chiefly of magnetite but contains traces of bismuth.

The pay gravel is said to be poor and spotty, and the operators stated that they were not making expenses.

CRYSTAL GULCH

At the lower end of Crystal Gulch and on Ruby Creek just below it small placers have been worked for several years. Pearson & Strand were doing a little mining in 1924 on Crystal Gulch. The ground was reported to be very poor, running only 15 to 25 cents to the square foot. All the better ground has been worked out.

The gold in these placers doubtless is derived mainly from the Pearson-Strand lode claims at the head of Crystal Gulch. Here, as at the other placers, a trace of bismuth is reported. These placers have also yielded a considerable amount of coarse lump magnetite, such as is common in many contact-metamorphic deposits in limestone in other regions, though it has not been noted in any of the developed workings here. This fact suggests that possibly some other ore body not yet discovered may have contributed to this placer gold. The source of this material might be worth investigation.

OTHER PLACER PROSPECTS

On almost every creek and gulch within this district more or less prospecting for placer gold has been done without any encouraging results, except at the four localities described.

RECOMMENDATIONS FOR PLACER PROSPECTING

A few generalizations regarding placer prospecting seem safe. First, all streams and gulches that drain nothing but areas of unaltered limestone ("blue lime") are not worth prospecting. Such streams, for instance, are those draining southeastward from Greens Head and Brushy Peak.

Second, a stream or gulch draining the monzonite area or some portion of its contact is suitable prospecting territory within and near the monzonite but for not more than a mile away from the monzonite. The gold does not occur in great quantity originally and becomes scattered quickly.

Third, gulches heading in or near known lode deposits are the most favorable areas for prospecting. It would seem, therefore, that the best remaining area is Mystery Creek and gulches draining into it, from the Southern Cross or McGowan-Mespelt claims. So far no pay ground has been discovered below these prospects. Possibly, however, none exists.

In view of the amount of prospecting already done and the nature of the developed placers, it appears unlikely that any placer ground of large area or great richness remains undiscovered. Small amounts of pay dirt may yet be found, however. There is little or no hope that large areas of low-grade ground suitable for dredging exist.

Wherever placer gold is discovered it should stimulate search for lode deposits. The character of the rocks and minerals associated with the gold should be studied and their source sought in deposits of similar kind upstream. The source of the gold on Hidden Creek, the most productive placer stream in the district, has never been found. The valley of this creek is much larger than any of the others and drains a large area of monzonite as well as smaller areas of slate and limestone. This gold may perhaps have come from a large number of small and insignificant veins in the monzonite and porphyry. On the other hand, it may have come from contact deposits similar to those already discovered but now almost or entirely eroded away. It hardly comes from any known contact deposit. The association of gold with bismuth may assist in locating the source, and bismuth itself in any notable quantity would be worth discovering.

DEPOSITS ON CROOKED CREEK

West by southwest from the Nixon Fork mines an isolated mountain ridge rises from the connected flats of the Kuskokwim and Nixon Fork. This range is reliably reported to be composed mainly of blue limestone similar to that at the Nixon Fork mines, with a small area of monzonite in the heart of the range. Whether or not slate occurs in the range is not known.

A stream called Crooked Creek heads in the monzonite area and drains southward to the Kuskokwim. On this stream, it is reported, Dave Clow and John Strand have found placer gravel running 38 cents to the square foot on two claims. They were expected to take out a little gold in 1924.

Lode deposits are not known to occur in this area. One report stated that a deposit of asbestos had been located.

The principles that have been brought out in describing the deposits at the Nixon Fork mines probably apply to this area also.

POSSIBILITIES FOR DISCOVERY OF OTHER LODE DEPOSITS

PALEOZOIC LIMESTONE

Whether or not other contact deposits occur in the limestone ranges north and east of the Nixon Fork mines is not positively known. Their presence depends mainly on whether or not other bodies of granite or monzonite intrude the limestone in that region. The writer explored the north slope of these ranges from the Nixon Fork mines to the head of Whirlwind Creek pretty thoroughly by actual observation and by studying the gravel in the beds of each stream crossed, and feels reasonably sure that no intrusive masses save possibly small dikes occur on that slope, except near Whirlwind Creek, as described on page 115. Prospectors might do well to make a similar examination of the slopes draining to the Kuskokwim, if that has not already been done. If pebbles and boulders of granite or monzonite are found in stream beds it should be easy to trace them to their source, and the margins of the intrusive masses should then be explored for lodes and the streams prospected for placer gold.

On the north slope of the limestone ranges, extending southward across Canyon Creek, pink granite is apparently in contact on one side with limestone (p. 117). The contact was studied from Canyon Creek southwestward to the end of the granite and shows no signs of mineralization, but between Canyon Creek and Whirlwind Creek it was not examined. It might be worth while to go over the ground carefully here and look for possible signs of mineralization. There has been so much prospecting for placer gold on Whirlwind and Canyon creeks in this region, however, without yielding anything promising, that it is not likely that valuable lode deposits occur along this contact.

UPPER CRETACEOUS SHALE AND SANDSTONE

No promising signs of mineralization have yet been found on the borders of the masses of monzonite and granite that cut the Upper Cretaceous shale and sandstone, and rocks of this kind are not generally as favorable as limestone for the occurrence of contact and replacement ore bodies. Careful examination of many contacts, both of the larger intrusive bodies and of the dikes and sills, failed to reveal any notable traces of mineralization, though pyrite has been introduced in scattered crystals at many places. Panning here and there in the streams yielded no unusual minerals, and the large amount of prospecting already done by experienced miners without success indicates that rich mineral deposits can not be common in this region.

Unverified reports state that silver-bearing veins have been found in the Sunshine Mountains. The contact of granite with slate in these mountains is very clearly exposed and was studied carefully about the head of Clearwater Creek without finding any evident signs of valuable minerals. A vein of pyrite several feet long and about 6 inches in maximum thickness was found in the slate at one place, and a sample was taken for assay. Along with this material a sample from a rusty quartz vein 4 or 5 miles northeast of this locality, in the slate, was also assayed. The results are given in the table below.

Assays of mineral samples from Sunshine Mountains [a]

	Silver (ounces per ton)	Gold (ounces per ton)
Pyrite vein near granite contact, Clearwater Creek	2.59	0.01
Rusty quartz vein northeast of Sunshine Mountains	Trace.	Trace.

[a] Analyses by E. T. Erickson, of the U. S. Geological Survey.

PLACER GOLD IN THE NIXON FORK COUNTRY AS A WHOLE

PREVIOUS PROSPECTING

Signs of the prospector can be found on almost all the larger streams of the region, and probably there is not an area of 5 miles square, outside the broad flats, where some prospecting has not been done. Nevertheless this region is one of the parts of Alaska little frequented by prospectors. Aside from the area near Nixon Fork containing the mines described above attention seems to have been directed mainly to three localities—the upper Nixon Fork basin, the Sunshine Mountains, and the area of schist and metamorphic rocks about the head of Our Creek.

From 1910 to 1915 reported strikes on the head of Nixon Fork near Von Frank Mountain and on lower Whirlwind Creek caused two or three small local stampedes, from which nothing ever developed. Numerous pits, ditches, dams, and cabins remain in these localities as evidence of the transient occupation. It is said that colors were found in many places on Whirlwind and Canyon Creeks. The area of porphyry near Boulder and Jones Creeks (p. 118) has also attracted attention, and the streams are said to yield colors of fine flake gold.

B. J. Bower, Jack Nixon, and others have prospected in the Sunshine Mountains and state that colors have been found at many places. Even the present gravel bars on Clearwater Creek are said to yield colors occasionally. Farther south, between Hosmer and Cottonwood Creeks, there has also been prospecting, and colors have been found which were supposed to come from the coarse conglomerate beds there, though this may or not be their true source. The writer suspects that they are more probably connected with the intrusive monzonite (p. 118) in the region.

Herman Hillman and Joe Saint Jemay have lately spent three or four years in the Our Creek region somewhere near the head of Bridge Creek. They are known to have found prospects at several places but apparently nothing that would pay to mine.

POSSIBILITIES OF GOLD IN THE DIFFERENT ROCK FORMATIONS

LIMITS OF PREDICTION

No geologic examination, however thorough, can take the place of actual prospecting in determining certainly whether or not a region contains valuable mineral deposits, especially placer gold. Nevertheless the geologist may indicate with fair accuracy the general nature of occurrences and the relative chances in different areas. These areas as a rule correspond with the areas of the different rocks and will be discussed in that way.

EXTRUSIVE IGNEOUS ROCKS

The extrusive igneous rocks include both the older and younger lavas described on pages 111–114. They lie mainly north of Agate Fork. The miner can recognize these rocks usually by their fine-grained texture, with scattered coarse crystals here and there, by their brown, reddish, or purple colors, and by their occurrence generally as loose-jointed pieces.

Volcanic rocks of this kind do not as a rule furnish favorable places for gold or other minerals unless later mineralizing solutions have formed veins in them. No evidence of such mineralization was noted, and no reports of placer gold in these areas were received. These rocks do not form promising territory for prospecting and probably are as unfavorable as any others in the region.

SHALE, SLATE, AND SANDSTONE

Shale, slate, and sandstone are the forms in which the Upper Cretaceous rocks described on pages 107–110 occur in this area. They cover a large area, as shown on Plate 5. The shale and slate are readily recognized by their fine grain and black color and the slaty fragments. The sandstone is also easily recognized. With these rocks should be included the coarse conglomerate beds south of the Sunshine Mountains (p. 107).

These rocks are cut by quartz veins at many places, especially near the intrusive igneous rocks, and by calcite veins at a few places. No veins containing valuable minerals were noted. The most favorable localities for prospecting are areas near the intrusive masses of quartz monzonite and granite which cut these rocks. The prospects reported from these rocks are usually poor, however, yielding only colors of placer gold. On the whole these rocks in the Nixon Fork country seem to be rather poor ground for prospecting, although possibly they may contain workable placer gold at localities not yet discovered. It is worth remembering that these are the same rocks in which the rich camps at Iditarod, Candle Creek, and Innoko are located.

LIMESTONE

Mineral deposits in the limestone have been rather fully covered in describing the deposits at the Nixon Fork mines and other possible contact deposits (pp. 123–138). Unless igneous rocks can be found cutting the limestone it is useless to prospect these areas for placer gold.

SCHIST AND METAMORPHIC ROCKS

The metamorphic rocks in the vicinity of Our Creek and westward to Nowitna River consist mainly of schist but include also slate, quartzite, crystalline limestone, and greenstone. As a rule experienced prospectors recognize these rocks readily. The schists and slaty rocks have a cleavage that causes them to break readily into thin, platy fragments, many of which glisten with mica and other crystals. On the whole, the places where these rocks occur are believed to be the most favorable in the area for prospecting. Placer gold in several camps near this area, as at Ruby, Long, and Poorman, has come from rocks of this class, and similar rocks in other parts of Alaska are a common source of gold. Moreover, the most reliable reports obtainable indicate that, except for the district of the Nixon Fork mines, these rocks have yielded better showings of gold than any others in the area.

The creeks of this area pass within rather short distances from their short, steep upper courses onto rather broad, flat courses with a deep filling of muck and gravel. Prospect pits must therefore be rather deep, except very near the heads of streams, where concentration of the placer gold probably is not so great as farther down. If workable gold occurs at all on a stream, however, it should be found within reach of prospect pits at some places. Although a little prospecting has been done in this area without much success, the writer believes there is hope of finding pay gravel here.

EFFECT OF GLACIATION ON PLACER PROSPECTS

Prospectors should appreciate the fact that some ground in the Nixon Fork country which might otherwise be favorable for prospecting has been glaciated, as described on page 111. This process destroys in a great measure the chances of finding placer gold, because the glaciers gouge up, tear away, and scatter the loose gravel in which the gold has been concentrated. Here and there the prospector may dig through the coarse glacial gravel and find a small pocket of gravel that was not disturbed and may possibly contain gold, but this is a rare occurrence.

The glaciers occupied nearly all the granite area in the Sunshine Mountains and spread out to the north and east, so that it is not likely that placer gold in paying quantity will be found there, even if it ever existed. This same situation is believed to have existed north of Von Frank Mountain, although this region was not examined at close range.

COAL IN THE NIXON FORK COUNTRY

Coal very likely occurs at some places in the Nixon Fork country in the shale and sandstone of the Upper Cretaceous and Eocene(?) rocks (pp. 107–110). These same rocks contain a number of thin coal seams in regions not far away. Mertie and Harrington[33] make the following statements about coal in near-by areas:

> Coal-bearing rocks of Cretaceous age occur at numerous places in the lower Yukon basin, and some small seams have been opened in them, but the demand for coal has been slight, and consequently development has not been intensive. * * *
>
> Coal has been found in a prospect hole sunk to a depth of 50 feet on Lower Poorman Creek. * * * Only a small quantity of the coal has been mined—at most a few tons. It is subbituminous, igniting with difficulty but burning readily after ignition.
>
> Maddren obtained information in 1910 from a prospector to the effect that coal had been found on Homestake Creek, in the Nowitna basin, at a depth of 46 feet, and that it also occurred at the head of the Nowitna.

A reliable person at the Nixon Fork mines made the following statement:

> There is a great deal of conglomerate on lower Hosmer Creek. It makes a big hogback near the Nixon Fork. Behind this, up Hosmer Creek, is black shale, and at one place there is 6 inches of coal in the shale.

This is the only definite information regarding coal in the Nixon Fork country. Any coal that might be found would probably be inferior in quality to the good bituminous coals in the United States and not of more than local value.

POSSIBLE OCCURRENCE OF PETROLEUM

For the sake of the completeness of this report a few words on the possible occurrence of petroleum in the area may be appropriate. No oil seepages are known or reported in this area, and the geologic features indicate that oil is not likely to be found. The only rocks that might possibly contain oil are the sandstone and shale of Upper Cretaceous and Eocene(?) age (pp. 107–110). These rocks seem to have been deposited partly in shallow sea water, but chiefly in deltas and flood plains on the land near the sea. The beds change in thickness and lithology within short distances. Moreover, they have been much folded and probably also faulted, and along the divide between Nowitna River and Nixon Fork they are cut by many masses of intrusive igneous rocks. These features are in general unfavorable to the accumulation of petroleum.

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[33] Mertie, J. B., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 119–120, 1924.

SILVER-LEAD PROSPECTS NEAR RUBY

By JOHN S. BROWN

INTRODUCTION

When the writer was on the way to the Nixon Fork country in 1924 his attention was directed to some silver-lead lodes that were reported to be promising. A brief examination of the property was made in July. At the time of this visit no one else was there, and the principal workings were not accessible, but later one of the partners interested in the prospects, Mr. Harry Boland, supplemented the writer's observations with valuable data. Later in the season the writer was able to stop again at these prospects and make some further examination.

The prospects are on the slopes north of Beaver Creek, about 14 miles nearly due south of Ruby and about 2 miles east of the present "Fourteenmile" roadhouse. They were indicated on the geologic map in the report by Mertie and Harrington,[1] but that report contains no further information about them.

GEOLOGIC FEATURES

The prospects consist of lenticular veins of silver-bearing galena, partly altered to cerusite, accompanied by a large amount of iron, which has been found only as limonitic masses. The veins attain a maximum thickness of a few feet and lie parallel to the cleavage of the inclosing wall rock, which is chiefly a micaceous quartz schist, in some places black and slightly carbonaceous and in many places considerably veined by small quartz lenses and stringers. Associated with the schist are minor quantities of slaty and cherty rocks. The cleavage, as indicated by exposures about a quarter of a mile west of the prospects and in a tunnel at one of the prospects and by the strike of the ore leads, has a regional trend of about N. 25°–30° E. and a dip of 60°–80° SE. The walls of the tunnel show considerable jointing and probably slight faulting in a nearly horizontal direction. These rocks belong to the metamorphic series described by Mertie and Harrington.[2]

[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pl. 3, 1924.

[2] Idem, pp. 14–17.

DEVELOPMENT WORK AND RESULTS

The plan of existing development work is shown in Figure 7. The first prospect was found on the nose of a hill between a small ravine and the edge of the narrow flats of Beaver Creek. A slight escarpment, fairly steep and from 25 to 100 feet high, borders the flats and turns back up the west bank of the ravine. Along this escarpment float from the underlying schist bedrock is common, and

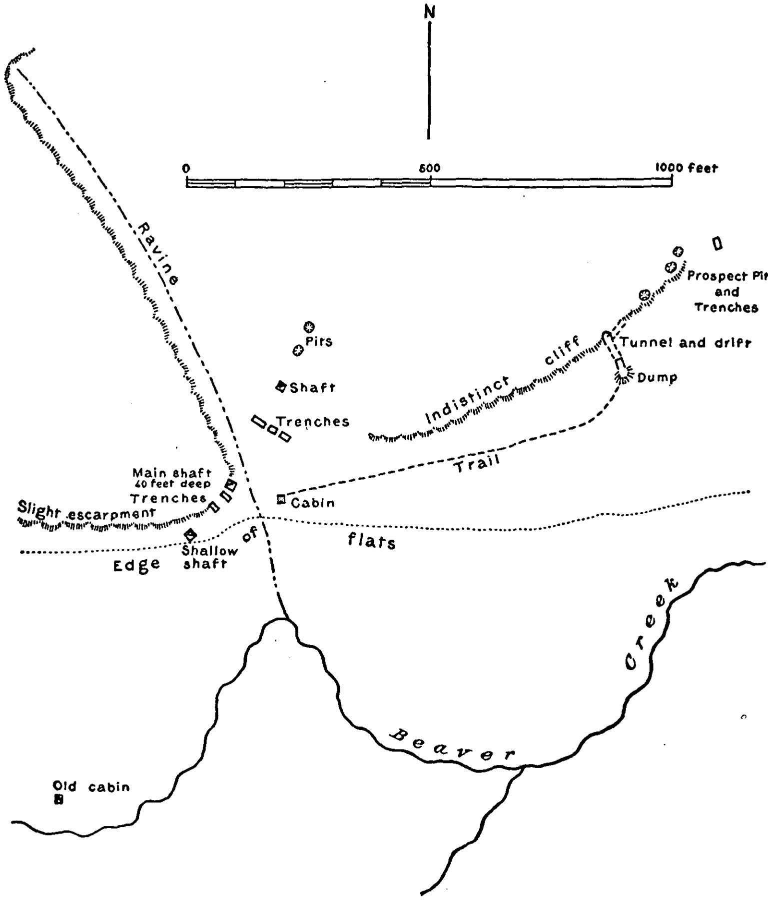

FIGURE 7.—Sketch map of silver-lead prospects near Ruby

exposures are found in places a few hundred feet to the west. Masses of limonitic cap rock carrying some galena were found on the surface and led to prospecting. A shaft 40 feet deep was sunk on the nose of the hill. This shaft is now nearly full of water. According to Mr. Boland the surface showing of mixed iron rock and galena was 15 feet wide, and at the bottom of the shaft the vein was 8 feet wide, with schist walls. The iron was completely oxidized and the lead partly so. The dump contains a few tons of ore, more or less separated from the waste. It consists of lumps of limonite, the largest a foot or more in diameter, carrying irregular masses and stringers of galena and a small amount of scattered cerusite crystals. Black stains and powder, apparently oxides of manganese, are fairly common. Much of the material is porous and cavernous. Inclusions of irregular size, shape, and distribution of the schist wall rocks are common.

The best assay obtained from this material is said to have been 32 ounces of silver to the ton and a trace of gold. This and the other assays quoted are said to represent reasonably careful sampling of the entire vein and not merely picked or grab samples. Samples of considerable size were cut and quartered and assayed by the Alaska station of the United States Bureau of Mines at Fairbanks.

Southwest of the shaft at intervals of about 30 feet are two hillside trenches, several feet deep at the upper end. The trench nearest the shaft shows a ton or two of ore which is said to have assayed 26 ounces silver to the ton and is similar to that at the shaft. The next trench showed no ore. A shallow shaft at the edge of the flat also showed no ore. This shaft contained much of a peculiar sandy slate, seamed by thin bands of limonitic matter along joints.

The bed of the ravine north of the shaft is filled deeply with muck and alluvium, but 150 feet away on a bearing of N. 25°–30° E. a shallow trench cut the continuation of the lead, which is said to have been there about 3 feet wide. The dump shows only a little mineralized material, which assayed 8 ounces of silver to the ton. Other diggings to the northeast, on the supposed line of strike, failed to find any trace of the lead. The hillside, however, is deeply covered by residuum, and bedrock is reached with difficulty.

This first lead was abandoned, and search was made for further outcrops. A single small piece of iron rock carrying some galena was found 800 or 900 feet northeast of the first outcrop at the foot of a faint cliff, much less distinct than the first escarpment but otherwise resembling it. A shallow excavation is said to have revealed three small seams of vein matter, only one of which carried any galena. These seams united at a depth of 8 or 9 feet to form a vein 4 feet wide. Down the hillside about 100 feet from this pit a tunnel was driven to crosscut the vein at a depth of about 40 feet. The lead was found, but only at the northeast side of the tunnel, and seemed not to extend to the southwest at that depth. A drift was driven to the northeast for 20 feet along the strike of the lead, which showed a thickness of 7 to 8 feet of vein matter, only a foot or two of which contained galena.

The dumps from the tunnel and from the open pit above both contain a few tons of ore, very similar at each place and not particularly different from that at the first shaft, except perhaps that the material contains less galena and proportionately more cerusite, much of it in long crystals. A trace of ruby silver was noted in one piece, separate from the galena. Copper stains are said to have been found, but the writer failed to recognize them in the material on the dumps.

The ore, especially that containing the most lead carbonate, is said to have been the richest encountered, one assay showing 82 ounces of silver to the ton for a width between 1 and 2 feet.

About 75 feet northeast of the surface opening a pit showed a mere trace of vein matter. A single small lump bearing galena was found on the dump. Other pits and trenches to the northeast failed to disclose any indication of ore. These prospect pits were all located on a bearing of N. 45°–60° E. from the first surface opening, and the writer questions whether they were well placed. Observations in the outer 50 feet of the tunnel, the remainder not being accessible, indicated that the strike of the schist and presumably of the vein was about N. 30° E., the same as that of the first vein and corresponding also to the regional strike of the schist as exposed farther west in the slopes north of Beaver Creek. As a drift was driven along the vein at the end of the tunnel, however, the strike of the lead should have been determined. Possibly the prospect pits should have been located somewhat farther northwest. The trace of ore in the first pit may represent not the main lead but another lead on an offshoot.

PROSPECTING

Prospecting in this region is difficult because of the thick overburden above bedrock and the lack of even float exposures. The writer searched the surrounding hill slopes to and beyond the next ridge to the northeast, from half a mile to a mile away, and found scarcely a piece of float rock. The slopes are covered mainly by a dense growth of tall redtop grass, which has occupied a considerable area of burnt birch and spruce forest. Fallen trees add to the mantle of vegetation, and the residual soil and muck beneath is at least several feet deep, except along the slight escarpment and the bench, indicated on the sketch, both of which have been searched carefully for signs of mineral. The operators propose constructing a ditch and sluicing off the overburden to expose the bedrock along a small stream nearly a mile to the northeast. Whether this would be worth while is questionable. No water is available in the vicinity of the prospects. The writer suggests that perhaps charges of dynamite placed at intervals several feet apart and as deep as necessary along a line cutting across the probable extension of a lead might be used to advantage in uncovering float material that would indicate the location of the ore body.

South of the prospects lie the flats of Beaver Creek, which are less than a quarter of a mile wide at most places. These flats are undoubtedly underlain by 25 to 100 feet of muck and alluvium. The country beyond for a mile or more is low and covered by moss and residuum, so that it would be difficult to trace the leads in that direction.

TRANSPORTATION AND SUPPLIES

The prospects are only slightly more than a mile at the nearest point from the Government road between Ruby and Long. A hillside road on a reasonable grade could be constructed to them without unusual difficulty, although all road building in this region is expensive. Winter transportation is used mainly at present. Powder is said to have cost 50 cents a pound for the work already done, and other supplies are costly, though not unreasonably so for this region.

Wood for fuel and mine timbers is available in sufficient quantity at no great distance on the adjacent hillsides. Water under gravity head could hardly be obtained, but an adequate supply for all purposes could be pumped from Beaver Creek.

CONCLUSIONS

It seems that the veins constitute small lenticular masses intercalated in the schist. From the nature of the oxidized ore it is probable that the unoxidized material consists of mixed carbonates and sulphides, probably galena and siderite, with some rhodochrosite (manganese carbonate), calcite, a trace of quartz, and possibly some pyrite. The upper, oxidized part has probably been somewhat enriched in silver both by the removal of other matter from the vein and by the carrying down of silver as erosion proceeded. Therefore, if the veins were followed down in depth they would probably contain less silver than at the surface, though possibly some spots might be richer than any surface ore yet discovered.

Most of the veins found are probably small and lenticular, pinching out within a short distance both laterally and vertically. New lenses of ore are often found, however, by following the line of probable continuation of such a lead, and larger ones may exist here and there.

Ore bodies of this nature must be very rich in precious metals to repay the cost of prospecting and extracting. The quantity of galena is too small to be of any great consideration. It is not impossible that an ore body large enough and rich enough to repay working would be discovered by further prospecting of the surface or by sinking to greater depth, but the chances are rather remote and hardly worth the risk by anyone who can not afford to lose if necessary considerable money. Nevertheless, it should be emphasized that most of the prospecting already done was justified by the surface showings, even though the results have been disappointing. Any similar outcrops of lead ore in the locality should be prospected sufficiently to determine their size and richness.