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THE GOODNEWS PLATINUM DEPOSITS ALASKA

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THE GOODNEWS PLATINUM DEPOSITS, ALASKA

By J. B. Mertie, Jr.

ABSTRACT

Platinum metals have been found in earlier years at several localities in Alaska, but, except a palladium-copper lode in southeastern Alaska, none of these deposits has been of much commercial importance. The platinum placers described in this report were discovered in 1926 and are now being worked on a large scale.

The area containing these deposits is in southwestern Alaska, close to Kuskokwim Bay. The bedded rocks consist of sedimentary and volcanic rocks of late Paleozoic (?) age that have been intruded by ultrabasic and granitic rocks; and overlying all of these is a variety of unconsolidated deposits of Quaternary age. The bedded rocks have an intricate structure and are more or less recrystallized. The ultrabasic intrusive rocks consist of several varieties of peridotite and perknite, but more specialized types of igneous rocks are closely associated with them. The Quaternary deposits reveal a long and intricate geomorphic history, which is likewise a history of the deposition of the platinum-bearing gravels.

The platinum placers occur principally in the valleys of the Salmon River and its tributaries Platinum and Clara Creeks, which drain the east side of Red Mountain. The bedrock of Red Mountain consists of ultrabasic rocks; and the genetic connection between these rocks and the platinum placers is definite and indisputable. The platinum metals consist of alloys of platinum, iridium, osmium, ruthenium, rhodium, and palladium. Some of these alloys are notable for their high content of iridium, but others are low in iridium. These differences have been traced to original differences in the proportions of the alloys in the bedrock sources. The percentage of platinum increases and the percentages of iridium and osmium decrease from the head of Platinum Creek northeastward along the flanks of the ultrabasic intrusive of Red Mountain. A small amount of free gold also occurs in these placers, and a part of this is related genetically to the platinum metals. A larger part has been introduced from outside the area through the medium of glacial deposits, which were transported to the head of the Salmon River and were subsequently concentrated by fluviatile action.

The platinum placers are now being mined by two companies with two dragline excavators, and a dredge that was installed in the fall of 1937. The production of platinum metals for 1937 was about 8,000 ounces; but in 1938, when the dredge operated throughout the season, the production is estimated to have mounted to about 34,000 ounces.

INTRODUCTION

The Goodnews district is a region of undefined limits that includes all the country contiguous to Goodnews Bay. The small part of the district described in this report lies south of Goodnews Bay and is designated Platinum and vicinity. (See fig. 1.) This small area is the site of the platinum deposits that constitute the principal thesis of this report.

The map of Platinum and vicinity (pl. 1) covers an area of about 210 square miles between 161°28′ and 161°49′ W. longitude and 58°48′ and 59°03′ N. latitude. This area is bounded on the west by Kuskokwim Bay, on the north by Goodnews Bay, and on the east and south by the Kinegnak River.

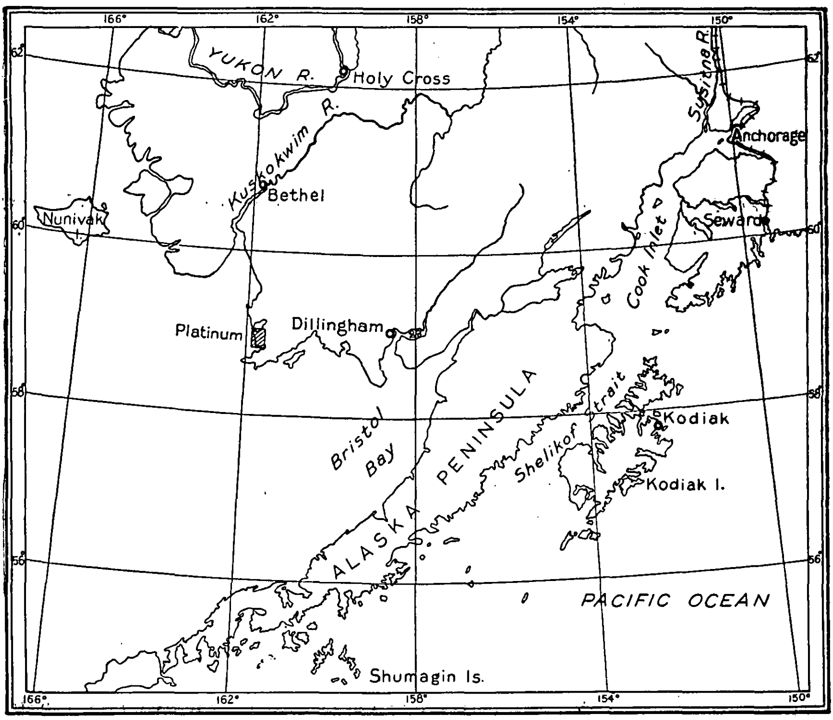


FIGURE 1.—Sketch map of part of southwestern Alaska showing location of Platinum.

The earliest explorations by the Geological Survey in this part of Alaska were made by Spurr [1] in 1898, in the course of a trip down the Kuskokwim River to its mouth and thence southward along the coast to the Alaska Peninsula. Spurr did not actually visit Goodnews Bay, because from Quinhagak he went up the Kanektok River, portaged to the Togiak River, and descended that stream to Togiak Bay, thus passing around the northern and eastern part of the Goodnews Bay district. Spurr's notes, however, still remain the only source of geologic information regarding the region lying 80 miles northeast of Goodnews Bay.

[1] Spurr, J. E., A reconnaissance in southwestern Alaska: U. S. Geol. Survey 20th Ann. Rept., pt. 7, pp. 31–264, 1900.

In 1919 a mapping party was dispatched by the Geological Survey to Goodnews Bay. The resulting topographic and geologic maps, which were prepared on a scale of 1:250,000, cover an area of about 1,000 square miles lying principally to the north and northeast of Goodnews Bay. The geology and mineral resources of this area were described by Harrington.[1a]

In recent years, interest in the district has been revived by the discovery and commercial exploitation of platinum placers in a small area just south of Goodnews Bay. Accordingly in 1937 the Geological Survey sent a topographic and geologic party into the platiniferous area to prepare maps and study the economic geology of the platinum deposits. Gerald FitzGerald, topographic engineer, prepared a detailed topographic map of the small area called Platinum and vicinity, which has been published with a 50-foot contour interval, on a scale of 1:62,500 (pl. 1). FitzGerald also did some topographic mapping to the east and south of Platinum and vicinity, which considerably amplified the old reconnaissance map of the Goodnews Bay district. The geological work was confined to the small area called Platinum and vicinity. In the course of 65 days the writer studied the areal and economic geology and prepared a detailed geologic map on a scale of 1:62,500 (pl. 2).

The detailed topographic and geologic mapping was done from field camps, but the two parties had no pack horses for transporting their working equipment from camp to camp. For this purpose, automotive tractor transport was furnished by the Goodnews Bay Mining Co. and the Clara Creek Mining Co.; and the writer, on behalf of Mr. FitzGerald and himself, wishes to thank these two companies for their generosity and helpful cooperation in this and other ways, as a result of which the work was materially aided and expedited. Grateful acknowledgment is also made to the miners, prospectors, and traders of Platinum and vicinity for their hospitality, for information furnished, and for the sundry other voluntary help that they gave the survey parties.

A preliminary report[2] on this area has already been issued, which gives the more important economic results of this investigation. This earlier report, however, contained only a brief statement of the regional geology, which was illustrated by means of a small-scale sketch map showing only the sites of the intrusive rocks. The present report gives a more complete description of all the rocks of the area and is illustrated by means of topographic and geologic maps. (See pls. 1 and 2.) The present report also contains many more analyses of the platinum metals than the preliminary report.

[1a] Harrington, G. L., Mineral resources of the Goodnews Bay region, Alaska: U. S. Geol. Survey Bull. 714, pp. 205–228, 1921.

[2] Mertie, J. B., Jr., Platinum deposits of the Goodnews Bay district, Alaska: U. S. Geol. Survey Bull. 910, pp. 115–143, 1940.

GEOGRAPHY

DRAINAGE AND RELIEF

The region lying between the southwestern parts of the Nushagak and Kuskokwim Valleys may be divided into three general physiographic provinces. In the central part of this region are high rugged mountains, exemplified by the Tikchik and Oklune Mountains, some of which have altitudes of 7,000 feet or more. This alpine province was intensely glaciated during the last ice age and was the source of numerous glaciers that discharged mainly to the west and south. Between these high mountains and the coast is a piedmont province of lower hills of smoother outline, whose altitudes range from 1,000 to 3,000 feet, decreasing in height toward the coast. Most of this province has not yet been mapped, so that no final statement is warranted regarding its physiographic character and geomorphic history. Apparently some glaciers originated within these lower hills; yet it is not believed that all of this province was regionally glaciated during the ice age. But the master streams that drain these hills head in the higher mountains, so that the trunk valleys were the sites of large glaciers that formerly discharged westward and southward toward the coast. This piedmont province therefore shows physiographic features of both glacial and nonglacial origin. At many places a low foreland, devoid of relief, lies between the low hills and Kuskokwim Bay. This lowland constitutes the third, or coastal province of this region. The area here designated as Platinum and vicinity, lies mostly within the piedmont province, but for several miles south of Goodnews Bay and for an equal distance north of Chagvan Bay a coastal foreland intervenes between the hills and Kuskokwim Bay.

Goodnews and Chagvan Bays are shallow tidal estuaries that indent the coast of Bering Sea and exemplify the drowned or flooded valleys that characterize this coast from Bristol Bay to Kuskokwim Bay. Goodnews Bay, at the north end of the area here described, has a length of 10 miles, a width ranging from 2 to 7 miles, and is separated from Kuskokwim Bay by two sand spits, called the North Spit and the South Spit, which extend part way across the mouth of the bay, curving inward like the fangs of a rattlesnake. The entrance to the bay, between these spits, is three-quarters of a mile wide, and the deepest part of its channel is 8 to 12 fathoms, but inside the bay the depth rapidly decreases to 3 fathoms or less. For 15 miles or more offshore from Goodnews Bay, the depth of Kuskokwim Bay is less than 10 fathoms, and for many miles farther offshore the water is relatively shallow. Similar conditions obtain elsewhere between Bristol and Kuskokwim Bays, so that it is apparent that a well-defined submerged coastal shelf lies offshore. Chagvan Bay, at the south end of the mapped area, is similar in character to Goodnews Bay, but it is smaller and much shallower, with a length of 5 miles and a width of 1 to 3 miles. At Chagvan Bay, the hills approach closely the south side of the entrance, and an enclosing sand spit about 3 miles long lies altogether on the north side of the entrance. These sand spits at the entrance of Goodnews and Chagvan Bays have been built by wave action and are relatively recent geologic features.

The Goodnews River is the principal stream that drains into the head of Goodnews Bay. In fact Goodnews Bay may be regarded as the submerged lower valley of the Goodnews River. The Goodnews River is a large stream, with several forks, but as its valley lies outside the area under present discussion, its geographic features will not be described. It should be mentioned, however, that the main branch of the Goodnews River occupies one of the trunk valleys above referred to that extend from the higher mountains on the northeast across the piedmont area to Kuskokwim Bay. The valley of the Goodnews River was therefore formerly occupied by a large glacier that issued from these mountains and discharged southwestward to the sea.

The Kinegnak River, the second largest river of the area, has a length of only 20 miles and is therefore a much smaller stream than the Goodnews River. Its longest tributary, the Unaluk, heads against another stream, known locally as the Osvyak River, and flows westward through a wide swampy lake-dotted valley for 15 miles. The Kinegnak River, however, heads against certain tributaries of the South Fork of the Goodnews River about 20 miles northeast of Chagvan Bay, flows southwestward in a circuitous course, and is joined by the Unaluk River about a mile from Chagvan Bay. Four western tributaries of the Kinegnak River drain a considerable part of the area under present discussion. These streams, named in order downstream, are Wind, Fog, Shaw, and Kookukluk Creeks. Fog Creek heads against Medicine Creek, a tributary of the Salmon River, in a low gap, which is considered to be the best means of access from the coast into the valley of the Kinegnak River when traveling with pack horses.

The Salmon River, a small clear-water stream that lies between the northwest branch of the Kinegnak River and the coast of Kuskokwim Bay, drains the area containing the platinum deposits that are now being worked. The Salmon River is almost too small to be properly designated a river. Its air-line length from its source to its outlet into Kuskokwim Bay is only about 8 miles, and within a mile of its mouth the width is 40 feet or less, with a depth on the riffles of 10 or 12 inches at ordinary stages. The general course is S. 20° W., but about a mile from its mouth, where the stream issues from confining hills, the channel veers to S. 70° W., and follows this course to the sea.

The Salmon River receives several small tributaries from both sides of its valley. The largest of these, Medicine Creek, whose length is 3½ miles, enters the Salmon River from the east about 5 miles from its mouth. Upstream from Medicine Creek and on the same side of the valley are several small unnamed drains, but downstream from Medicine Creek are five gulches, each about 2 miles in length. In order downstream, the first two of these are Snow Gulch and Anita Creek; the next three are unnamed; and the last, which is called Happy Creek, enters the Salmon River at the point where that stream veers westward toward the sea. On the west side of the Salmon Valley, the uppermost tributary of any size is Clara Creek, which enters about 7 miles in an air line above the mouth of the Salmon. Downstream from Clara Creek the more important western tributaries are successively Dowry, Boulder, Platinum, and Quartz Creeks. Platinum Creek, with an air-line length of 2 miles, is the longest of the western tributaries.

The valley of the Salmon River is practically straight, and its width between the boundary ridges is 3 to 4 miles. The valley floor ranges in width from 500 to 2,000 feet, the narrowest place being about 2,000 feet upstream from the mouth of Medicine Creek and the widest in the short stretch between Medicine Creek and Snow Gulch. At the point where the Salmon River issues from the hills the width of its valley floor is about 1,500 feet. The average gradient of the valley floor, from the mouth of Clara Creek to the mouth of Happy Creek, is about 32 feet to the mile, or about 0.6 percent, but upstream from Clara Creek the valley gradient is somewhat higher. Throughout most of its course, however, the Salmon River meanders along its valley floor, so that the actual stream gradient is much less than the figure cited. The valley has an asymmetrical cross section, with a more gentle slope on the east side; and the stream tends to cut against the west side of the valley, particularly downstream from the mouth of Platinum Creek. The Salmon River, except in its extreme headwater part, is incised in its valley floor, so that at many places there are low bounding bluffs on one side or the other. At a few places, as for example in the constricted stretch above Medicine Creek, and also at one or two localities along the west wall of the valley downstream from Platinum Creek, bedrock appears in these bluffs. At most localities where the materials of the bluffs are visible, however, they consist of stream gravels. These bluffs, which are low and inconspicuous in the upper valley, become progressively higher downstream, and a short distance above Happy Creek, the gravel bluffs along the east side of the river have a height of about 35 feet.

Certain significant subsurface conditions in the valley of the Salmon River have been revealed by drilling operations. Thus the records of the Goodnews Bay Mining Co. show that the surface of bedrock in the Salmon Valley for some distance above and below the mouth of Platinum Creek is covered with about 25 feet of alluvial material. Within this wide and generally flat bedrock surface, however, is a narrow sharply incised bedrock channel that has an additional depth of about 25 feet, so that the surface of the channel bedrock is covered by about 50 feet of alluvium. This narrow channel has been traced for 2 miles upstream and downstream from the mouth of Platinum Creek, and additional drilling would no doubt trace it farther downstream and probably farther upstream. This channel has also been traced for 2 miles up the valley of Medicine Creek. In the valley of Platinum Creek it terminates, merging in the general bedrock surface about half a mile upstream from the Salmon River.

Another subsurface condition has also been revealed by drilling operations about a quarter of a mile east of the Salmon River and a short distance south of Happy Creek. A line of four drill holes about parallel with Happy Creek showed that the surface of bedrock there lies between 31 and 40 feet below sea level. These drill holes were obviously not sunk in the deep channel, above mentioned, nor were they sunk in the lowest part of the main valley floor. It therefore follows that the general bedrock floor of the valley of the Salmon River in the vicinity of Happy Creek lies more than 40 feet below sea level and that the bedrock at the bottom of the narrow incised channel is at least 25 feet lower. It will be observed on the accompanying topographic map, plate 1, that the 50-foot contour line crosses the Salmon River about 0.4 mile upstream from the mouth of Happy Creek; and it also appears that the mouth of Happy Creek is about a mile from the mouth of the Salmon River. Making due allowance for the fact that the drill holes south of Happy Creek were not located in the central part of the Salmon Valley and allowing a bedrock gradient of the same order as the present stream gradient, it appears likely that at the mouth of the Salmon River the bedrock at its lowest point may be 100 feet or more below sea level.

The northern part of the area under discussion is drained by the Smalls River and its tributaries, of which the longest is Tundra Creek. The Smalls River heads against some of the headwater tributaries of the Kinegnak River and follows a general westerly course, discharging into Goodnews Bay at the town of Platinum. The airline distance from its source to its mouth is about 8 miles, so that it is comparable in size and length with the Salmon River, but its true length is somewhat longer, because it flows southwest for 5 miles, northwest for 3 miles, and west for 2 miles. From its source to the place where it emerges from the hills, the valley of the Smalls River is narrower than that of the Salmon River, both with regard to the width of the enclosing ridges and the width of the valley floor. Beyond the enclosing hills, however, it flows across a low-lying coastal foreland of glacial outwash deposits, in which it has incised itself in a valley floor ranging in width from 1,000 to 2,000 feet. The Smalls River heads in hills that rise about 1,700 feet above sea level, and its valley floor has a gradient of about 60 feet to the mile from its head-water forks to its mouth, which is appreciably higher than that of the Salmon River. Even in the lower part of its course, where it flows across the coastal foreland, the gradient of its valley floor is more than 20 feet to the mile.

One of the significant physiographic features of the valley of the Smalls River is a short constricted stretch just east of the gravel divide that separates the Smalls River from the head of the Salmon River. Here for a few hundred yards the river is bounded by rock walls, and its bed consists of such a thin veneer of gravel overlying the bedrock of sheared chert that at stages of high water the river undoubtedly cuts to bedrock. (See pl. 3, *A*.) About 1,500 feet upstream from this constriction or gorge, a line of seven drill holes, the surface elevations of which are practically indentical, has been sunk by the Goodnews Bay Mining Co. in the valley floor. The depths of these holes to bedrock, from south to north, are 6, 9, 19, 15, 16, 31, and 42 feet. About half a mile downstream from the gorge, the same company sank another line of four drill holes in the valley floor, which from south to north showed depths to bedrock of 47½, 50, 55, and 59 feet; and just downstream from the mouth of McCann Creek a single hole in the valley floor was driven to a depth of 62½ feet without reaching bedrock. It thus appears that an old channel of the Smalls River follows to the north of the gorge and that the hard rock butte on the north side of this constriction is really an old spur projecting northward into some preexisting valley floor. In other words, this gorge was caused by aggradation and superposition of the Smalls River onto a southern spur of its valley. The drill holes farther down this valley also show that the bedrock surface of the valley must be at sea level at some point near the mouth of Tundra Creek and that, as on the Salmon River, the surface of bedrock at the mouth of the Smalls River is well below sea level.

About half a mile upstream from the constricted stretch described, a small tributary of the Smalls River about 1½ miles long enters from the northeast. Between this tributary and the Smalls River is a low spur extending about a mile northwestward from the confluence. This spur is the site of two well-defined gravel terraces, the first about 35 or 40 feet above the level of the Smalls River (pl. 3, *B*), and the second about 35 or 40 feet higher. The surfaces of these two terraces slope gently southwestward toward the confluence. These are the most clearly defined terraces observed in the Platinum district.

Tundra Creek enters the Smalls River from the northeast about 3 miles from its mouth. The valley of Tundra Creek is a wide depression that lies between the high hills northwest of the Smalls River and a range of low hills that flank the south side of Goodnews Bay. In large part these low hills are covered with gravels of glacial origin. The valley of the Smalls River was itself the site of one lobe of an ancient glacier that once discharged southwestward through this depression. Tundra Creek is fed mainly by several short gulches with high gradients that enter from the southeast, but the gradient of the main valley of Tundra Creek is low, being only a little greater than that of the lower valley of the Smalls River. Foreshortened spurs are noticeable along the southeast wall of the valley of Tundra Creek.

The mouth of the Salmon River is about 11 miles south of the mouth of the Smalls River, and throughout this distance, except a stretch of 1¼ miles, where the hills reach to the sea, a narrow beach borders Kuskokwim Bay. At a point about 2 miles south of Platinum the width of this beach from low water to the bounding gravel cliffs on the east is 80 yards, in which distance the east-west gradient was determined to be about 5 percent. The beach naturally varies more or less in width, but except at the mouth of the Salmon River it is nowhere wider than 150 yards. The maximum tidal range is said to be about 14 feet, but a line of driftwood known locally as the level of high drift lies about 11 feet above mean high water, so that at times of westerly gales the beach must be practically everywhere submerged. The gravel cliffs that border the beach have a considerable range in height. At the town of Platinum and on the sand spit to the north there are no gravel bluffs, and even at ordinary high water much of the South and North Spits at the entrance to Goodnews Bay are submerged. A short distance south of Platinum, low gravel bluffs rise to a height of only about 10 or 15 feet, but farther south they rise to a height of 25 feet or more. The highest gravel bluffs occur in a stretch of 2 or 3 miles from the mouth of the Salmon River northward. At one place these bluffs rise to a height of 50 feet. The beach, which is composed of sand and shingle, affords good footing as well as sound traction for tractor haulage.

The area here designated Platinum and vicinity consists of low rolling hills that are most prominent where they form ridges lying between streams with westerly or southwesterly courses. The general strike of the country rock is southwest, and it appears that stream erosion in that direction has been especially active, resulting in the sharper delineation of a ridge topography. The two highest mountains are Red Mountain and Susie Mountain. Red Mountain is the northern part of the ridge that lies between the Salmon River and

Kuskokwim Bay, and its highest point rises to an altitude of 1,903 feet above mean sea level. About 3 miles south of Red Mountain another eminence called Thorsen Mountain rises from this same ridge to an altitude of about 1,100 feet. About 4 miles N. 80° E. from Red Mountain, Susie Mountain forms the most prominent point in the group of hills bounded by the Salmon and Smalls Rivers and Medicine, Fog, and Wind Creeks. (See pl. 4, *A*.) The altitude of Susie Mountain is 1,823 feet above mean sea level. The ridge between the Smalls River and Tundra Creek also includes high hills, many of which are sharply separated from one another by low saddles. The highest of these, shown at the northeastern limit of the area mapped, rise to altitudes of about 1,500 feet. The ridges between the Salmon River and Kookukluk Creek and between Kookukluk and Shaw Creeks are much lower, and their tops are generally broad and smooth. Kemuk Mountain, about 3¼ miles east of Thorsen Mountain, is the highest point between the Salmon River and Shaw Creek. Another hill lying about 5½ miles N. 65° E. of Thorsen Mountain has an altitude of about 1,400 feet above mean sea level. It thus appears that the maximum relief in this area is about 1,900 feet, but the mean relief is probably closer to half that amount.

Red Mountain, not only on account of its height but also because of its closeness to the sea, is the most prominent landmark in this area. The east slopes of Red Mountain are only moderately steep, with gradients on the spurs of about 25 to 30 percent, but the west slopes are much steeper, and at the point where this ridge rises directly from the sea the slopes are precipitous, with a rise of 1,500 feet in about half a mile. The east side of the mountain is shown on plate 4, *B*. One of the significant geomorphic features along the western side of this ridge is a cirquelike basin that forms the head of Last Chance Creek. Several steep equally spaced headwater gullies drain this basin and unite to form a gorge about 50 feet deep, which cuts through the western lip of the basin at an altitude of about 600 feet above sea level. Two smaller and less perfectly developed high basins lie along the same slope south of Last Chance Creek, and a low very imperfectly developed basin occurs north of Last Chance Creek in the headwaters of one of the forks of Seattle Creek. No high basins similar to these have been observed elsewhere within the mapped area. The stream that issues from the Last Chance Basin splits into two distributaries, of which the more southerly constitutes Last Chance Creek. The northern distributary is evidently a flood-stage overflow channel that reaches the sea nearly a mile north of the mouth of Last Chance Creek.

Red Mountain is of special importance in that it is composed of ultrabasic rocks, which are the source of the platinum metals that are now being mined in the district. All the streams that drain the east side of Red Mountain contain detrital deposits of platinum metals, and some of these deposits constitute commercial placers. Clara Creek, at the north end, and Platinum Creek, at the south end of Red Mountain, are commercially the two most important of these streams; but the Salmon River, into which all these streams drain, is the site of the greatest volume of platinum placers in this area.

SETTLEMENTS AND POPULATION

The only permanent settlement and post office in the area shown on plate 1 is the town of Platinum, on the southeast end of the South Spit at the mouth of the Smalls River. (See pl. 5, *A*.) This town was founded in the fall of 1933, at which time a general store was built by the Alaska Traders, Inc. Prior to that time, the settlement of Goodnews Bay, on the north shore of Goodnews Bay at the mouth of the Goodnews River, had been the only settlement and commercial distributary point for the Goodnews Bay district. At present the town of Platinum consists of two stores, one roadhouse, and about a dozen cabins and tents, so that the permanent white population can scarcely exceed 50 people. Adjoining the town on the north is also a small settlement of Eskimos. In the vicinity of Platinum, however, and on various creeks and in the hills to the east is a considerable number of white people who are engaged in mining and prospecting and who are intermittently in and out of Platinum. Including these people, the population that looks to Platinum for mail and supplies may be as much as 150.

Two semipermanent settlements are located in the valley of the Salmon River on Platinum and Clara Creeks. These are the mining camps respectively of the Goodnews Bay Mining Co. and of the Clara Creek Mining Co., which together probably aggregate 80 persons during the summer but are practically deserted in winter. The camp of the Goodnews Mining Co., which is the largest mining camp in the district, is located at the mouth of Squirrel Creek, a northern tributary of Platinum Creek. (See pl. 5, *B*.)

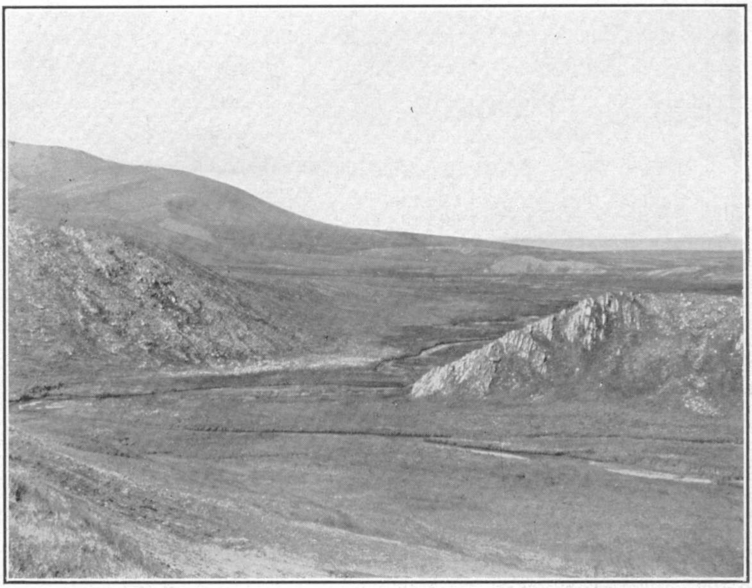
On the north side of the Kinegnak River at the mouth of the Kookukluk River is an Eskimo village called Kinegnak, which has a population of about 35. At the settlement of Goodnews Bay is a somewhat larger Eskimo village known as Mumtrak.

TRANSPORTATION AND COMMUNICATION

Platinum, the distributory point for mail and supplies in this district, may be reached either by steamship or by airplane. The principal carrier of freight is a steamship operated by the Santa Ana Steamship Co., which makes at least 3 trips each summer from Seattle to Bethel, stopping at way points, including Dillingham and Platinum. This ship takes about 2 weeks for the trip from Seattle to Platinum and on her first trip usually arrives in Platinum during the first week in June. When the volume of freight is sufficiently great the Alaska Steamship Co. also runs a freighter to Platinum. Another vessel that carries freight to Platinum is the motorship *Fern*, a vessel of 250 tons registry, which arrives at Platinum from Seattle before the larger ships and thereafter during the summer plies between Anchorage and Platinum on an irregular schedule. The motorship *Moravian* also makes an occasional trip to Platinum from Bethel during the summer, chiefly for the purpose of bringing fresh meat. The minimum freight rate from Seattle to Platinum, including wharfage in Seattle and handling charges, as advertised by the Santa Ana Steamship Co. is $19 a ton, but on many commodities the effective rate is 10 to 100 percent greater. A lighterage charge amounting to about $10 a ton is also collected by the Alaska Traders, Inc., at Platinum. The rate on horses from Seattle to Platinum, exclusive of lighterage, is $80 a head. The passenger rate from Seattle to Platinum, via the Santa Ana Steamship Co., is $100 for the one-way passage. Most passengers and a small amount of freight enter Platinum from Anchorage by airplane. The passenger rate from Anchorage to Platinum is $96, and the freight rate is 48 cents a pound.

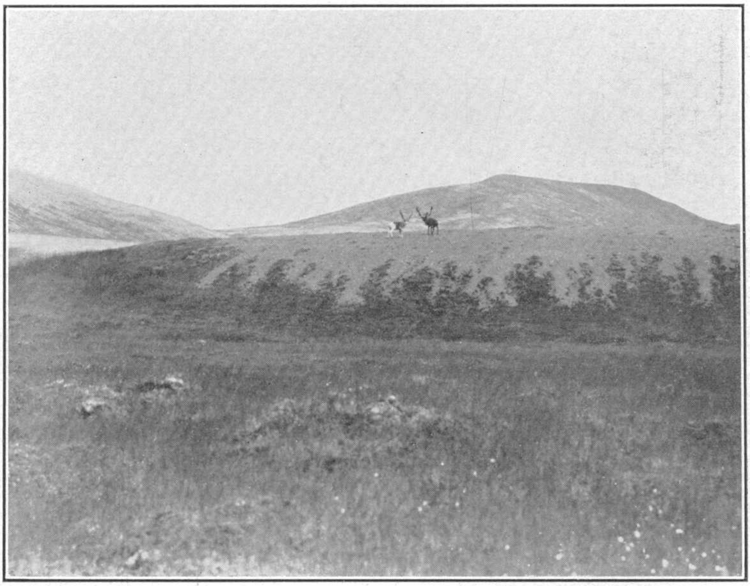
Platinum is the site of a fourth-class post office, which receives mail both by steamship from Seattle and by airplane from Alaskan towns. From May through October the mail for Platinum is relayed through Fairbanks, Nenana, and thence by river boat to Russian Mission, on the Yukon River, where it is transported bimonthly by airplane to Bethel. From November through April the mail is flown directly from Fairbanks to Bethel. From Bethel to Platinum the mail is transported every month of the year excepting May and October on a regular airmail contract and during May and October on an emergency airmail contract. In addition, the various airplane companies operating out of Anchorage bring first-class mail from Anchorage, Flat, or Bethel to Platinum as a matter of accommodation to the local inhabitants. For this incoming mail, they receive no compensation, but for outgoing first-class mail of this kind, they receive 25 cents a pound to Bethel, Flat, or Anchorage.

Platinum and vicinity has rapid communication with other Alaskan towns by means of a commercial radio station located at the mining camp of the Goodnews Bay Mining Co. on Squirrel Creek, a tributary of Platinum Creek. This station, designated KICJ, is equipped for transmitting and receiving messages both by code and by radiophone. Both incoming and outgoing messages are handled by the United States Signal Corps station at Bethel, which works with Nulato, Fairbanks, Nome, and other Alaskan towns. The Alaska Traders,



A. SHORT GORGE IN VALLEY OF SMALLS RIVER, ABOUT 6 MILES IN AN AIR LINE FROM THE MOUTH.

Bedrock is sheared chert. Gorge caused by aggradation and superposition of Smalls River onto a southern spur of its valley.



B. GRAVEL TERRACE ALONG NORTH SIDE OF SMALLS RIVER, ABOUT 6½ MILES IN AN AIR LINE FROM THE MOUTH.

Inc., at Platinum, also operate a radiophone, by means of which messages are relayed back and forth between station KICJ and Platinum.

From the foregoing description it will be seen that the mining district in the vicinity of Platinum is not readily accessible except by airplane. The principal difficulty is in the transportation of freight, which is slow and uncertain; and although the freight rates are not excessive, it is necessary to look months ahead in ordering supplies and equipment from Seattle. Moreover, on account of the absence of trees in this region, fuel, timber, and building materials, which can be obtained locally in other parts of Alaska, must here be imported.

Gasoline and fuel oil are largely used by the white population for fuel and power. In drums, gasoline sells at Platinum for 40 cents a gallon, but in 10-gallon cases it sells for 50 cents a gallon. Fuel oil costs 19 cents a gallon in drums, and coal sells for $1.75 for a 100-pound sack. The price of lumber is $45 a thousand board feet.

CLIMATE

The stations nearest to Platinum at which climatic records have been kept long enough to be useful are Dillingham, at the head of Bristol Bay, and Bethel, near the mouth of the Kuskokwim River. Neither of these two localities are really representative of the climatic conditions at Goodnews Bay, but they do give an insight into the general climate of the coastal province of Bering Sea from Bristol Bay to Kuskokwim Bay. The records of mean temperature and of precipitation at Dillingham are based on incomplete observations extending from 1881 to 1934, when observations were discontinued. The record of snowfall at Dillingham, which is likewise incomplete, is based on partial observations from 1902 to 1934. The records for Bethel are based on almost uninterrupted observations from 1923 to 1934. The climatic records of Dillingham and Bethel, as given by the United States Weather Bureau, are presented below.

Climatic records at Dillingham and Bethel

Month	Mean temperature (°F.)		Mean precipitation (inches)		Mean snowfall (inches)	
	Dillingham	Bethel	Dillingham	Bethel	Dillingham	Bethel
January	16.3	8.1	1.75	0.84	11.3	7.1
February	16.7	7.9	1.36	.53	8.9	4.0
March	21.5	12.2	1.86	.74	13.7	5.4
April	29.2	25.0	1.22	.53	3.9	3.4
May	40.9	39.3	1.62	.76	2.3	.4
June	51.6	52.1	1.81	1.20	0	0
July	54.9	54.0	2.90	2.48	0	0
August	54.4	52.6	4.00	3.83	0	0
September	46.8	45.1	4.13	3.69	.2	.3
October	35.8	30.8	2.68	1.64	3.2	4.0
November	24.4	17.2	1.78	.68	8.9	4.8
December	15.8	8.6	1.41	1.00	13.0	10.5
Annual	34.0	29.4	26.52	17.92	65.4	39.9

Partial records of the climate at Goodnews Bay have been kept in earlier years, but such records are not sufficiently complete to give any dependable idea of climatic conditions. Yet comparison of such records with records for the same periods at Dillingham and at Bethel indicates differences. Thus there exists complete records of mean temperature, precipitation, and snowfall at Goodnews Bay for the months of January to May, inclusive, of 1929; of July and August of 1926; and of September to December, inclusive, of 1928. These records have been combined and then compared with the records for the same months and years in Dillingham and Bethel. For mean temperature the results of such a comparison are fairly dependable, but for precipitation they are probably less so.

This comparison indicates that the mean annual temperature at Goodnews Bay is about 1.8° lower than at Dillingham and about 2.8° higher than at Bethel. The mean annual precipitation at Dillingham, as shown in the preceding table, is about 8.6 inches more than at Bethel, but the comparative data of the three stations suggest that the precipitation at Goodnews Bay is still greater than at Dillingham, being possibly between 35 and 40 inches. The snowfall at Goodnews Bay, however, is less than at Dillingham, being possibly on the order of 40 inches, and nearly the same as at Bethel.

These deductions are in accord with the general impressions of the writer and of the people who live in the vicinity of Platinum. The early spring weather is fairly good for outdoor work, but the summers and autumns are in general rainy, foggy, and raw, and the winters are cold and very windy.

During the winter Bering Sea and Kuskokwim Bay are closed to navigation, but from June to October, inclusive, no difficulty from ice is experienced by shipping. Foggy weather, however, is a menace during the summer, both to ships and to airplanes but particularly to the planes, and for this reason aviators seldom start from points in southern or interior Alaska for Goodnews Bay in advance of a weather report; and even with such a report, flying conditions are undependable, because the weather changes very rapidly.

PLANTS AND ANIMALS

The area of Platinum and vicinity is part of the treeless region that flanks the shores of Bering Sea. Neither spruce nor poplar are found in this area, and even willows and alders are sparse. In the immediate vicinity of Platinum and along the coastal foreland for 7 miles to the southward no brush of any kind grows. But from this point southward to the mouth of the Salmon River alder brush grows at the foot of the steep mountain slopes. The line of separation between the non-alder-bearing and the alder-bearing terrain is very sharp and coincides with the contact between the ultrabasic rocks of Red Mountain and the country rock to the south, clearly indicating that the soil derived from ultrabasic rocks is inhospitable to vegetation.

Willows near the mouth of the Salmon River are medium-sized. They are intermittent and decrease in size up the valley of the Salmon River to a point a short distance north of the mouth of Medicine Creek. Small stunted willows also grow here and there in the valley of Medicine Creek for about 2 miles above its mouth. Willows are also found in the stretch from the mouth of Tundra Creek downstream almost to the mouth of the Smalls River and in the headwater part of the valley of Fog Creek, about a mile east of the head of Medicine Creek. Both willow and alder brush are believed to be fairly plentiful in the headwaters of the Kinegnak River and farther on to the east and northeast.

No complete collection of plants is known to have been made in this area, so that the character of the low-growing and recumbent plants cannot be stated. There are, however, many flowering plants, grasses, mosses, and lichens. Blueberry and cranberry plants grow in the area, but many of the berries do not mature. There appears to be grass enough on the valley floor to support pack horses during the summer. Along the coast, a veneer of wind-blown sand, accumulated locally on top of the gravel bluffs and at places for some distance up the mountain slopes, is everywhere covered by a growth of the wild ryegrass *Elymus mollis Trinius.*

Animal life in this area is likewise scant. Moose and woodland caribou are not found, and only one or two bears have ever been reported in this vicinity. Several foxes were seen during the summer of 1937, but this in general cannot be regarded as an area of fur-bearing animals. The principal animal life consists of medium-sized herds of reindeer, amounting at times to several hundred, which have apparently reverted to the wild state and roam the country like barren-land caribou, to which indeed they are closely related. The principal fish are salmon, which during the spawning season enter the mouths of the Salmon and Smalls Rivers but more particularly the Kinegnak River. These are caught by the natives of Kinegnak, who depend upon them for a part of their food supply. Grayling are scarce in the streams.

GENERAL GEOLOGY

Both bedded and intrusive rocks are present in this area. The bedded rocks are divided into three mappable groups, which comprise both indurated rocks and unconsolidated deposits. The oldest and most widely distributed group is an assemblage of sedimentary rocks.

which comprise graywacke, chert, argillite, slate, and some tuff, together with their metamorphic equivalents. These rocks, which have a great thickness, are complexly folded and in part recrystallized. They are considered to be of late Paleozoic (?) age. Interbedded with these sedimentary rocks, and therefore of approximately the same geologic age, is a formation that consists dominantly of tuff and lava. The youngest sediments, which are unconsolidated, are divisible into older and younger deposits.

The intrusive igneous rocks consist of two major groups, the first and economically the most important of which is ultrabasic and includes several varieties of peridotite and perknite. These rocks form Red Mountain, where they constitute the source of most of the known platinum metals in this district. Associated with these are dikes of other intrusive rocks of specialized types, which are not separately mapped. The second major class of intrusives is granitic. A variety of dike rocks of different ages also occur in this district.

BEDDED ROCKS

LATE PALEOZOIC (?) ROCKS

DISTRIBUTION

All the country rock of this area except the intrusives and the lavas and tuffs is mapped as a single unit, although at different localities there are marked differences in lithology and degree of metamorphism. The largest mass of these bedded rocks is in that part of the area southeast of the band of lavas and tuffs, where they form the bedrock on the ridges between Fog and Shaw Creeks, between Shaw Creek and the Salmon River, and on the southern end of the ridge between the Salmon River and the sea. The other principal outcrop is along the ridge north of the Smalls River, but a narrow extension of this outcrop continues southwestward into the head of the Salmon River and in decreasing width to the head of Platinum Creek.

LITHOLOGY AND STRUCTURE

The late Paleozoic (?) fragmental series, which comprise a wide variety of rocks in different stages of metamorphism, consist dominantly of graywacke, chert, argillite, and slate and subordinate amounts of tuffaceous rocks and the metamorphic equivalents of all these. Among the latter are partly recrystallized graywacke, quartzite, and green schists. Associated with the fragmental rocks are also various intrusive rocks, in the form of dikes and sills, which likewise vary in comparison and in their degree of metamorphism. One characteristic of all these rocks is their greenish color, due to the almost universal presence of epidote and chlorite. As a result of this coloration, many of these rocks have been thought by prospectors and by mining men to be altered basic or ultrabasic igneous rocks, to which the name serpentine was loosely applied. In reality, these rocks are difficult to identify, and the true character of many of them is not determinable except by microscopic examination.

Three principal facts were learned from the field examination of these rocks. First, they strike about northeastward; second, rocks of the same general lithologic character appear to be continuous for considerable distances along the strike; and third, the degree of regional metamorphism, though variable, is greatest in the southern part of the area. In view of these facts, it might be thought that the various lithologic types could be separated into mappable formations, but this is impracticable, chiefly because of the scarcity of rock exposures on the ridges and the almost total absence of exposures in the valleys. Although tentative contact lines could be drawn even with poor exposures, the gradation of the lithology across the strike and the complex structure of the rocks introduce factors of such indefiniteness and irregularity as to preclude the separation of these rocks into definite formations. In lieu of such a separation is a general description of the lithology from the northern to the southern part of the area.

In the northern part of the area, particularly north of the Smalls River, the country rock consists largely of dark-gray graywacke and impure argillite in an advanced stage of induration and replacement by secondary minerals but not dynamically recrystallized. One specimen of graywacke from this area appears under the microscope to be composed largely of angular to subangular crystals of altered plagioclase feldspar and a minor amount of hornblende, in a matrix that is essentially epidote, chlorite, and albite. The plagioclase is albitized and more or less chloritized, and the hornblende, which itself may be secondary, is more or less chloritized. Most of the argillite in this part of the region as in other parts is not essentially different from the graywacke, except in the smaller grains of the component minerals.

Few of the various sedimentary rocks in the headwater valley of the Salmon River and in contiguous parts of the valley of the Smalls River are well exposed. On the dome north of Clara Creek, is rubble of argillite, slate, chert, quartzite, and siliceous greenish rocks but little or no tuff. In this part of the area there seems to be a prominent proportion of the siliceous rock, such as chert and quartzite derived from chert, and in the rock-cut gorge of the Smalls River the bedrock consists altogether of sheared and schistose siliceous rocks, including cherty schist, siliceous chloritic schist, and white quartzite. These same schistose and semischistose siliceous rocks, together with metamorphosed tuffaceous rocks, appear in the bedrock of Clara Creek beneath the stream placers, but the surficial alteration succeeding the regional alteration has rendered them almost indeterminate.

The country rock at the head of the Salmon River continues southwestward in the valley of Platinum Creek, where it is poorly exposed. It is evident from the large volume of rubble atop the spur lying between Squirrel Creek and the Salmon River, that the country rock in this vicinity consists of graywacke, massive and banded dark-gray quartzite, some beds of the conglomerate, and a variety of sheared and semischistose greenish rocks. Unquestionably most of these rocks are of sedimentary origin, though they may include some tuffaceous rocks. Among the rubble are also found fine- to coarse-grained dike rocks composed of green and brown hornblende, altered plagioclase feldspar, and iron ores. The plagioclase is albitized and more or less replaced by epidote and chlorite, so that the original character of these rocks is indeterminate; but they are probably related closely to the basaltic and andesitic lavas. Similarly on the small spur northwest of the camp of the Goodnews Mining Co. both graywacke and igneous rocks of the same type have been identified, and in the absence of more exact information the igneous rocks are interpreted as intrusive. Sedimentary rocks associated with tuffs and intrusive rocks also appear to continue up the north side of Platinum Creek, and dike rocks are exposed at the southwest end of the saddle at the head of Platinum Creek. Still further southwest, however, argillitic rocks appear in the bluffs facing the sea.

Southeast of the formation of lava and tuff that lies along the north side of Platinum Creek there occurs for a distance of about 3 miles across the strike a great variety of rocks, mainly of sedimentary origin, that appear to be progressively metamorphosed to the south. On the spur southeast of Thorsen Mountain the sequence consists dominantly of semimetamorphic graywacke, consisting of detrital grains of plagioclase feldspar, and a little quartz, in a recrystallized matrix. The feldspar occurs as angular to subangular grains and is completely albitized. In some of these rocks, the grains of feldspar have been elongated and oriented by shearing. The matrix consists of chlorite, sericite, albite, and quartz together with considerable semiopaque epidote. In many specimens the micaceous minerals are oriented in the matrix in such a way as to produce an incipient cleavage. Rocks of the same type occur farther southwest on the spur between Quartz Creek and the Salmon River, but at the southeast end of this spur they merge into bedded chert, which represents one of the best exposures of bedrock in this region. (See pl. 6, *A*.)

At the north end of the two ridges lying between the Salmon River and Shaw Creek and between Shaw and Fog Creeks are rocks of the same general types as those northeast and southwest of Quartz Creek, but a larger proportion of cherty rocks appears to be present, many of which grade into quartzitic types. Thus on the ridge west of the head of Fog Creek there occur two buttes, of which the one farther to the southeast is the higher. The country rock in the vicinity of the northwestern butte consists of graywacke, argillite, and chert, but in the direction of the southeastern butte, chert becomes the dominant rock. Still farther southeast this chert has been metamorphosed into quartzite and quartzite schist. It thus appears that from three-quarters of a mile to a mile southeast of the formation of lava and tuff is a well-defined band of rocks composed of chert and quartzitic rocks derived therefrom. The width of this cherty band is indefinite, but in places it is as much as half a mile across the strike.

Southeast of this horizon of chert the country rock for a distance of about 2 miles across the strike consists of sheared and semischistose greenish rocks that appear to be dominantly metamorphosed graywackes. Samples of these rocks from the top and sides of Kemuk Mountain were seen under the microscope to consist of detrital grains of albitized feldspar and quartz, which are stretched, elongated, and broken into heterogeneous optical fields. The groundmass consists of epidote, chlorite, sericite, and albite, together with some secondary quartz and calcite. The sericite of the groundmass is fairly regularly oriented, producing an irregular cleavage.

Still farther to the southeast occur the most highly metamorphosed rocks found in this district. Rubble of these rocks covers the southern dome between the Salmon River and Kookukluk Creek and the similar high dome between Kookukluk and Shaw Creeks. At the former locality the country rock is essentially a pale-greenish fine-grained quartzite and a quartzite schist, both of which are clearly derived from chert. At the latter locality, however, there occurs a variety of fine-grained to granular, greenish, schistose rocks which under the microscope are seen to be so completely recrystallized that their original character is largely indeterminate. Most of these rocks are chlorite-albite schists, but their composition is such that they could have been derived by the metamorphism of graywackes. In fact, there is not such a great metamorphic difference between these rocks and those of Kemuk Mountain. Intermingled with these are some other recrystallized rocks that appear to have been of igneous origin. The chlorite-albite schists have a granular fabric and are composed of fresh-looking secondary minerals, of which chlorite and albite (or oligoclase) are present in all specimens. Epidote occurs also in most of these rocks and sericite, hornblende, and quartz in a few of them.

The associated meta-igneous rocks are coarser-grained, darker in color, and are characterized under the microscope by the constant presence of a colorless to light-green amphibole. Old phenocrysts of feldspar, now altered to albite, epidote, and chlorite, are also visible in some of these rocks. Epidote, chlorite, and sericite are the common constituents of the groundmass, though some calcite and quartz, as well as iron ores, are also present. Though not specifically determinable, these altered igneous rocks are probably metadiorites of intrusive origin.

At its extreme southeastern end, the ridge between Kookukluk and Shaw Creeks is divided into two subsidiary spurs by a small stream that drains into the Kinegnak River. The western spur and the southern end of the eastern spur are composed dominantly of intrusive diabase, but the northern end of the eastern spur is essentially chert. These rocks are probably the least altered of any found in the district, though they occur in close proximity to the most metamorphosed types. No definite explanation of this anomalous condition can be given, as the facts in the absence of structural or stratigraphic evidence may be variously interpreted. It is not known whether these slightly altered cherts and diabase continue northeastward beyond Shaw Creek.

Little is known regarding the structure of the country rock of this area. About a dozen localities were found by the writer where strike and dip could be observed, and of these six observations refer to bedding planes, three to cleavage planes, and the remainder to a dominant but indeterminate structural feature. Half of the observations on the bedding planes show a dip to the southeast and half to the northwest, but all of the observations on cleavage indicate that the cleavage planes dip generally but in a variable degree to the southeast. It is evident from the observations and local details of structure that those rocks are complexly folded. It is also clear that a secondary cleavage has been developed, which is more perfectly developed in the southern part of the area. The direction of the regional dip is uncertain, though it is believed to be probably to the southeast. The cleavage plane, though it also dips to the southeast, may have been more or less deformed subsequent to its formation.

AGE AND CORRELATION

No fossils have been found anywhere in this area, so that the geologic age of the rocks is indeterminate. It is therefore only by a lithologic comparison of these rocks with those in other parts of Alaska that any idea of their age can be obtained. These rocks appear to be too greatly indurated and folded to be of Tertiary age. They contain too much chert to be of Tertiary, Cretaceous, or Jurassic age. The Triassic has been found in some parts of Alaska to contain considerable chert, but cherty rocks have their highest development in Alaska in the Carboniferous, and particularly in the lower Carboniferous. Chert is likewise found in pre-Carboniferous Alaskan formations but usually in association with limestone formations. The presence of intercalated lavas and tuffs likewise has a bearing on the problem, and in this connection it should be stressed that one of the greatest outpourings of lava in Alaska took place during the Carboniferous. The amount of lava in the area considered in this report is relatively small, but in short distances to the north, in the valley of the Goodnews River, Harrington[3] has mapped a large volume of lava that he designated Mesozoic.

In the country northwest of Goodnews Bay are Permian limestone and associated lavas that are probably also of Permian age. The fossils on which the age of the limestone is based were found a few years ago, long after Harrington's map was published. Farther to the southeast are "sandstones, slates, argillites, cherts, and graywackes, with some included flows and tuffs of basalt." Still farther southeast, in the main valley of the Goodnews River, are "basaltic intrusives, flows, and tuffs." And finally, farthest to the southeast, in the area described in this report, are rocks that appear to be essentially the same as the noncalcareous sediments, lavas, and tuffs described by Harrington. This lithologic sequence suggests that the rocks become generally older from north to south and that the country rock of the Platinum area is likely to be of early Carboniferous, but in any event of late Paleozoic age. The available structural data serve neither to prove nor to disprove this belief, but the increasing degree of metamorphism to the southeast is not inconsistent with this interpretation.

LAVAS AND TUFFS

DISTRIBUTION

Ancient lavas and tuffs may be found at many places among the sedimentary rocks, but in one particular area such rocks are sufficiently prominent to justify their separate delineation. This belt is of irregular width and trends somewhat sinuously but generally northeastward across the district. At its southwest end it is about a mile wide and includes the area at and in the vicinity of Thorsen Mountain. At its northeast end, where its width is at least 1¾ miles, it includes the summit and southern and eastern slopes of Susie Mountain and the high hills at the heads of Fog and Wind Creeks.

For several reasons the exact boundaries of this belt of rock are not entirely determinable. The scarcity of outcrop on the ridges is

[3] Harrington, G. L., Mineral resources of the Goodnews Bay region, Alaska: U. S. Geol. Survey Bull. 714, pl. 7, 1921.

perhaps the most serious deterrent to an exact areal delineation. In general the tops of the hills are covered with rock debris that is derived from nearby bedrock. On the summits of the ridges this debris gives a fair idea of the general character of the underlying bedrock, but it conveys no idea of either the minutiae of contact features or the general structure. On down the slopes from the ridge crests only rock rubble is visible at best, the original position of which is indeterminate. It might be thought that the approximate location of contacts at widely separated intervals might be adequate for mapping, but various facts throughout this report indicate that the country rock has a complex structure, so that the true contact is probably a decidedly irregular line, which could not be accurately interpolated from isolated observations.

Another difficulty arises from the fact that lavas and tuffs, in smaller volume, are also found in the general country rock, so that the actual contacts may not be at definite stratigraphic planes but instead may be transition zones of some width between the lavas and tuffs and the other country rock. Again, the recognition and mapping of one zone of lavas and tuffs may be taken to imply that no other similar zones exist. This impression must be corrected, for it is a well-known fact that lavas and tuffs have also been recognized at other localities in the sedimentary sequence, but such zones have either been too thin or too inconspicuous to warrant their separate delineation.

In spite of these cartographic difficulties and shortcomings, the writer has elected to map one conspicuous zone of lavas and tuffs occupying the general area above indicated. The existence of this zone is indicated by many thin sections of the rocks, so that its general position is not subject to doubt. But the area mapped as lava and tuff is also known to contain more or less sedimentary rocks, particularly in the vicinity of Thorsen Mountain. For these and the other reasons cited the belt of lavas and tuffs is to be interpreted as a zone in which the rocks are dominantly but not exclusively of this type. The boundaries are to be regarded only as approximations to the true contacts.

PETROLOGY AND STRUCTURE

Fragmental rocks of tuffaceous character appear everywhere to form a major part of this sequence, but more lavas occur in the hills at the heads of Fog Creek and Wind Creek than elsewhere in this belt. Also in this vicinity relatively few sedimentary rocks are included with the volcanic series. Farther to the southwest, however, the volcanic sequence appears to contain very little lava, and only the coarse-textured tuffs can be identified with any assurance in the field. Many of the other rocks at this end of the belt are so fine grained that they cannot be determined without microscopic examination. Moreover, as stated above, they are intermingled with an indeterminate quantity of sedimentary rocks, chiefly semimetamorphic varieties of graywacke, slate, argillite, and chert.

The classification of igneous rocks depends in large measure on exact determinations of the feldspars. In these lavas and tuffs practically no feldspars are present in the form in which they originally crystallized. Instead all of them are to a greater or less extent albitized, and replaced by secondary minerals, which veils their original character. Apparently the lavas include both basaltic and andesitic rocks, but a description of them must of necessity be mainly an enumeration of secondary minerals and a description of the original structure that has not been completely obliterated by the secondary processes.

Most of the basaltic lava consists of fine-grained greenish rocks, which are not everywhere distinguishable from fine-grained tuffs. Some of them, however, are reddish, as for example in the low hill northeast of the mouth of Medicine Creek. Some of the lavas are also marked with greenish-white spots, which are either amygdaloids or old phenocrysts.

The porphyritic character of some of the basaltic lava is recognizable under the microscope, and the phenocrysts, so far as can now be determined, were composed of plagioclase feldspar. The original phenocrysts are represented by light-colored areas composed largely of chlorite and albite, though epidote also replaces feldspar to a greater or less degree. Both the porphyritic and nonporphyritic rocks had originally a fine-grained matrix that consisted of small laths of plagioclase feldspar in a matrix of pyroxene (?) or glass or both. This groundmass is in large measure altered to secondary products. In the least altered of the lavas the original intersertal fabric may still be recognized, but in none of the lavas are the lath-shaped feldspars sufficiently well preserved for identification. In general they appear cloudy and porous, and under considerable magnification they are found to be a mixture of albite (or oligoclase) and chlorite minerals. The interstitial minerals, which originally were probably pyroxene, and the interstitial glass are completely altered to secondary minerals, of which epidote is the most common. The original iron ores are altered to iron hydroxides. Crystals of apatite, and less commonly titanite, are also present. The more altered types of lavas are more or less recrystallized, and some of them are laminated, so that their original structure is either indistinct or completely obliterated.

In addition to the lavas of basaltic types, there also occur in the lava belt numerous rocks that consist essentially of much altered plagioclase feldspar, green hornblende, and iron ores. These rocks likewise include both porphyritic and nonporphyritic types and are not glassy in the groundmass, but they are in general not so fine grained as the basaltic lava. Most of the feldspar in these rocks is albitized and replaced by secondary minerals, principally chlorite and epidote. The hornblende, however, is unaltered, though some of it appears to be secondary. Quartz also occurs in some of these rocks, but some or all of this may also be secondary. As the feldspars of these rocks are indeterminate, the original character of the lavas cannot be stated. But their mineralogy and texture suggest strongly that they were originally of a less basic type of rock, probably of andesitic character.

Tuffaceous rocks which form a major part of this sequence, are particularly noticeable at Thorsen Mountain, on the hill next west of Thorsen Mountain, and on the spurs extending northward from these hills to Platinum Creek. There the fragments of lava are ample to be easily seen with the naked eye. The fragmental character of such rocks is unmistakable, but the finer-grained varieties are distinguishable from lava and graywacke only under the microscope. In fact, they grade rather imperceptibly into graywacke, so that even under the microscope the tuffaceous character of the material is not always surely determinable.

All the tuffaceous rocks have a greenish hue, due to the large proportion of epidote and chlorite that they contain; but this same coloration is likewise characteristic of all the sedimentary rocks of the region, so that it has no diagnostic determinative value. The grains that compose the tuffs, as seen both in hand specimens and under the microscope, are in large measure angular and irregular in shape. But some of the grains show a certain degree of imperfect rounding, suggestive of abrasion by moving water. It is believed that these fragments resulted from explosive vulcanism and that they represent volcanic ejectamenta that were subsequently consolidated into tuffs. The presence of a considerable volume of fine-grained interbedded sedimentary rocks, however, such as chert and argillite, leads to the conclusion that the vulcanism occurred in or close to a body of standing water. These tuffs are therefore in part of subaerial character but are also in part waterlain, as indicated by the imperfect rounding of some of the detrital material.

Under the microscope the tuffs are found to consist essentially of angular to subangular fragments of lava and grains of albitized plagioclase feldspar closely welded together. In some of these tuffs only a mixture of fine-grained secondary minerals is now visible. In addition to albitization, the plagioclase is also extensively altered to chlorite, epidote, and sericite. The groundmass is a mixture of secondary minerals, of which epidote is by far the most common; but chlorite, albite, calcite, sericite, and other secondary products also occur. The tuffs have yielded more readily to dynamic stresses than the lavas, so that some of the finer-grained varieties show a roughly parallel orientation of the chlorite and sericite, resulting in an incipient cleavage.

This belt of rocks trends about N. 55° E., but as shown on plate 2 its width is variable. There is no way of determining whether the variation in the width of this belt is due to a lateral variation in thickness, to structure, or to a combination of these. It is probable, however, that the country rock lying south of the two masses of ultrabasic rocks is greatly faulted and otherwise disturbed, so that complexity of structure probably plays an important part in the irregular distribution of these rocks. It is equally likely that the intermingling of igneous and sedimentary rocks at the southwest end of this belt may similarly be due in large measure to intricate folding and faulting. It is assumed that these rocks are conformable with those of the sedimentary sequence, and therefore it is believed that the general dip of the lavas and tuffs may be to the southeast. With such fragmentary data, however, and with the belief that all the country rock south of the major intrusions is greatly disturbed, no estimate of the thickness of this formation seems warranted.

AGE AND CORRELATION

It has been shown that the sedimentary rocks of this area cannot be assigned a definite geologic age based upon the evidence of fossils, but it has been suggested that most of the sedimentary sequences may be of late Paleozoic age. It therefore follows as an equal probability that the lavas and tuffs may also be of late Paleozoic age.

It is a well-known fact that great floods of basic lava were poured out in southern and central Alaska during the Carboniferous and Permian periods. It has been shown by Moffit [4] and Mertie [5] that in the Copper River region the Mississippian lavas were interbedded with a variety of sedimentary rocks. The writer has also shown that less extensive lava flows have occurred in interior Alaska during the Devonian period; and these likewise are interbedded with sedimentary rocks. So far as it goes, therefore, the lithology likewise points to a late Paleozoic age, but no closer correlation seems warranted.

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits of Quaternary age are spread over a considerable part of the area described in this report. These deposits originated in various ways and may therefore be classified genetically

[4] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S Geol. Survey Bull. 745, pp. 54–67, 1923.

[5] Mertie, J. B. Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872, pp. 91–103, 1937.

according to their mode of origin. Five general types of deposits have been recognized, namely, glaciofluviatile, fluviatile, eluvial, marine, and eolian deposits, but of these only the glaciofluviatile, fluviatile, and eluvial deposits occupy any considerable areas.

Although it is thus possible to divide the unconsolidated deposits into various genetic types, it is not practicable to map them according to such a classification, as many of them have originated as the result of a complex interaction of several agencies and are therefore not representative of pure genetic types. Thus no sharp line could be drawn between fluviatile and glaciofluviatile deposits, because at some distance from the discharging glacier these two types of deposits are practically indistinguishable. Similarly, it would be difficult to draw any sharp line between eluvial deposits and gully deposits of fluviatile type. And again, the marine deposits of this area are merely a narrow fringe of glaciofluviatile and fluviatile material that has been reworked by the action of the surf.

A second method of classifying and mapping Quaternary unconsolidated deposits is based upon their geologic ages, utilizing the terms "Pleistocene" and "Recent." The term "Pleistocene" is used to denote the age of all deposits formed during the last great ice age. Even in the United States and Canada the time interval thus designated is an indefinite one, but in Alaska it is much more indefinite because large ice fields still persist, so that locally the ice age has not yet terminated. It is therefore impracticable to distinguish sharply between deposits that were laid down in the latter part of the Pleistocene and some of those that are still in process of formation. Hence the terms "Pleistocene" and "Recent" are not strictly applicable in Alaska and cannot in general be used to denote geologic time intervals.

A third criterion used for mapping unconsolidated deposits is their relative ages. For two reasons this method likewise results in considerable cartographic ambiguity. In the first place, many of the various deposits grade so continuously into one another in a chronologic sense that it is difficult to decide upon a stratigraphic line of division and even more difficult to draw such a line, on the geologic map. And secondly, even if a clean-cut separation on the basis of relative age could be made, both the older and the younger deposits would then include material of very diverse origin.

Notwithstanding its inherent shortcomings, the third method of classification appears to be the most feasible, not only in the particular area under discussion but also in most other parts of Alaska. On the geologic map, plate 2, the alluvial deposits are therefore represented by two patterns, which indicate two general ages of unconsolidated material. Neither the older nor the younger of these two cartographic types are genetically homogeneous, nor are they strictly distinct in a chronologic sense. Some of the limitations implied by this method of mapping will appear from the description of the character and genesis of these deposits.

OLDER DEPOSITS

DISTRIBUTION

The older alluvial deposits are most prominent in the northwestern part of the area here designated Platinum and vicinity, where they occupy large tracts in the lower valleys and extend upward onto the tops of the lower ridges. These deposits are also prominent farther south in the valley of the Salmon River and in some of its tributaries and to a smaller extent in the streams that drain the eastern and southeastern part of the area. From Platinum southward, the older alluvial deposits also cover the foreland between Kuskokwim Bay and the bordering hills to the east. In the aggregate these older unconsolidated deposits probably cover at least a fourth of the area shown on the accompanying map.

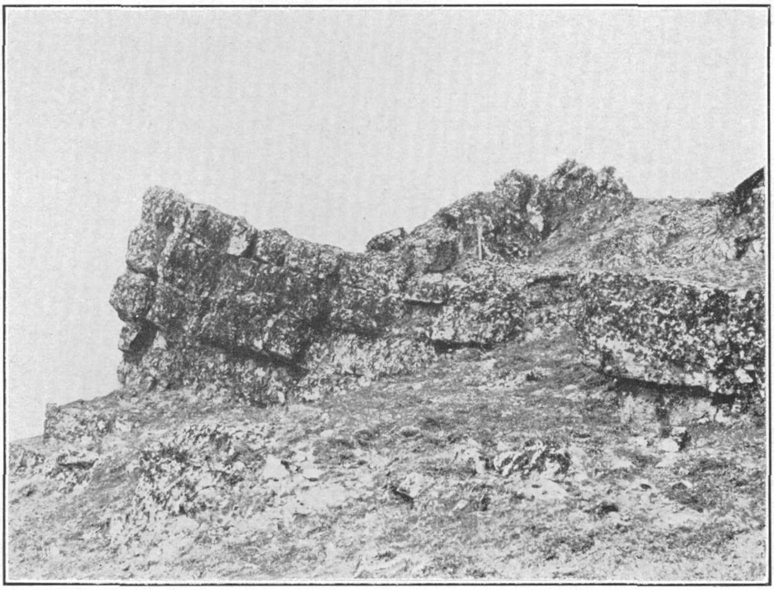
The vertical distribution of these deposits is erratic, first because deposition in some localities was at higher levels than in others, and second, because of differential erosion. Moreover, the surficial covering of moss and other vegetal material in this region does not everywhere permit recognition of the limits of these deposits. In the valley of Tundra Creek and in that part of the valley of the Smalls River contiguous to the mouth of Tundra Creek, including the divide between the Smalls and Salmon Rivers, the older gravels have been mapped up to an altitude of about 400 feet above sea level. This altitude, however, does not represent the original upper limit of the older gravels, because a part of all of them have at places been eroded. For example, a few erratic cobbles are present on the north slopes of Red Mountain, about half a mile west of McCann Creek, at an altitude of 825 feet above sea level, or about 600 feet higher than the bed of the Smalls River. Another erratic feature in the vertical distribution of the gravels is noticeable north of Clara Creek, where one hill with an altitude of about 400 feet is covered with gravels, whereas another dome of the same height a short distance to the northeast is mapped as bedrock.

Along the steep northwest slopes of Red Mountain the older gravels reach an altitude of 350 feet, but they descend from that altitude to 100 feet to the southwest. Between a point south of that part of the Red Mountain massif that reaches the sea and the mouth of the Salmon River, the upper limit is about 100 feet above sea level. And within the valley of the Salmon River the upper limit ranges from 400 feet above sea level, at the head of the valley, to 300 feet above sea level, in the southern end of the valley. It is evident, therefore, that the contact between the older gravels and bedrock does not follow any one contour line.

CHARACTER AND SURFICIAL FEATURES

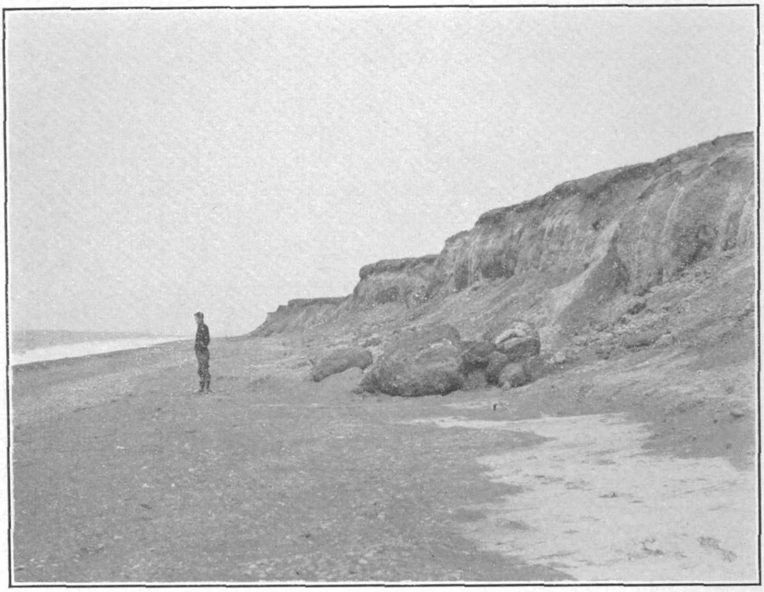
The character, size, and shape of the older gravels are not generally visible in the northwestern part of the area, though this is the locality in which they are principally deposited. The presence of the older deposits is indicated merely by cobbles and occasional boulders that show at the surface, and these give little information regarding the general characteristics and thickness of the deposits. Along the north bank of the Smalls River, however, and a short distance east of the mouth of McCann Creek the deposits crop out in a bluff about 75 feet high. Here the deposits consist of subangular to subrounded pebbles and cobbles, with practically no boulders and with little interstitial sand. Many of the cobbles are faceted on one or more sides, and the general character of the deposits suggests material that was transported by a glacier but was subsequently subjected to considerable sorting and rounding by fluviatile action. A large variety of rocks are found in these deposits, including most of the rocks known to occur in the valley of the Goodnews River, but chert and argillite and basaltic rocks are the most common. Some granitic rocks are also present.

North of this bluff for a distance of about three-quarters of a mile and for a similar distance from east to west, the surface of the country is hummocky and poorly drained, with several small lakes, one of which is mapped. In this locality the gravel seen at the surface is imperfectly rounded and poorly sorted and the fragments range in size from small pebbles up to large boulders. This typical "sag and swell" topography is associated with the moraines that are deposited from a retreating glacier. Similar topographic features exist in the divide at the head of the Salmon River, about 1½ miles north and a little east of the mouth of Clara Creek. This divide in general is a broad low gravel-filled and poorly drained depression, which on its eastern side is characterized by two elongate gravel mounds resembling kames or eskers. Between the more easterly of these and the rising bedrock hills still farther east is a narrow shallow lake about 900 feet long. Both the elongated gravel ridges and the lake trend about N. 10° E. The gravel deposits at these two localities, one on the north side of the Smalls River and the other at the head of the Salmon River, are the only deposits seen in the area that are suggestive of moraines. But the distinctness of the diagnostic features of morainal deposits at these localities and the presence of erratic cobbles high on the north slope of Red Mountain leave little doubt that a glacier formerly existed in this general vicinity.

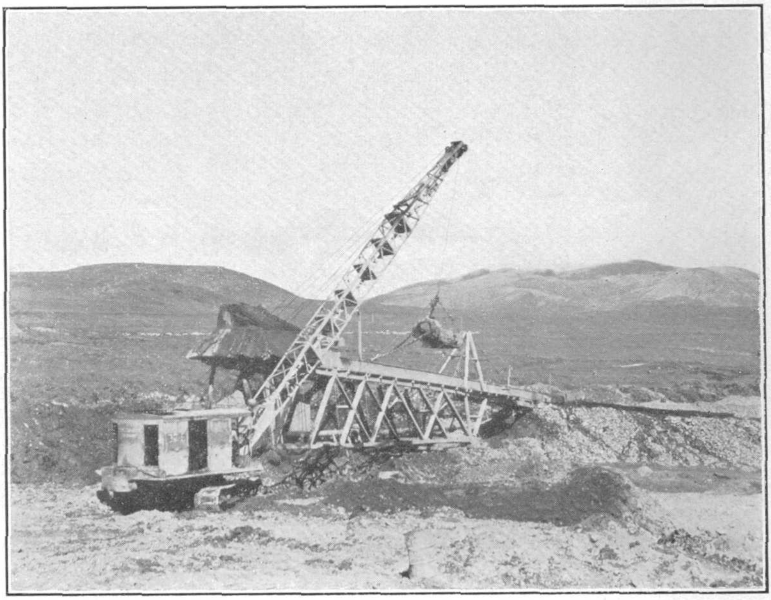


A. OUTCROP OF BEDDED CHERT ON HILL ABOUT 1½ MILES NORTHEAST OF MOUTH OF SALMON RIVER.

B. VIEW LOOKING SOUTH ALONG SEACOAST NEAR MOUTH OF LAST CHANCE CREEK
Shows cliff of outwash deposits on left and Red Mountain in background.



A. OUTWASH DEPOSITS FORMING SEA CLIFFS, ABOUT A MILE NORTH OF MOUTH OF SALMON RIVER.



B. DRAGLINE EXCAVATOR AT WORK ON PLATINUM CREEK.

A considerable tract of older gravel deposits is also mapped along the north side of the valley of the Smalls River between 1 and 3 miles east of the mouth of McCann Creek. About 1¾ miles east of McCann Creek, a tributary of the Smalls River enters from the northeast. Between the valley of this tributary and the valley of the Smalls River is a gently rising spatulate spur, which at its southwest end breaks off into two successive gravel bluffs, limiting two well-defined gravel terraces. The surface of the lower terrace is about 35 or 40 feet above the valley floor, and the surface of the upper terrace is about the same height above the surface of the lower one. The top of this spatulate spur is in no sense suggestive of morainal topography but instead is the kind of surface that might be expected to develop as a result of normal stream erosion. Moreover, the gravel fragments are fairly well rounded, well sorted, and of moderate size. Upstream from this deposit, the spurs descending from the valley walls of the Smalls River are interlocking, the valley is not U-shaped, and there are no headwater cirques nor any other indication that glacial ice ever crossed the divide into the head of the Smalls River. Similarly, no ice appears to have pushed into the valley of the Smalls River from the head of Wind Creek. From the character of the deposits and their surficial configuration, it therefore follows that the older gravel deposits in the eastern part of the valley of the Smalls River are neither glacial nor glaciofluviatile deposits but instead are normal fluviatile deposits.

From the foregoing descriptions it is almost self-evident that the glacier which at one time blocked the valley of the Smalls River and produced the ground moraine at the head of the Salmon River and north of the Smalls River was a lobe of the Goodnews Glacier, which came from the northeast down the valley of Tundra Creek. Between Tundra Creek and Goodnews Bay is a low ridge that rises at one point to an altitude of 650 feet above sea level but that in general is considerably lower. The southwest end of this low ridge has a veneer of older gravels, but along the higher part of the ridge to the northeast gravels do not now occur in any appreciable quantity above the 400-foot level. To the southeast is a broad swampy valley, now occupied by Tundra Creek, in which are visible a number of small lakes as well as drumlin-shaped ridges. Moreover, the spurs to the southeast of this depression are noticeably foreshortened, as a result of glacial erosion. The gravel-covered foreland south of the western part of the Smalls River, however, shows a topography characteristic of glacial outwash deposits rather than of ground moraine. South of Seattle Creek and about a mile from the coast is a shallow lake that has a length of about 500 feet and a major trend somewhat north of east, but this is the only significant feature along this part of the foreland that is suggestive of an undrained terrane. The alluvial deposits that occupy the valley of Tundra Creek and spread out to the west and southwest to the shores of Goodnews and Kuskokwim Bays are essentially deposits of glacial origin. They include ground moraine but are dominantly outwash deposits, particularly where they occur in the littoral bluffs along the shores of Goodnews and Kuskokwim Bays.

Along the beach of Kuskokwim Bay, particularly within a stretch of 2 miles extending northward from the mouth of Last Chance Creek, the outwash deposits are intermittently exposed as gravel bluffs. (See pl. 6, *B*.) The material composing these bluffs is poorly sorted yet stratified, but it seems to be inconsistent in the degree of the sorting and stratification. At most places it consists of imperfectly rounded pebbles and cobbles ranging in diameter from 1 to 8 inches, but here and there at the foot of the bluffs are cobbles and boulders ranging from 12 to 15 inches, thus showing the presence of a minor proportion of such coarse material. In places the gravels are interstratified with thin beds of pure sand as much as a foot thick, but these sand beds are neither horizontal nor laterally persistent for any considerable distance. A large proportion, perhaps half, of the pebbles above 3 inches in diameter are well faceted, but some of these surfaces may be the result of original structure in the bedrock, which caused it to break down into angular fragments. These gravels consist dominantly of fine-grained basaltic greenstone, argillite, and chert, with a smaller proportion of other rocks, including mainly granite, diorite, gabbro, shale, conglomerate, and here and there a pebble of limestone. Practically no ultrabasic rocks of the type that forms Red Mountain occur in these gravels, and it is probable that most of these rocks were transported a long distance from the northeast.

The gravel bluffs north of the mouth of Last Chance Creek range in height from 10 to 25 feet. At a point about 2 miles south of Platinum, however, and 125 yards east of the face of the gravel bluff a drill hole was sunk to a depth of about 100 feet without reaching bedrock. The unconsolidated material found in this and other drill holes sunk in the foreland appears to be the same as the material seen in the gravel bluffs. This indicates a minimum thickness of the outwash gravels in this vicinity of 135 feet, but actually the deposits may be much thicker than this. Farther south another hole was drilled along the north side of Last Chance Creek, about 2,000 feet from the beach, and therefore much closer to the western slopes of Red Mountain. At this locality bedrock was reached at a depth of 110 feet. The top of this hole has an altitude of about 70 feet above sea level so that even at this distance from the sea and relatively close to the slopes of Red Mountain the surface of bedrock lies 40 feet below sea level. A third drill hole driven to bedrock was sunk in the floor of the next small gulch south of Last Chance Creek about 400 yards east of the sea. This hole, the top of which had an altitude of about 30 feet above sea level, reached bedrock at a depth of 94 feet, thus showing that bedrock at this site, which is only about 3,000 feet from the steep slopes of Red Mountain, is 64 feet below sea level.

For a short distance south of Last Chance Creek the gravels in the bluffs along the beach are similar to those above described, but close to the hard rock of the Red Mountain massif the bluffs become much higher, and the outwash deposits disappear under an overburden of younger deposits composed essentially of angular hillside debris, or eluvial material. South of the hard-rock bluffs the zone of eluvial deposits is repeated, but from that place southward to the mouth of the Salmon River there occur more gravel bluffs, composed of glaciofluviatile and perhaps in part of fluviatile material. The differences in these two types of material, however, are noted below.

For 2,400 feet north of the mouth of the Salmon River, the seaward-facing bluffs rise from a height of 5 feet at the mouth of the Salmon River to 25 feet farther north. In this stretch the gravels are similar to those north of Last Chance Creek, being subangular to subrounded but showing a considerable degree of sorting and stratification. Thin beds of sand, lying almost horizontal, are also visible. Most of the gravel fragments are less than 8 inches in diameter, with essentially no large cobbles. Some of the pebbles are faceted, and relatively little clay is present. For the next 4,300 feet northward, the formation changes to one in which much clay is present. At the base of the bluffs is a continuous horizon of reddish iron-cemented gravel consisting of angular to subangular unsorted cobbles, with a clayey matrix. At some places this horizon extends to the top of the bluffs, but at other places the upper 5 to 10 feet of the deposits consists of black clay, and in the last 500 feet of this stretch the deposit consists almost exclusively of fine silt or clay. This material is gray when dry. In its water-soaked condition it sloughs away and oozes down onto the beach. The iron-stained and cemented gravel material, which has a high degree of coherency, breaks off in lumps as much as 4 feet in diameter and rolls down onto the beach into the clay ooze. (See pl. 7, *A*.) North of this zone for 500 feet the normal outwash material occurs. Still farther north for 1,075 feet the deposit is again silt and clay, followed by 2,250 feet of fairly well rounded and stratified gravel showing distinct cross bedding. In the next 700 feet the gravels and fine sediments alternate along the beach, but for the next 2,200 feet to the north the material appears to be a mixture of the fairly well sorted and rounded material found north of Last Chance Creek and the tillitic material above described. Within this stretch occur the highest bluffs of unconsolidated material along the beach between Goodnews and Chagvan Bays, rising in places to a height of 40 or 50 feet. Between the north end of this stretch and the eluvial and bedrock marine bluffs of the Red Mountain massif, a distance of about three-quarters of a mile, are low scarps 5 to 8 feet high, composed of 2 to 4 feet of eolian sand underlain by 2 to 3 feet of peat, which is in turn underlain by soft reddish soil.

Within the stretch of low scarps above described and directly west of the saddle at the head of Platinum Creek three drill holes were sunk to bedrock in 1938. The first of these, about 200 feet from the beach, was begun at a point 25 to 30 feet above mean sea level and was driven 75 feet to a pyroxenite bedrock. The second hole, 200 feet farther east and 12 feet higher than the first hole, reached the same bedrock at a depth of 80 feet. The third hole, still farther east and 4 feet higher than the second hole, reached bedrock at a depth of 92 feet. These results show that the surface of bedrock between the third and first holes is uneven and also that it is 40 to 50 feet below sea level practically at the beach, and also very close to a bedrock hillside on the east. Evidently the steep bedrock hillside that faces the sea plunges downward rather steeply for some distance below the present surface.

Many other drill holes were sunk along the foreland between Platinum and the mouth of the Salmon River during the summer of 1937 by prospectors who thought that these outwash deposits included elevated marine beaches that might be the sites of beach placers. Most of these holes were drilled in the vicinity of Seattle and Last Chance Creeks and in the area between these two streams. With the exception of the drill holes above noted, none of them was driven to bedrock, though some penetrated to depths of 100 to 165 feet. The appearance and nonfossiliferous character of the materials exposed by these drilling operations, the character of the deposits forming the gravel bluffs along the beach, the depth to bedrock not only along the foreland but also at the mouths of the Smalls and Salmon Rivers, the evidences of glaciation, and all other available data, suggest that the foreland deposits south of Platinum are largely glaciofluviatile or outwash deposits. These data, in conjunction with the height of the alluvial bluffs facing the sea, indicate that the shore line at the time when outwash deposits were first laid down was a considerable distance west of its present site. It therefore follows that the latest geomorphic event in this area has been an elevation of the base level of erosion, or in other words an invasion of the sea onto the land, which resulted in submergence of the old foreland and drowning of the valleys that led to the sea.

The mapping of the older deposits in the valley of the Salmon River and in the other valleys farther to the east is less accurate than along the seaward-facing foreland. In the valley of the Salmon River the contact between the older and younger deposits is drawn along a scarp or noticeably steep slope that limits the present valley floor. At many other places, however, and especially in the valleys of the tributary streams, this contact is indefinite because the line of demarcation between the older and younger gravels is not marked either by topographic expression or by lithologic differences in the deposits. As these deposits thus grade rather imperceptibly into one another, this contact line necessarily represents in large measure the writer's interpretation of the distribution of these two types of deposits. The upper limit of the older deposits is likewise an interpretation rather than an accurate delineation of a contact, but for another reason. In this area the lower ridges and all the gentler spurs and slopes leading from such ridges are covered with a mantle of residual and eluvial deposits that effectively conceal the underlying bedrock. The upper line of the older deposits therefore represents roughly, according to the writer's ideas, the position on the hillsides where the older gravels terminate and the eluvial deposits become the dominant form of detritus.

The Tundra Creek lobe of the Goodnews Glacier, which delivered the morainal and outwash material to the head of the Salmon River, really impinged directly against the north end of Red Mountain and was shunted off to the southwestward toward and across lower country toward the sea, so that the ice apparently ended at the head of the Salmon River. The thickness and lateral limits of the gravels in the Salmon Valley just prior to the deposition of this latest glacial material is not exactly known, but the volume of such preexisting gravels was probably materially less than the present volume of unconsolidated deposits in this valley. As the ice did not follow down the valley of the Salmon River, those deposits, antedating the last thrust of the ice, were not eroded by glacial action, though in the early stages of the downstream distribution of the outwash they may have been reworked by water to some extent. Soon, however, the Salmon River became overloaded with glacial debris, and thereafter it became an aggrading stream that rapidly buried the preexisting fluviatile deposits under a blanket of outwash material. This redistributed outwash material constitutes most of the older deposits of the main valley of the Salmon River. In this connection, however, it should be stressed that those fluviatile deposits that existed in the valley of the Salmon River before the last thrust of the ice against Red Mountain must also be regarded as another part of the older unconsolidated deposits. In other words, the fluviatile deposits that antedate the outwash deposits are considered to be of Pleistocene rather than Pliocene age, because no geomorphic reasons are known for their assignment to the Pliocene and because they could have been deposited at any time in the long Pleistocene interval between the end of the Pliocene period and the last advance of the ice.

These conditions resulted in an erratic distribution of the older gravels in the tributaries of the Salmon River. In the headwater part of the valley, above the mouth of Medicine Creek, the tributaries of the Salmon River are small, and outwash material occurs throughout the length of these streams. In the valleys of Medicine and Platinum Creeks, on the other hand, the outwash deposits occur only in those parts of the valleys that are contiguous to the Salmon River. Upstream from these zones, the deposits are probably in large measure gravels of local origin and were deposited when the main Salmon Valley was being aggraded by the glaciofluviatile deposits. This is also true of Quartz Creek, but in the eastern tributaries of the Salmon River, below the mouth of Medicine Creek, the glaciofluviatile deposits occur in varying degrees from the mouths of these tributaries upstream, to the extent indicated on plate 2.

Certain significant results and conclusions followed from these conditions. One of the important results was the preservation of the platinum deposits in the valley of the Salmon River. If the glacier that terminated at the head of the Salmon River had continued down the valley it is likely that all of the preexisting placer deposits on Clara Creek and in the main valley of the Salmon River would have been scoured out and dissipated. This fact alone dates the platinum placers as older than the overlying glaciofluviatile deposits. A second result is that the glaciofluviatile material, coming as it did in greater or less degree from the gold-bearing area to the northeast, necessarily carried some gold disseminated in the gravels. Part of this gold was deposited by the streams that distributed the outwash materials, so that the platinum placers of Clara Creek and the Salmon River were somewhat enriched by the addition of placer gold. The commercial analyses of the precious metals found in these placers as compared with those of Platinum Creek and its tributaries verify this interpretation.

Sections of the upper horizons of the older deposits of the Salmon River are visible at only a few places, and the lower beds, except in mining excavations, are everywhere concealed. One of the places where the upper beds of the older unconsolidated deposits are exposed is along the east side of the river a short distance north of the mouth of Happy Creek, where the Salmon River flows at the base of some gravel bluffs composed of this material. At this site the bluffs are about 35 feet high, and the older deposits consist of well-washed rounded to subrounded gravel fragments that range in size from a fraction of an inch up to 6 inches in diameter, averaging perhaps 1½ to 2 inches. The interstitial material is sandy. Some of the pebbles are faceted, but this material has been so extensively handled by stream action that most of the original glacial earmarks have been obliterated, and the deposits are not essentially different from those of the present valley floor. The gravel consists of many types of rocks but includes chiefly chert, argillite, and basic igneous rocks, together with minor amounts of other types of country rock. One of the significant features of the lithology is the presence of a small percentage of granitic and dioritic pebbles. A few dikes of granitic rocks have been found among the ultrabasic rocks of Red and Susie Mountains, but if these granitic and dioritic pebbles came from those mountains there should also be present a very much larger proportion of the ultrabasic rocks. On the contrary, in these gravels ultrabasic rocks are more sparsely distributed than the granitic rocks. It is therefore believed that the granitic and dioritic pebbles did not originate within the valley of the Salmon River. The general impression gained from these observations is that the upper half, at least, of the older alluvial deposits of the valley of the Salmon River were derived mainly from a preexisting supply of debris of glacial origin that was dumped at the head of the river by the Tundra Creek lobe of the Goodnews Glacier and that these deposits were laid down much more rapidly than they could have been if the materials had been derived from hard-rock sources within the drainage basin of the Salmon River.

Little is known regarding the character of the older gravels in the streams east of the Salmon River, including chiefly Wind, Fog, Shaw, and Kookukluk Creeks, as the geology of the unconsolidated deposits in these valleys was not studied. All these streams discharge into the Kinegnak River, but so far as now known, no glacier occupied the valley of that river. The older gravels of Wind, Fog, Shaw, and Kookukluk Creeks are therefore presumed to be fluviatile deposits of local origin.

YOUNGER DEPOSITS

Younger alluvial deposits, of the fluviatile type, form the valley floors of all the principal streams and their tributaries within this region. The approximate distribution of such deposits is shown on the geologic map, plate 2. Along the shore of Kuskokwim Bay a narrow streak of younger unconsolidated deposits form the present beach (pl. 2). Eolian and eluvial deposits are also a part of the younger unconsolidated materials, but for reasons given below these are not separately represented on the geologic map.

A considerable part of the younger alluvial deposits that occur in the valley of the Salmon River and in the western part of the valley of the Smalls River are reworked glaciofluviatile material, but the deposits of the headwater tributaries of the Smalls River and of the larger tributaries in the lower valley of the Salmon River are fluviatile deposits of local origin. All these deposits consist mainly of gravel and sand and merit no special description. They differ from one another, to be sure, in the character of the gravels, as those which have been derived from glaciofluviatile material contain some rocks that are not native to the valleys in which they occur. The pebbles also differ in size and degree of rounding, depending upon their position in the various valleys and upon a variety of other factors. Such physical differences, however, are seldom apparent at the surface of the stream beds but are noticeable only where placer excavations have been made. Some of these variations are given in the description of the placers of Platinum and Clara Creeks.

The marine beach deposits between Platinum and the Salmon River are composed mainly of glaciofluviatile materials that have been washed from the bluffs along the foreland and milled by the surf. Along that part of the beach in which the sea beats against the bedrock that composes Red Mountain these reworked glaciofluviatile deposits are intermingled with materials that have either been cut from the bluffs by wave action or with eluvial detritus of the same lithologic character that has slid down from the steep upper slopes of the mountain. Within this stretch are here and there surficial concentrations of black sand along the beach that is comparable with the black sand at the base of the placer deposits. This sand, which consists of the heavy minerals derived from the ultrabasic rocks, is analogous to the garnet sands found at Nome, Lituya Bay, and at other localities, where rocks containing such heavy minerals lie close to the sea. As the ultrabasic rocks of Red Mountain are considered the source of the platinum metals found in this district, it might be expected that some beach concentration of platinum metals might here be present. On the contrary, panning of these black sands, both by the people of the country and by the writer, reveals only a few grains of platinum. This fact may be interpreted to mean that the platinum metals are not omnipresent in the ultrabasic rocks but instead are localized in pockets, possibly along certain zones such as the contacts. It may also be interpreted to mean that the hard-rock bluffs have not been exposed to direct surf action for sufficient time to produce any considerable concentration of the platinum metals.

Eolian deposits containing recent marine shells occur close to the beach, along the entire stretch from Platinum to the Salmon River. A thin deposit of wind-blown sand, at most places 2 to 12 inches thick, occurs along the tops of the bluffs of outwash material that face the sea, but these deposits thin rapidly toward the east and in a short distance disappear. The thickest deposit of wind-blown sand mantles the low seaward-facing scarp about 3½ miles north of the mouth of the Salmon River, where the material is 2 to 4 feet thick. At the south end of the hard-rock bluffs that face the sea and about 4½ miles north of the mouth of the Salmon River layers of wind-blown sand containing fragments of marine shells lie upon hillside debris, well above the level of high tide or of "high drift." Such deposits, which are as much as 2 feet thick, lay on the narrow divides between steep gullies for distances at most places of 20 to 30 feet but do not occur in the gulches. These sands and the fragments of marine shells were traced up the steep bedrock slopes to a height of 220 feet above sea level. Wherever the eolian sand occurs, a species of wild ryegrass (*Elymus mollis Trinius*) grows, holding with its tenuous roots the sandy material. This dune material does not occupy a sufficient area to be represented on the geologic map, but on a larger scale it could readily be mapped by delineating the limits of the wild ryegrass. A species of this grass is said to have been observed by Leif Eriksen when he landed somewhere on the coast of New England before America was discovered by Columbus.

Residual and eluvial deposits cover a large part of the area shown on plate 2, but they have not been specifically mapped because to do so would conceal most of the bedrock geology. Excepting Susie Mountain and several localities on Red Mountain and the other higher hills, few outcrops of bedrock occur in this area. The tops of the hills are composed mainly of angular rock debris that represents the general character of the bedrock but gives no clue to the stratigraphic and structural relations. At some undetermined distance down the slopes from the crests of the ridges and spurs this residual material acquires sufficient mobility and subangularity to be classified as eluvial detritus, but its exact thickness at any one locality is not readily determinable. Probably all of the residual and most of the eluvial detritus is part of the later unconsolidated deposits, but some of the eluvial deposits on the lower slopes close to the older fluviatile and glaciofluviatile material should possibly be classified as older alluvial material.

GEOMORPHOLOGY

The data that have been given in the description of the Quaternary deposits together with the facts that are evident from the geography and the records of mining lead to some fairly definite general conclusions regarding the Quaternary history of this area. Before stating those conclusions, however, it seems best to define certain terms that will be used.

Reference has already been made to the impracticability of classifying the unconsolidated deposits of this or any other part of Alaska as Pleistocene or Recent, using those terms in the sense in which they are used in the United States and Canada. In ordinary geologic parlance the term "Pleistocene" is used as synonymous with ice age, but this usage cannot be applied in Alaska, because certain parts of Alaska are still covered with ice caps, and at such places the ice age still exists. Moreover, the several stages of advance and retreat of the ice, or in other words, the glacial and interglacial stages of the Pleistocene as recognized in the United States and Canada, have not been generally recognized in Alaska. Apparently the last advance of the ice in Alaska, corresponding roughly to the Wisconsin stage in the northern United States, was so widespread and so severe in its erosional effects that the evidence of earlier advances and retreats of the ice, if they occurred, was largely obliterated. Moreover, it is not known with assurance that the beginnings of the Pleistocene and the Wisconsin stage of the Pleistocene in the United States correspond, respectively, with the advent of glaciation or with the advent of the last glacial stage in Alaska. For these reasons, therefore, the term "pre-Wisconsin" is not specifically utilized as a chronologic designation, and the term "preglacial" will not necessarily connote Pliocene time. And similarly, the term "postglacial" as used in this report must be understood to mean merely the period that has elapsed since the ice finally retreated from this coastal province.

Another concept requiring definition is that conveyed by the expression "base level of erosion." The base level of erosion for any particular area may be defined as the lowest level that can be assumed by the surface of running water within that area. Streams, of course, can erode below their surfaces, but practically, the upper surface of a stream marks closely the level to which a country may be reduced by erosional processes, so long as the base level of erosion remains essentially constant. In a country bordering upon the sea, as in the Goodnews Bay district, sea level may be said to constitute the base level of erosion. The base level of erosion, however, seldom remains constant for any considerable length of time, measured in geologic intervals, as the land may be elevated or depressed, and the level of the sea, and therefore eventually the levels of the rivers, may change, either relatively, as compared with some surface datum, or absolutely, as referred to the center of the earth. Any of these processes, acting singly or concurrently, serve to change the base level of erosion. Close to the sea, any geomorphic process or combination of processes that result in an elevation of the land with respect to sea level will cause a lowering of the base level of erosion; and conversely any geomorphic process or combination of such processes that result in a depression of the land with respect to the sea level will cause an elevation of the base level of erosion. On the other hand, observed or inferred changes in the base level of erosion close to the sea may not be interpreted as due solely to changes in the elevation of the land nor solely to changes in the position of sea level without other supplementary data. A lowering of the base level of erosion, for example, is not necessarily accompanied either by an elevation of the land or by a lowering of the absolute sea level; but insofar as vertical movements of the land or the sea level are concerned, it may be produced in any of the four following ways: By an absolute elevation of the land with regard to a fixed datum, when (1) the absolute sea level remains constant, (2) the absolute sea level is concurrently lowered, (3) the absolute sea level is concurrently elevated but at a rate less than the rate of absolute elevation of the land; or by an absolute depression of the land with regard to a fixed datum, when (4) the absolute sea level is concurrently lowered, but at a rate greater than the rate of absolute depression of the land.

Similarly an elevation of the base level of erosion may take place in four equivalent ways. Inasmuch as vertical movements of the land and of the sea level may readily take place concurrently, it is evident that some knowledge of the rates and accelerations of both these movements must be known before any statement is justified to the effect that the land rose, or the sea level fell, or vice versa. These vital facts are seldom obtainable in ordinary geologic work, and therefore in the absence of the necessary data it is desirable to state merely that a lowering or an elevation of the base level of erosion took place without making any commitment as to the geomorphic movements that produced such changes.

It should also be emphasized that changes in the base level of erosion for any one locality may also be produced by a variety of other causes. Along a coast line, for example, an inland regression of the strand line, due to wave action, may result in anomalous erosional effects that are not predictable unless the concurrent changes in the local base level are also known. And in interior regions, away from the sea, changes in the local base level of erosion may be produced by surficial warping, glacial damming, avalanche filling, and in many other ways.

In preglacial time the valleys of the Salmon and Smalls Rivers were fairly wide and open, and it seems likely that a long period of relative stability of the base level of erosion had resulted in the development of a mature type of topography. The strand line at the end of this period lay farther to the west than it does at the present time. At the end of this period of stability the base level of erosion was greatly lowered, which resulted in a rejuvenation of the streams that emptied into the ocean.

The movements of the land and sea level that produced this lowering of the base level of erosion are not definitely known, but it is pertinent to point out that a lowering of the sea level alone might have produced a regional lowering of the base level of erosion without causing local rejuvenation of the streams. Thus offshore shoals similar to those of the present day may have existed at the end of this period of stability. If so and if the offshore gradient of the sea bottom was the same or less than that of the streams in their lower courses, a lowering of the sea level alone would not have produced rejuvenation in the streams tributary to the ocean. It is not necessarily true, therefore, that eustatic lowering of the absolute sea level resulting from abstraction of a part of the hydrosphere for glacial storage would result in rejuvenation of the streams in this vicinity, though the same process might cause rejuvenation elsewhere. The probability of a long-continued period of glaciation on a major scale in this region indicates that the large rivers of southwestern Alaska may then as later have been carrying a large volume of sediments to the sea; and this in turn suggests that great offshore shoals may have existed in Kuskokwim Bay then as they do now. Hence it is probable that the local rejuvenation above described was due to an upward movement of the land, with or without a concurrent lowering of the sea level. From the mouth of the Arolic River southward for 60 miles or more the hills terminate rather abruptly on their west side against a low coastal foreland. The area just south of Goodnews Bay lies within this stretch. It is possible that this abrupt declivity corresponds to an ancient fault zone along which movement took place such that the land east of the fault was elevated with respect to that west of the fault, thus producing the lowering of the base level of erosion above postulated and the resulting rejuvenation of streams like the Salmon River.

As a result of this lowering of the regional base level of erosion the streams, like the Salmon and Smalls Rivers, that discharged into the ocean were rejuvenated and began to incise their old channels. The preexisting fluviatile gravels of the valley floors were in part eroded, the streams began to incise their channels in bedrock, and, as this process continued, they cut a narrow notch or gorge in the old valley floor. These gorges were extended progressively upstream, and concurrently alluviation in the lower parts of the valleys tended to fill in the gorges. It should be stressed that this process, while it disturbed and reworked the preexisting placers of the Salmon Valley, did not dissipate them, nor were the precious metals necessarily moved very far downstream. Subsequently this process of rejuvenation would have extended the gorge topography into the headwaters of the Salmon River and its tributaries, and eventually the old valley floor would have been obliterated and replaced by another valley floor at a lower level. But the process of rejuvenation was interrupted before the new cycle of erosion was completed, so that the gorge was not developed to the extreme heads of the several streams. On the Salmon River, as previously shown, this bedrock gorge has been traced 2 miles up the valley of Medicine Creek and half a mile up the valley of Platinum Creek. Mining operations in the western part of the valley of Platinum Creek also indicate that the original bedrock floor still remains. The degree of weathering and alteration of the bedrock in this part of the valley is also in accord with this interpretation.

The process of rejuvenation of the Salmon and Smalls Rivers, as above outlined, was interrupted finally by the deposition of a large volume of glaciofluviatile material in their valleys. In other words, the ice that had gradually been accumulating in the higher country to the northeast finally reached into the valleys of the Smalls and Salmon Rivers. The extent of this regional glaciation is not at present known, as much of the country northeast of the Goodnews Bay district has not been geologically mapped; but it is a well-known fact that the high Oklune and Tikchik Mountains, which lie 75 to 100 miles to the northeast, were at this time the site of an ice cap from which trunk glaciers discharged westward and southwestward through the larger valleys to the ocean. The topographic features of some of the country that lies between these mountains and the sea indicates that local glaciers also contributed to the volume of seaward-moving ice. And, as noted in the geographic description of the Platinum area, it seems likely that incipient glaciation existed locally, as in the cirquelike basin at the head of Last Chance Creek.

The ice that penetrated into the valleys of the Smalls and Salmon Rivers was a distributary lobe of the Goodnews Glacier that moved southwestward down the valley of Tundra Creek, thence across the valley of the Smalls River, and on southwestward toward the sea. The north end of Red Mountain lay almost athwart the path of this lobe of the glacier, so that some of the ice was pushed high onto the north end of Red Mountain, leaving erratics, as previously stated, as high as 825 feet above the present sea level. Naturally some of this ice, with its load of contained sediment, was shunted southward across the divide of the head of the Salmon River, but the main thrust of the glacier was southwestward toward the sea, so that only a relatively small volume of ice penetrated into the headwater part of the valley of the Salmon River.

One of the principal effects of the presence of the glacier in the valley of the Smalls River was that this valley was either dammed by the ice or was aggraded to such an extent that the Smalls River was diverted southward across the divide into the head of the Salmon River. There was thus created a river system that consisted of the headwater part of the Smalls River to which was added the preexisting Salmon drainage. It is readily seen, therefore, that much of the outwash thereafter discharged from the east side of the glacier was diverted into the valley of the Salmon River together with the normal fluviatile deposits that originated in the headwaters of the Smalls River. This blocking of the valley of the Smalls River and the aggradation of its headwater part resulted eventually in the development of a wide valley floor of alluvial material over which the Smalls River meandered, departing finally at some places from its former course. In fact, at one locality a short distance east of the divide at the head of the Salmon River, the Smalls River was diverted southward against the south wall of its valley and was superposed above one of the old spurs that formerly projected northward in its valley. Subsequently, after the retreat of the glacier, the Smalls River cut through the glacial material and reestablished its course in its original valley, but as a result of the superposition, the stream thereafter intrenched itself into the old spur, thus producing a short gorge. The river in the gorge is now cutting bedrock, which is sheared chert, though upstream and downstream from this gorge bedrock is overlain by a thick cover of alluvial material. Plate 3, *A*, is a view of this gorge looking downstream on the Smalls River.

This influx of glaciofluviatile and fluviatile material into the headwater part of the valley of the Salmon River resulted quickly in an overloaded stream, so that aggradation of the valley took place from the headwaters to the mouth. Another factor that favored the rapid aggradation of the valley of the Salmon River was the fact that the main Goodnews Glacier and its Tundra Creek lobe in the meanwhile were discharging a large volume of outwash deposits on the west side of Red Mountain and were thus aggrading the foreland between the Smalls and Salmon Rivers. Hence the lower valley of the Salmon River was at the same time being aggraded, thereby elevating the local base level of erosion and making it even more difficult to dispose of the oversupply of gravels being dumped into the headwater part of its valley. Under such circumstances the process of aggradation in the valley of the Salmon River was a rapid one, and the glaciofluviatile deposits were probably deposited on top of the preexisting fluviatile gravels without greatly disturbing them.

Chagvan Bay and the valley of the Unaluk River, a wide, flat, lake-dotted alluvial basin, form a wide reentrant that extends backward from the coast into the hills for nearly 20 miles. So far as now known, no glacier occupied the valley of the Unaluk River or of the Kinegnak River, which it joins close to the sea. Hence, the alluvial deposits within this reentrant are not considered to be of glacial origin. But the long spit that forms the west side of Chagvan Bay may possibly be composed in considerable part of glaciofluviatile deposits that issued from the valley of the Salmon River and were subsequently reworked by the waves of Kuskokwim Bay. The building of an outwash barrier across the lower valley of the Unaluk River should have operated, likewise, to raise the base level of that stream, thus inducing alluviation farther upstream. But it is questionable if this cause alone suffices to explain the extensive alluviation of the valley of the Unaluk River; and it is probable that this process was subsequently accentuated and accelerated by the regional elevation of the base level of erosion, which drowned the western parts of the main valleys along this coast.

It has thus been shown that the extensive aggradation of all the streams of this area during the final stage of glaciation resulted from local elevations of the base level of erosion or from other causes acting more or less concurrently with glaciation. Concomitantly, the strand line was moved westward, but it is not known whether its shifting resulted entirely from offshore alluviation or whether changes in the elevation of the land with regard to the sea were also in progress at the same time. In any event, the net result appears to have been an extensive westward migration of the strand line.

After the aggradation of the valleys in this region was essentially completed, there began a general elevation of the base level of erosion, which resulted in an eastward migration of the oceanic strand line. This phenomenon is the latest recognizable geomorphic process of major magnitude in this region, but it has been followed by another process of minor importance, the combination of the two resulting in some anomalous effects. Any general elevation of the base level of erosion resulting from relative changes in the level of the land with respect to the sea might or might not result in regional aggradation in the valleys of the streams entering the sea, depending upon the preexisting gradient of the streams in their lower reaches and also upon their ability to adjust their longitudinal gradients to a rising base level of erosion. This is a question of the rates at which the different processes occurred. Drowning of the lower reaches of the larger valleys, however, would at least be expected, and this, in the valleys of the Goodnews and Kinegnak Rivers actually occurred, resulting in the formation of Goodnews and Chagvan Bays.

No rejuvenation of the streams, however, could be expected to result from a general elevation of the base level of erosion; yet in the valleys of certain smaller streams, notably the Smalls and Salmon Rivers, the streams are incised in the alluvial deposits that fill their valleys. In the lower reaches of the valley of the Salmon River, for example, close to the sea, the present valley floor lies from 12 to 35 feet below the general level of the valley fill. It also happens that these minor valleys discharge directly into the sea, as in the case of the Salmon River, or nearly so, as in the case of the Smalls River. The explanation of this apparent anomaly is that after the process of general elevation of the regional base level of erosion had been terminated, the strand line migrated still farther east, as a result of wave action on the alluvial cliffs, but without the accompaniment of a relative elevation of the sea with respect to the land. This resulted in a shortening of those streams which emptied directly into the ocean, and in a steepening of the gradients in their lower reaches. If this foreshortening of the stream valleys occurred at a rate that was faster than the rate at which a new valley floor could be developed at a lower elevation, there would result an incision of the stream in the old valley floor. This apparently is what has occurred in the valley of the Salmon River. It therefore appears that the foreshortening of the valley by wave action has locally lowered the base level of erosion, without any necessary elevation or depression of the land and without any change in the absolute level of the sea.

The eastward migration of the strand line as a result of wave cutting is essentially a postglacial process, and to have been effective in increasing the gradients of the lower reaches of streams like the Salmon River it must have been a fairly rapid process. At the present time the sea washes only a short stretch of hard-rock bluffs of the Red Mountain massif, and the curvature of these bluffs is such that a strand line lying not far to the west would miss them entirely. The implication is that in the rapid eastward migration of the strand line, as a result of wave action, these cliffs have been exposed to the action of the surf for only a relatively short time. It is possibly in part for this reason that so little platinum has been concentrated in the marine sands at the foot of these cliffs.

INTRUSIVE ROCKS

The igneous rocks in this area are of two general types, which differ from one another in age and in mode of formation. The first type includes lavas and associated tuffs, which occur at one or more stratigraphic horizons in the sequence of sedimentary rocks. These are volcanic rocks that at one time were discharged at the surface. As they are evidently of the same geologic age as the sedimentary rocks with which they are interbedded, they are described as a part of the sequence of bedded rocks.

The second type of igneous rocks is intrusive, but on the basis of petrographic character and relative age, the intrusive rocks are divisible into several different kinds. From the standpoint of their economic significance as well as relative extent, the most important of these are the ultrabasic rocks and certain other intrusive rocks associated with them. Thus the same eruptive activity that produced the ultrabasic rocks also gave rise to the less basic types that occur only as dikes along and near the peripheries and within the main ultrabasic masses. Among these associated intrusives are basic rocks of specialized kinds and also certain soda-rich granitic rocks. Another type includes granitic rocks of normal type, which crop out principally in a large mass that is comparable in size with the larger masses of ultrabasic rocks. Still other intrusive rocks, which are principally dikes, invade the sedimentary sequence. Some of these occur in such associations and with such degrees of alteration as to suggest that they are not much younger than the rocks that they intrude, possibly roughly contemporaneous with the lava flows and associated tuffs. Others that are particularly close to the ultrabasic rocks appear to be offshoots from the intrusive masses.

ULTRABASIC ROCKS

DISTRIBUTION

Two principal masses of ultrabasic rocks crop out in this area. The larger of these forms an elongate ridge, which is known as Red Mountain, but a small extension of this mass crops out farther north, along the north side of the Smalls River. The smaller mass of ultrabasic rocks forms a large part of the spur between Medicine Creek and the headwaters of the Salmon River. Although this body of ultrabasic rocks does not form the bedrock at the summit of Susie Mountain, it is referred to as the Susie Mountain intrusive mass.

The Red Mountain intrusive body has a length of about 5 miles, a width in its widest place of nearly 2 miles, and an area of about 8 square miles. These measurements represent the actual surficial outcropping, but the subsurface dimensions of the mass are somewhat different. For example, drilling has shown that the ultrabasic rocks extend eastward almost to the mouth of Dowry Creek, from which place the contact turns northwestward and crosses Clara Creek southeast of the contact line shown on plate 2. This eastward extension of these rocks is obscured at the surface by overlying outwash deposits. Similarly at the north end there is probably an underground connection with the small outlying body along the north side of the Smalls River. At the south end some drilling has been done on the coastal foreland close to the sea and west of the saddle at the head of Platinum Creek. Drill holes revealed bedrock of pyroxenite, so that it seems likely that the mass extends southwestward for some distance below the sea. Considerable drilling has also been done in the foreland west and northwest of Red Mountain, but a few of these holes, which were driven entirely through the alluvial deposits, showed a different type of bedrock.

Hence the western contact is probably also a close representation of the contact for some distance below the surface. The general elongation of the mass is roughly but not exactly that of the surrounding country rock, the divergence being that the trend is more nearly north-northeast instead of northeast.

The Susie Mountain intrusive body has a length of about 2 miles, a maximum width of two-thirds of a mile, and occupies an area of about 1 square mile. This mass of ultrabasic rocks appears to have been intruded along the northern boundary of the lavas and tuffs; and following this contact, its trend appears to conform more nearly with the structure of the country rock.

LITHOLOGIC AND PETROGRAPHIC CHARACTER

The ultrabasic rocks consist primarily of peridotite and subordinately of perknite, with numerous varieties of these two general types. Dunite, a variety of peridotite, forms the bedrock throughout most of the Red Mountain intrusive mass; in fact, with the exception of dike rocks, the perknitic varieties occur only along the margins of the mass. The central part of the Susie Mountain mass, on the other hand, is not a dunite but instead consists of perknitic pyroxene-bearing rocks. This distribution of the pyroxene-free and pyroxene-bearing rocks suggests that the central and lower parts of the magmas are dunitic in character and that the margins and apical parts are perknitic.

These ultrabasic rocks in their unaltered state are dark-colored, ranging from black to greenish-black. Under atmospheric conditions, however, they weather readily to a yellowish-brown color, which when viewed from a distance looks brownish-red, thus giving to Red Mountain and the ridge northwest of Susie Mountain a characteristic color. In this area they are everywhere covered by a surficial layer of oxidized material that commonly ranges in thickness from one-eighth to one-half inch. The crest of the ridge forming the Red Mountain area is covered by talus composed of large and small subangular fragments of ultrabasic rocks, but the eastern slopes are relatively smooth.

One of the interesting properties of these ultrabasic rocks is their well-known inhospitality to vegetation. Although this area is one in which no trees are found and brush is scarce, yet the feature above noted is unmistakably evident. Thus, for several miles southwest of the Smalls River no brush of any kind grows along the west flanks of Red Mountain. But from a point south of the head of Platinum Creek low alder brush grows along the steep seaward-facing slopes of the hills west and southwest of Thorsen Mountain. The southeastern contact of the ultrabasic rocks can be closely located by the distribution of the alders. Another example of this feature may be observed on the knob that forms the southeastern end of the spur between Squirrel Creek and the Salmon River. In this part of the area brush is confined to the valley floors, but this knob, which is not the site of ultrabasic rocks, is definitely greener with grass and moss than is a corresponding altitude on the slopes of Red Mountain, a short distance to the northeast.

The unaltered dunite is a black to greenish-black rock composed almost entirely of olivine more or less altered to serpentine and containing small amounts of iron ores and monoclinic pyroxene. The olivine crystals vary considerably in size, but most of the dunite is sufficiently coarse grained so that the individual crystals are readily visible. In the coarser-grained varieties of dunite many of the crystals of olivine exceed one centimeter in diameter. The pyroxene is colorless augite.

In thin section the olivine is colorless, optically negative, and has an optic angle ranging from 85° to 90°. About 25 percent of the olivine is altered to serpentine, as a result of which the large crystals are separated into many small fragments that extinguish simultaneously, when the stage of the microscope is revolved. The serpentine occurs in reticulating veinlets that intersect the crystals of olivine in all directions, giving a characteristic pattern. There appear to be two generations of serpentine, the older of which is greenish-yellow in thin section. The younger serpentine, veinlets of which intersect the older, is nearly colorless and has a somewhat lower index of refraction. In a few specimens, particularly in the pyroxenic and dike rocks, a small amount of reddish antigorite is developed as a secondary product. A little talc also occurs as veinlets with some of the serpentine.

Fragments of serpentine are visible at places on Red Mountain, showing that some of the dunite has been completely serpentinized. Some of this material is light green and banded and appears to have been formed in veins, seams, and crevices. Another and more common variety of serpentine is dark green and commonly shows shearing striae, suggesting that it was formed along zones of faulting. At some places on Red Mountain and on the ridge northwest of Susie Mountain dark-green serpentine talus occurs along zones that trend eastward, suggesting lines of faulting and serpentinization in that direction. Some of these zones are the sites of topographic swales. A very small amount of low-grade asbestos also occurs in the talus of Red Mountain.

In the sea bluffs along the southwest side of Red Mountain the process of serpentinization is also clearly visible. Here the ultrabasic rocks are greatly fractured, and the irregular blocks that have fallen to the beach show thin layers of greenish-gray serpentine along their edges. These rocks are also intersected by thin veins and seams of green serpentine, which at a distance appear to have definite boundaries but close at hand are seen to grade rather imperceptibly into the ultrabasic rock. Irregular-shaped replacements of serpentine are also visible, but in general there is a tendency for these serpentine seams and replacements to approach verticality and to strike eastward.

Disseminated iron ores are rather scant in the dunite, but the proportion of them increases in the perknitic rocks. For the most part these ores are opaque, but some of them are slightly transparent on thin edges, suggesting surficial alteration. These opaque ores are not specifically determinable in thin sections, but they probably include magnetite, ilmenite, and chromite. This deduction is based on the presence of these three minerals in the concentrates recovered with the platinum metals and also on the presence of Cr_2O_3 in the chemical analysis of the dunite (p. 50). Stretching across sections of some of the dunites are stringers of opaque iron ores associated with serpentine and for the most part surrounded by it. In some sections discontinuous linear patches of opaque ores follow cleavage cracks, intersecting one another in a geometric pattern. The large size of some of the pebbles of magnetite, ilmenite, and chromite in the concentrates suggests that a considerable part of this material comes from basic segregations within or along the borders of the ultrabasic rocks.

With an increase in the amount of monoclinic pyroxene and a corresponding decrease in the amount of olivine, the dunite grades into wehrlite. Such rock has been observed chiefly in the central part of the Susie Mountain mass and at the southern end of the Red Mountain mass just north of the saddle at the head of Platinum Creek. A still further increase in the proportion of pyroxene leads to the development of perknitic rocks, particularly of pyroxenite and specific variations thereof, depending upon the paucity of olivine and the presence of other rock-forming minerals. Most of the pyroxene is augite, but in a few specimens enstatite constitutes a small proportion of the rock. Practically none of these rocks is entirely free of olivine.

Rocks of various special types occur as dikes, intersecting the principal ultrabasic rocks. These are commonly coarse-grained, but some fine-grained dike rocks are also present. In color they are not particularly different from the rocks they intrude. Many different petrographic varieties are doubtless present, but no special study of the different types has been made. Their principal characteristic is the fact that most of them contain more or less hornblende, which in thin sections is seen to be strongly pleochroic, ranging in tones from green to bluish green and from brown to violet brown. They therefore include both ordinary and basaltic hornblende. A small amount of a leached biotite was also observed in one of these rocks. Iron ores are fairly plentiful, and apatite also occurs.

The contact of the ultrabasic intrusives with the country rock is nowhere actually visible at the present time, but mining operations on Squirrel Creek exposed this contact at the northern end of claim 1 below Discovery. The contact is now covered by sediment, but the materials thrown out on the dump show the character of the rocks in this vicinity. At this point the ultrabasic rocks do not actually lie in contact with the country rock, but instead there appears to be a narrow zone of a specialized kind of intrusive rock consisting of coarse crystals of dark green hornblende intergrown with smaller crystals of albite. Light-green crystals of epidote are also commonly present as clumps in and between the crystals of hornblende and albite. This rock is obviously a gabbro pegmatite, which is probably a product of differentiation from the ultrabasic magma. Where the hornblende and albite occur separately as good-sized pieces of rock, however, these would more naturally be designated as hornblendite and albitite. Presumably the gabbro pegmatite and related rocks have been intruded along the periphery of the main mass of ultrabasic rocks at this locality, but the linear extent of rocks of this type along the contact is not known. They have not been observed, however, in the country rock close to the contact, so that they are likely to represent mainly a specialized dikelike differentiate of the ultrabasic magma. Others of the dike rocks also contain more or less basic plagioclase feldspar. One rock of this type was taken from the bottom of a drill hole on Fox Gulch at or near the intrusive contact. This rock consists of colorless to very pale green augite more or less replaced by hornblende, together with saussuritic areas of muscovite, chlorite, and epidote that represent original feldspar. Another dike rock that originally contained feldspar was seen in the sea bluffs at the southwest end of Red Mountain. Here the feldspathic (?) area consists largely of chlorite and epidote. Still another dike rock at the same locality was dioritic in character and contained definitely recognizable crystals of plagioclase feldspar, zonally grown, with albite and pericline twinning. The centers of the crystals were altered to sericite and epidote. Hornblende is the principal dark mineral of this rock, but titanite and apatite are also present, together with some quartz that may be of secondary origin.

CHEMICAL COMPOSITION

In order to learn as much as possible regarding the origin of the platinum metals and the character of the rocks in which they originated, two complete analyses of the ultrabasic rock of Red Mountain were made in the chemical laboratory of the Geological Survey by E. T. Erickson.

Composite samples were taken at more or less regular intervals from the south to the north end of Red Mountain. The first composite sample consisted of fresh, unweathered rock, which, though dominantly dunite, included a representative proportion of the marginal pyroxenic rocks. The second composite sample consisted of the brown weathered shell that exists as a veneer on all these ultrabasic rocks. The results of these two analyses and the normative minerals computed from the first analysis are given below.

Chemical analyses of ultrabasic rocks, Red Mountain

[Analyses by E. T. Erickson]

	1	2		1	2
SiO_2	39.20	38.54	H_2O-	.19	.43
Al_2O_3	1.50	.78	TiO_2	.05	.14
Fe_2O_3	3.10	5.29	Cr_2O_3	.27	.13
FeO	7.35	5.99	MnO	.01	.01
MgO	37.79	42.29	NiO	.077	.053
CaO	4.66	.34	CuO	.007	.004
Na_2O	(1)	(1)			
K_2O	(1)	(1)		100.014	99.527
H_2O+	5.81	5.53			

[1] Undetermined.

Mr. Erickson states that cobalt, if present, is less than 0.002 percent. The potassium-iodide test, which will detect platinum in amounts somewhat less than 0.01 ounce to the ton, in duplicate assays of sample 1, each using 1 assay ton of sample, gave no evidence of platinum.

Norm of ultrabasic rocks, Red Mountain

Anorthite	4.09	Ilmenite	0.09
Diopside	14.97	Chromite	.40
Hypersthene	29.75		
Olivine	48.43		102.23
Magnetite	4.50		

The first sample thus represents a rock that falls in class 5, order 1, section ''2, rang 1, subrang ''2, according to the systematic classification of igneous rocks by Cross, Iddings, Pirsson, and Washington.[6]

The norm given above does not correspond closely to any of the norms given by Washington,[7] but inasmuch as it refers to a composite rather than an individual sample of ultrabasic rock, this is not surprising. It does correspond generally, however, to a group of ultrabasic rocks of the same general type as that which forms Red Moun-

[6] Cross, Whitman, Iddings, J. P., Pirsson, L. V., and Washington, H. S., Quantitative classification of igneous rocks, pp. 162–185, Univ. Chicago Press, 1903.

[7] Washington, H. S., Chemical analyses of igneous rocks: U. S. Geol. Survey Prof. Paper 99, pp. 734–737, 1917.

tain. The norm shows anorthite, but the alumina, which requires this allocation, actually goes into the aluminous pyroxene augite in the mode. The content of ilmenite is surprisingly low and suggests that much of the ilmenite found in the placers was eroded from pyroxenic rocks along the margins of the intrusive mass. Although nickel and copper are reported in the analysis, no minerals containing these elements have been observed in the dunite or in the placer concentrates, so that it is possible that the nickel at least is molecularly combined with olivine.

A comparison of the two analyses shows well the effects of weathering on these rocks. The weathered sample shows a 70-percent increase in the amount of Fe_2O_3 and about a 20-percent decrease in the amount of FeO as compared with the unweathered sample. An even more striking effect is shown by the fact that 93 percent of the original content of CaO is dissolved in the process of weathering. The other differences may be accidental and are therefore not necessarily significant.

Another significant feature is the percentage of Cr_2O_3 contained in these rocks. Elsewhere in this report it has been stated that the placers contain nuggets of the platinum metals intergrown in chromite. An analysis of pebbles of chromite selected from the placer concentrates shows a content of 0.05 ounce of platinum to the ton of chromite. The amount of Cr_2O_3, however, in a sample of the size used for a rock analysis is only one-twentieth the amount required for the potassium-iodide test. It is therefore not surprising that no trace of platinum was found in the analysis of the dunite. But if it is assumed that all the dunite of Red Mountain contains the amount of Cr_2O_3 shown by the analysis and if all the chromite contains 0.05 ounce of platinum to the ton, it may be shown that the dunite of Red Mountain contains about 0.0002 ounce of platinum to the ton. With platinum valued at $50 an ounce, the lode value for the dunite is about 1 cent a ton.

By making certain further assumptions, these and other quantitative data can be utilized to deduce a minimum value for the volume of rock that has already been eroded from the intrusive mass of Red Mountain to produce the present platinum placers. Some of these assumptions unduly simplify the problem, so that they must afterwards be corrected by some factor of proportionality in which the personal equation enters. Others of the assumptions are subject to large errors that cannot properly be corrected; but by accepting the lowest values the result of the computation can be stated to be a minimum, which is the result desired. One of the greatest intangibles is the fact that the part of the intrusive mass removed by erosion was probably not dominantly dunite but instead was a pyroxenic phase of the ultrabasic rocks, which probably had a much lower content of chromite and platinum than the underlying dunite. As a first approximation, however, it will be assumed that the intrusive mass of Red Mountain was uniformly dunitic in composition. It is further assumed that chromite was uniformly distributed in the dunite and that the platinum metals were uniformly distributed in the chromite. The next assumption is that at least 400,000 ounces of platinum metals have been eroded from Red Mountain, though this is not intended to imply that any such amount of these metals will necessarily be recovered or are even present in the valley of the Salmon River and its tributaries. And finally for the purposes of a first computation, the shape of the intrusive mass will be considered to be a vertical cylinder with a cross section similar in size and shape to that of its present perimeter. Now if the dunite contains 0.0002 ounce of platinum metals to the ton, if the specific gravity of dunite is 3.3, and if the present area of the intrusive mass of Red Mountain is 8 square miles, the assumptions above given lead to the conclusion that 0.14 cubic mile of rock has been eroded, which corresponds to a cylindrical height of 90 feet. But if the shape of the intrusive mass is considered to be lenticular instead of cylindrical, this height should be increased to 270 feet. This is the minimum height by which the elevation of Red Mountain has been reduced as a result of erosion. But if the upper part of the intrusive mass is considered to have been dominantly pyroxenic rather than dunitic it will be evident that a much larger volume of intrusive rock had to be eroded to form the present placers and that the height of Red Mountain may have been reduced by several times 270 feet during this process. Possibly 0.5 cubic mile or more of ultrabasic rocks has been removed, corresponding to a superjacent mass rising 1,000 feet above the present level of Red Mountain.

STRUCTURE AND AGE

Few data are available regarding the shape and structure of the ultrabasic intrusive mass that forms Red Mountain, and practically no data can be given regarding the Susie Mountain mass. Reference has already been made to a rather prominent structural easterly trend in both the Red Mountain and Susie Mountain masses, which seems to define the direction of jointing or faulting and along which serpentinization has taken place. Some of the dikes also tend to strike in this direction. This, however, is probably secondary structure.

From the standpoint of the localization of platinum metals, it is also desirable to know the shape and primary structure of these intrusive masses and to learn, if possible, whether they have been tilted or whether they lie essentially in their original orientations.

The shape and general alinement of the two intrusive masses seem to indicate that they are elongate, if not actually lenticular, igneous masses. On Squirrel Creek the line of contact bulges slightly to the south as it passes from one side of the valley to the other, thus suggesting a southeasterly tilt to the mass, but this may be only a minor irregularity of the contact line. Drilling operations, however, have revealed another protuberance in the outcrop, which extends the ultrabasic rock eastward nearly to the mouth of Dowry Creek, from which point it retreats northwestward to the head of Clara Creek. These irregularities suggest that the ultrabasic mass of Red Mountain is not only irregular in outline but also pitches at some undetermined angle to the southeast.

One theory of the formation of dunites is that the crystals of olivine, having separated from a molten magma before the whole mass solidified, settled to the bottom of the magmatic reservoir. As the iron ores and metallic components of magma have only a limited miscibility, it might be expected that such components would also settle out during or before the differentiation of the olivine crystals. Therefore the platinum metals should be found mainly in the basal parts of lenticular or tubular intrusive masses. If such masses were originally emplaced horizontally, or nearly so, and were subsequently tilted so as to have a southeasterly dip, a concentration of platinum metals should appear along the northwest side of Red Mountain, but the reverse appears to be true. Hence, unless the rocks of this area are overturned, the idea of an original horizontal emplacement is untenable.

A second alternative under the same hypothesis of ore accumulation is that the ultrabasic rocks were injected as elongate and probably tabular masses that originally conformed to the regional structure and therefore dipped to the southeast. If these tabular bodies had a moderate southeasterly dip, a concentration of platinum metals should still appear on the northwest side, but if the dip were steep, approaching verticality, other factors may have exerted an equal influence on the horizontal distribution of the platinum metals. The actual shape and inclination of the ultrabasic mass composing Red Mountain is not known, but the surface outcrop and drilling records along its southeast side suggest that the shape is rather irregular with a general dip to the southeast. This condition does not explain the apparent concentration of platinum metals along the southeast side of Red Mountain, but it does offer an explanation for the absence or paucity of platinum metals in the pyroxenic rocks of the Susie Mountain mass, for under this hypothesis the dunitic core of Susie Mountain and the associated platinum metals may not yet be exposed to erosion.

A third possible explanation of the distribution of the platinum metals in this area is that they are in part epigenetic with reference to the main body of ultrabasic rocks and that they may have been contained in or associated with the more specialized types of intrusives localized along the border of the dunite. Some evidence in favor of this interpretation is found in the fact that the high-grade part of the placer pay streak on Squirrel Creek did not extend upstream beyond the contact between the ultrabasic rocks and the country rock and that this contact is the site of specialized types of intrusives, such as gabbro pegmatite and related rocks.

The geologic age assigned to the ultrabasic rocks depends upon the manner of their emplacement and the age of the invaded country rock. It seems probable that the ultrabasic magma was injected later than the principal regional deformation as its trend corresponds closely to the dominant regional structure.. But neither the age of the country rock nor the time of the principal deformation can be determined from any paleontologic or structural evidence available in this district. As stated elsewhere in this report, however, lithologic evidence indicates that the country rock is of late Paleozoic age. It is fairly well established that in much of interior and southern Alaska the late Paleozoic rocks received their maximum deformation in mid-Mesozoic time. These factors collectively indicate, though they do not actually prove, that the ultrabasic magma was injected later than the mid-Mesozoic. It is therefore concluded that the dunite, perknite, and associated platinum metals probably originated in late Cretaceous or early Tertiary time.

GRANITIC ROCKS

DISTRIBUTION

Granite rocks of two distinct types are found in this area. One consists of dikes of a specialized petrographic character that occur only at Red and Susie Mountains and are rather definitely associated with the ultrabasic rocks. Such dikes in reality have been observed only at three localities, and at only one of these localities were they found in place. One locality is on a spur of Red Mountain, north of Squirrel Creek, at an elevation of about 800 feet above sea level. Another is along the crest of the ridge northwest of Susie Mountain. At both of these localities lines of talus of granite material occur at the surface for short distances, suggesting the presence in the underlying bedrock of these granitic rocks. It should be emphasized, moreover, that at neither of these localities can this granitic material represent glacial erratics. The third locality, where these rocks are in place, is along the contact exposed by mining on Squirrel Creek. Here thin dikes of these peculiar granitic rocks cut the hornblendite, which lies along the periphery of the ultrabasic rocks.

The other type of granitic rock occurs in a large intrusive mass that forms the ridge southeast of the headwater part of the valley of the Smalls River. This intrusive body is about a mile wide and at least 4½ miles long, but its northeastern limit is not definitely known, as it extends well beyond the mapped area.

PETROGRAPHIC CHARACTER

The granitic dikes associated with the ultrabasic intrusives are white to cream-colored nonporphyritic granular rocks that grade into finer-grained varieties. They are classified as albite granite, and syenite and albite rhyolite and trachyte. In this section they show essentially albite, more or less quartz, and a few other primary minerals, principally muscovite, together with a little biotite and titanite. Some secondary minerals, however, occur in all these rocks, and of these the principal ones are epidote, clinozoisite, and a colorless spherulitic pennine. One of these rocks, an albite rhyolite, is cut by minute veinlets of secondary quartz. The sodic character of these rocks appears to relate them genetically to the albitic phases of the gabbro pegmatite of Squirrel Creek, and like the gabbro pegmatite, they are also believed to be a specialized differentiate of the ultrabasic rocks.

In the valley of Squirrel Creek and in the valley of Platinum Creek upstream from the mouth of Squirrel Creek a small amount of gold is recovered with the platinum metals from the placers. This gold, as later shown, has a peculiar dross that seems to relate it to the platinum mineralization. It is possible that this peculiar gold is connected genetically with these specialized types of granitic rocks found at Red and Susie Mountains.

The normal type of granitic rocks that occur southeast of the head of the Smalls River are light- to dark-gray nonporphyritic rocks with a variable petrographic character. From an examination of seven thin sections of these rocks they seem to include principally quartz monzonite, granodiorite, and quartz diorite. They consist essentially of plagioclase feldspar and orthoclase in variable proportions, quartz, and hornblende. The common accessory minerals are titanite, apatite, and iron ores, but in one of these rocks a small amount of augite was also observed. Much of the plagioclase feldspar is zonally grown, with borders that are more sodic than the cores, but the average composition appears to be close to that of andesine. Some of the plagioclase cores are more or less altered to sericite, zoisite, and other secondary products. On the whole these rocks appear to correspond fairly closely with the granitic rocks in the Nushagak district, about 125 miles to the northeast.[8]

[8] Mertie, J. B., Jr., The Nushagak district, Alaska: U. S. Geol. Survey Bull. 903, pp. 75–87, 1938.

AGE

No stratigraphic data are available for assigning a geologic age to the granitic intrusive rocks. The dikes of sodic granite and related rocks intersect the ultrabasic rocks, which shows that they are of later origin but not necessarily that they are geologically much younger. In reality, since they appear to be related genetically to the ultrabasic rocks, they are likely to be of the same geologic age—probably late Mesozoic or early Tertiary.

The granitic rocks of normal type intrude the country rock of this area and moreover occur in an intrusive mass the major elongation of which coincides with the strike of the country rock. As with the ultrabasic rocks, this feature leads to the belief that they were intruded along some structural line of weakness and originated after the major deformation of the country rock. They therefore are probably not older than mid-Cretaceous, but their petrographic similarity to the early Tertiary granitic rocks of nearby regions indicates a probability that they are likewise of that age.

ECONOMIC GEOLOGY

Placer gold has been mined in a small way for many years in the part of the Goodnews Bay district north of Goodnews Bay, but in recent years platinum placers have been discovered and mined in the area south of Goodnews Bay. These deposits are particularly important, not only because they are the first placers found in Alaska that are workable primarily for their platinum content, but also, because the present production is far in excess of that from any other area so far developed in the United States or its possessions. A small amount of gold is recovered with the platinum metals. Chemical examination of the rocks from which the platinum metals are derived also shows the presence of chromium, nickel, and copper, but none of these elements have been found in this vicinity as commercial ores. Platinum metals are therefore the principal mineral product of commercial value.

The only considerable production of the platinum metals from any other part of Alaska is the palladium that comes from the old Salt Chuck mine, on Kasaan Peninsula, in southeastern Alaska. Platinum metals, however, have been found at several other places in Alaska but have been recovered only as a byproduct of gold placer mining. Probably the most significant of these are several localities in the eastern part of Seward Peninsula lying in a northward-trending zone of about 35 miles in linear extent. Within this general area a few ounces of platinum metals are recovered annually from the gold placers of Dime and Quartz Creeks, and some has also been recovered from Bear Gulch. Small quantities of platinum metals have also been recovered from Cache Creek and Slate Creek, in south-central Alaska.

Platinum metals have also been reported at several other localities in Alaska, but none of these are thought to have much commercial significance. Among these localities are the auriferous beach placers of Kodiak Island and similar placers at Lituya Bay. Traces of platinum metals have also been found in the stream placers on Granite Creek, in the Ruby district, and on Metal Creek, in Kenai Peninsula. Platinum in small quantity is also reported to occur on Willow and Wilson Creeks, in the Marshall district of southwestern Alaska, and with gold on the bars of the Anvik River.

PLATINUM DEPOSITS

THE PLACERS

GENERAL FEATURES

The general history of the discovery of platinum in this district together with a sketch of earlier mining operations has been given by Irving Reed.[9] According to this account platinum was discovered in 1926 at the mouth of Fox Gulch, a tributary of Platinum Creek, by an Eskimo named Walter Smith. This native, who thought the platinum was "white gold," related his discovery to another native called Henry Whuya. Whuya in turn communicated the information to Charles Thorsen, a local resident and miner, who had lived in this district for many years. Thorsen went to the site of the discovery, panned some of the metallic material, and sent it to the office of the United States Bureau of Mines at Fairbanks, where it was analyzed and determined to be platinum. In 1928 Thorsen discovered platinum in the gravels of Clara Creek, and in the same year Edward St. Clair made the first discovery of platinum on Squirrel Creek.

The complete history of the earlier mining in this district is not known, but small-scale mining plants were operated on Platinum, Clara, and Squirrel Creeks and on Fox and Dry Gulches from 1927 and 1928 intermittently to 1934, when the large-scale plant of the Goodnews Bay Mining Co. began work. Thus Reed [10] has recorded the fact that on Platinum Creek, Charles Thorsen worked on Discovery claim in 1927; that George Wickert operated on the same claim in 1929 and 1930; and that Charles Tonietzko and John Bennett worked bench ground on claim 2 below Discovery in 1930 and 1931. On Squirrel Creek placer mining was done on claim 3 below Discov-

[9] Reed, Irving, Mining investigations and mine inspection in Alaska, for biennium ending March 31, 1933, pp. 103–126, Juneau, Territory of Alaska, 1933.

[10] Reed, Irving, op. cit., pp. 117–122.

ery in 1931 by W. B. Moeck and Fred Wolters, and in the same year on claims 1 and 2 below Discovery by Tupper Thompson and Edward St. Clair, respectively. Some small-scale mining was done on Fox Gulch on claim 2 above Discovery by natives as early as 1927; and on Discovery claim of Fox Gulch, Neal Corrigal worked an open cut from 1929 to 1935. Some mining was also done on Dry Gulch in 1930 by Joe Chanie and Edward St. Clair.

Placer mining began on Clara Creek in 1928, and in the period from 1928 to 1931 or later Charles Thorsen and Andrew Olson mined on Discovery claim. Mining operations were also in progress until 1931 or later on claims 1, 2, and 3 above Discovery. The work on claim 1 above Discovery was done by Martin Garthe; that on claim 2 above Discovery by O. J. Sampson and Martin Garthe; and that on claim 3 above Discovery by John Haroldsen and August Wicklund.

Most of this earlier mining was done in the valleys of Squirrel and Clara Creeks and on Fox Gulch, where the overburden was not too deep to be removed profitably by small-scale methods. Farther north in Alaska, where the ground is perpetually frozen to considerable depths, small-scale drift-mining methods could have been used, but in this part of Alaska there is no permanently frozen ground and no timber for timbering, and therefore underground mining was not practicable. Moreover, all the earlier mining was done in small valleys, where the supply of water is scarce, and hence most of the work had to be accomplished by hand methods consisting of ground sluicing and shoveling into sluice boxes. It finally became evident to the several small operators that although this was a promising field, mining would have to be done on a large scale in order to be profitable. Consequently the many mining claims began to be consolidated and eventually passed into the control of two concerns, the Goodnews Bay Mining Co. and the Clara Creek Mining Co., which are now carrying on all the placer-mining operations in this area.

The Goodnews Bay Mining Co., the larger company, holds or leases more than 150 claims in the valley of the Salmon River and its tributaries. (See pl. 8.) This company began mining with a dragline excavator on Squirrel Creek in August 1934, and in the 3 years 1934–36 mined most of the high-grade placers in the valley of that stream. Mining of the same kind was begun on claim 2 below Discovery on Platinum Creek in 1937, and the work was carried upstream to Fox Gulch and for some distance up Fox Gulch during that year. This does not mean, however, that all the pay streak on Platinum Creek within this stretch has been mined, as one or more parallel cuts will doubtless be worked later. The Goodnews Bay

Mining Co. began the construction of a dredge in the summer of 1937, completed it that fall, and began operations on November 10, working until December 20. About 50 persons are employed by this company.

The Clara Creek Mining Co. holds or leases about 20 claims located mainly in the valley of the Salmon River north of the mouth of Platinum Creek and in the valley of Clara Creek. This company began work in 1936 on the east end of claim 1 above Discovery on Clara Creek, and in the years 1936 and 1937 worked up that stream to the west end of claim 3 above Discovery. About 23 persons are employed in this work. As on Platinum Creek, this does not mean that all of the pay streak on Clara Creek within this stretch has been worked, as one or more parallel cuts will also be mined here.

It is estimated that in the older mining operations from 1927 to 1934 about 3,000 crude ounces of platinum metals were recovered from the placers of this area. From 1934, when large-scale mining began, to the end of 1937 the production is believed to have been about 18,000 crude ounces. In 1938 the production from this area amounted to about 34,000 crude ounces.

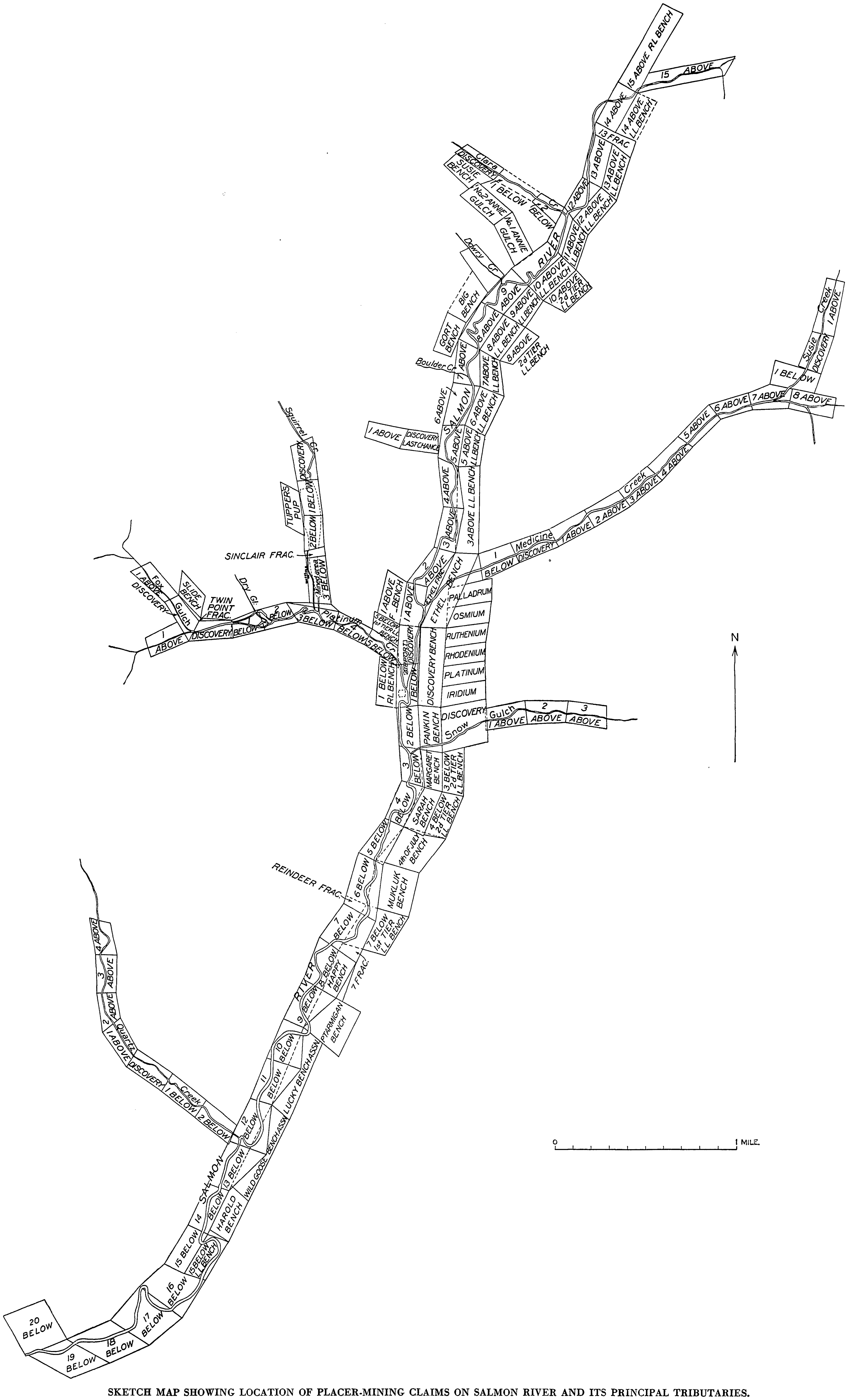
PLATINUM CREEK AND FOX GULCH

Platinum Creek is a western tributary of the Salmon River with an air-line length of about 2 miles, though its length by the course of the stream is somewhat greater. Platinum Creek heads in a low divided only half a mile from Kuskokwim Bay, though it is about 650 feet above sea level. On its south side and a little more than half a mile from its source a small valley known as Willow Gulch enters the valley of Platinum Creek. This gulch is unimportant both geographically and economically and merits no further mention. No other tributaries enter Platinum Creek from the south. On its north side Platinum Creek has three tributaries, which named in order downstream are Fox Gulch, Dry Gulch, and Squirrel Creek. All three head in the ultrabasic intrusive mass to the north, and all three have deposits of platinum in their valleys. Fox Gulch, the most westerly of these tributaries, has a length of nearly a mile, but the downstream or southeastern part of its valley is inconspicuous, being merely a narrow incision in the north wall of Platinum Creek. Dry Gulch is shorter and even less conspicuous. Squirrel Creek, however, has a length of about 1½ miles and occupies a well-defined valley. The lower end of Squirrel Creek and Platinum Creek from its mouth to a point between Fox and Dry Gulches are shown in plate 9, *A*. The total area drained by Platinum Creek and its tributaries is only about 5 square miles.

The longitudinal and lateral limits of the platinum pay streaks on the various streams of this area may not be definitely stated because the extent to which the platinum-bearing gravels may be worked in the future depends upon conditions that cannot at present be properly evaluated. One of these conditions is the relative proportions of the different platinum metals, which varies from place to place; another is the future price of platinum metals and other economic conditions; and finally, in the last stages of mining, when the original cost of mining equipment has been amortized, it might be desirable to salvage ground that was not considered workable in the earlier stages of mining. At the present time, however, the pay streak on Platinum Creek is considered to begin at the west end of Discovery claim at the mouth of Fox Gulch and to continue to the east part of claim 2 below Discovery, a short distance upstream from the mouth of Squirrel Creek. From this point to the mouth of Squirrel Creek, a short stretch of perhaps 1,000 feet, the gravels are not at present considered workable. From the mouth of Squirrel Creek the pay streak continues down Platinum Creek without interruption to its mouth. Above the mouth of Fox Gulch the gravels of Platinum Creek are not considered to be of workable grade, so that the pay streak of Fox Gulch may be said to constitute the headwater part of the pay streak of Platinum Creek. In view of the fact that the headwater branch of Platinum Creek does not drain an area occupied by ultrabasic intrusive rocks, this lack of workable placers is a significant condition.

The workable width of the pay streak on Platinum Creek is even more difficult to state. Above the mouth of Squirrel Creek the Goodnews Bay Mining Co. has so far worked the platinum gravels for a width of 100 to 120 feet. At the mouths of Dry and Fox Gulches the pay streak widens appreciably. It is probable, however, that this part of the pay streak will ultimately be worked over a width of at least 200 feet. Downstream from the mouth of Squirrel Creek the pay streak on Platinum Creek widens rapidly, and near the mouth of Platinum Creek, where the dredge operated in 1937, the pay streak is at least 400 feet wide. It must be stressed, however, that this width is based on the presumption that it will be mined by dredging.

The tenor of the platinum-bearing grounds in the valley of Platinum Creek is not sufficiently well known to the writer to warrant any general statement, though it is known that the pay streak between the mouths of Fox Gulch and Squirrel Creek has shown a lower tenor than the pay streak of Squirrel Creek. One clean-up on Platinum Creek a short distance downstream from the mouth of Fox Gulch yielded about 0.02 ounce of platinum metals to the cubic yard, or about 0.009 ounce to the square foot of bedrock; and for some distance downstream from the site of this clean-up the pay streak is likely to have a lower rather than a higher tenor than this. For some distance downstream from the mouth of Squirrel Creek,



SKETCH MAP SHOWING LOCATION OF PLACER-MINING CLAIMS ON SALMON RIVER AND ITS PRINCIPAL TRIBUTARIES.

however, the pay streak on Platinum Creek may have a higher tenor than shown by the figures above. It is also likely that the pay streak in Fox Gulch may have a high tenor, probably comparable with that on Squirrel Creek.

The alluvium of Platinum Creek, in the stretch between the mouths of Fox Gulch and Squirrel Creek, consists of about 12 feet of subrounded to subangular gravels, overlain by about 3 feet of moss and turf, which locally is mixed with more or less dark-colored sand and eluvial detritus. Drilling on Fox Gulch shows that the gravels decrease in thickness upstream. Just downstream from the mouth of Fox Gulch, and also in the southeastern end of the valley of Fox Gulch, the gravels are rather large and subangular, averaging perhaps 8 to 12 inches in diameter, with some boulders as large as 3 feet in diameter; but farther downstream they are more rounded and have an average diameter of 5 to 6 inches, though large boulders are also present. In both Platinum Creek and Fox Gulch the gravels consist of the same kinds of rocks as the bedrock found in the valleys of these streams. The platinum metals occur mainly on the surface and in the crevices of bedrock but they occur also in the lower 2 to 3 feet of the gravels. In mining with a dragline excavator, the upper half to two-thirds of the alluvium contains too little of the precious metals to warrant washing; hence this part of the overburden is lifted by the excavator and dumped to one side of the cut.

The bedrock of Platinum Creek consists of a mixture of sedimentary and igneous rocks. Among the sediments, graywacke and sheared argillite have been identified; and the igneous rocks include lavas or dikes and tuffs, mainly of andesitic character. As all the bedrock below the gravels is greatly altered, none of it can be accurately determined. When the bedrock is hard and much fractured, from 3 to 4 feet of it have to be removed in order to obtain a high percentage of recovery of the platinum metals. The bedrock in the lower valley of Fox Gulch is essentially similar to that of Platinum Creek, but it is believed that the contact with the ultrabasic intrusive mass will be uncovered when mining progresses upstream for about 1,000 feet from the mouth of the gulch. If the same conditions obtain on Fox Creek as on Squirrel Creek, it is unlikely that high-grade placers will be found upstream from this contact.

Most of the platinum metals on Platinum Creek occur in fine grains, and nuggets of any considerable size are uncommon, the largest found prior to 1937 weighing only 0.25 ounce. Some of the larger pieces of platinum are intergrown with chromite, but one small piece of platinum shown to the writer was intergrown with country rock of the type found on Platinum Creek. The commercial analyses of all the product mined on Fox Gulch and Platinum Creek up to the end of 1938

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show an average platinum content of about 62 percent and an average iridium content of about 20 percent. Mining operations on Fox Gulch, however, have shown a content of iridium attaining a maximum of 35 percent, with a corresponding decrease in the content of platinum. Osmium forms nearly 4 percent and rhodium about 1½ percent of the product, but ruthenium and palladium occur only in very small amounts. All of the percentages above cited, however, would be increased by recomputing the commercial analyses free of impurities. The commercial analyses also show that a small amount of free gold, amounting on the average to about one-third of 1 percent, is recovered with the platinum metals. Apparently the proportion of free gold decreases in going up Platinum Creek and is exceedingly scarce in the placers of Fox Gulch.

A large volume of concentrates is recovered with the platinum metals, and just downstream from the mouth of Fox Gulch the black sand amounted to 2 tons in a clean-up that yielded 250 ounces of platinum metals. These concentrates consist mainly of magnetite, ilmenite, and chromite. An analysis of carefully washed pebbles of chromite from these concentrates made by E. T. Erickson, of the Geological Survey, shows that the chromite contains 0.05 ounce of platinum metals to the ton. These metals would not be recovered on a concentrating table unless the concentrates were previously finely ground.

Upstream from Squirrel Creek the Goodnews Bay Mining Co. has worked the placers of Platinum Creek by means of a dragline excavator, of the type shown on plate 7, *B*. This is a type 37—B Bucyrus-Erie unit consisting of a 75-horsepower 6-cylinder caterpillar Diesel engine and a 60-foot boom, mounted on a tractor base. The boom swings a digging bucket with a rated capacity of 1¼ cubic yards. The washing plant is a rigid unit consisting of an elevated dump box and an elevated line of eight sluice boxes, mounted on skids, so that the plant may quickly be moved from one position to another. As soon as one cut is completed the excavator unit drags the washing plant to a new position, and in a very short time a new cut can be started. The dump box is 8 by 12 feet and is covered with a sloping grizzly to exclude large boulders. The sluice boxes are made of steel, and the sluice line, which is 30 inches wide and 100 feet long, is set to a grade of 1 inch in 12 feet. In the dump box iron rails are used as riffles, but in the upper 6½ sluice boxes, horizontally slotted block riffles made of manganese steel are used. These are 2 inches high with ¾-inch slots in them. In the lower 1½ sluice boxes undercurrents underlain by matting are used. The holes in the undercurrents are tapered, with the small diameter—about ⅜ inch—on the upper side. In order to distribute the tailings more evenly at the end of the sluice line, the last sluice box is equipped with a three-way outlet gate, so that the tailings may be discharged in three different directions. Near the lower end of the last sluice box is a transverse slot about 3 inches wide in the matting and the bottom of the sluice box through which fines escape below to a matting-covered table 5 feet wide and 10 feet long. This table, having twice the width of the sluice boxes, slows up the sluice water and causes the finest of the platinum grains to settle.

As the dump box and sluice boxes are elevated, water has to be pumped to the dump box both for the giant that washes the gravel and for sluicing. For this purpose a small dam is built in the bed of the creek a short distance downstream from the washing plant, in the cut where mining has already been completed. At this site is also mounted a 75-horsepower 6-cylinder caterpillar Diesel engine that operates a direct-connected Allis-Chalmers centrifugal pump, with a 12-inch intake and a 10-inch outlet. This pumping plant supplies 3,500 gallons a minute under an 80-foot head, but on account of loss of pressure in the pipe line, this is reduced to a 40-foot head at the dump box. To compensate in part for this loss of pressure, a small 20-horsepower Diesel engine and pump are mounted directly under the sluice line and are utilized as a booster unit. A giant with a 3-inch nozzle is used in washing the gravel in the dump box.

In the process of cleaning up, a large part of the platinum metals is found in the dump box, but the exact ratio between the recovery in the dump box and that in the sluice boxes is not known. About 13 percent is recovered in the undercurrents, and about 1 percent in the concentrating table below the sluice boxes. After the clean-up the platinum product is cleaned in several ways, in order to reduce the content of the black sand to a volume of not more than 20 percent. Above that amount a penalty is charged by the purchaser. The concentrates, consisting of both pebbles and grains of black sand, are twice classified, first through a ¼-inch sieve and later through a 12-mesh screen. The fines are run over a small Wilfley table two or three times, in the course of which most of the black sand is eliminated. After treatment on the table, the platinum product there recovered is further processed by an ingenious vibrating blower that separates the material into five fractions, one of which is almost pure platinum metals. The second is easily cleaned by blowing; and the others are returned to the table for further treatment. There is a certain residual product that cannot be satisfactorily cleaned with present facilities. The finest of this material contains about 2 ounces and the coarsest about 4 ounces of platinum metals to the ton of black sand. This is being saved for future treatment with a ball mill and classifier. Of the total clean-up about 15 to 20 percent is recovered from the black sand that goes over the concentrating table.

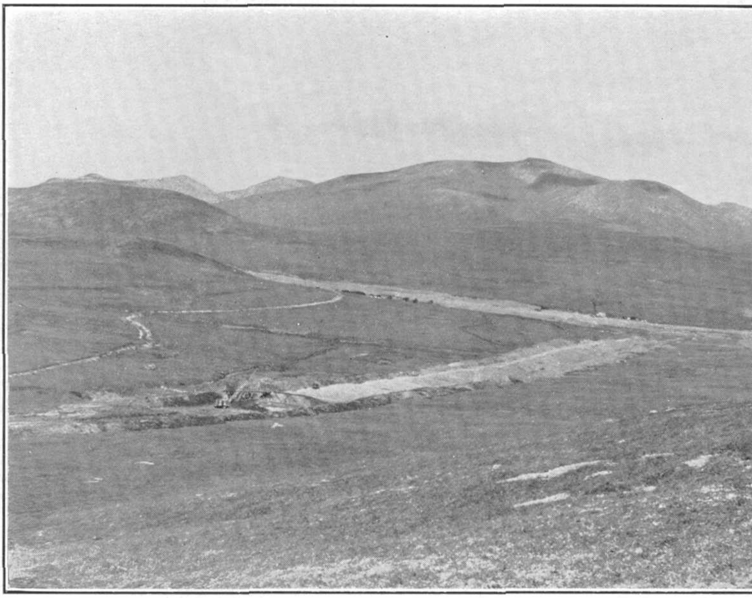
In addition to the mining equipment above mentioned, the Goodnews Bay Mining Co. also has a second dragline excavator of the erector type, which is convertible into a derrick hoist. This was used in some measure during the season of 1937 in conjunction with the other unit, mainly for removing that part of the overburden that is not put into the dump box. It was also used for a variety of other purposes, but chiefly as a derrick hoist in the construction of the dredge. This unit is a type 34–B Bucyrus-Erie excavator, equipped with a 100-horsepower caterpillar Diesel engine and a 55-foot boom that swings a bucket with a capacity of 1¼ cubic yards. The company also owns and operates a considerable variety of electrical equipment.

SQUIRREL CREEK

Squirrel Creek, the most easterly, and the largest tributary of Platinum Creek, enters that creek from the north. Squirrel Creek has a length of about 1½ miles and occupies a well-defined valley that is broad and open in its lower reaches. The headwater part of the valley is a narrow gulch, cutting well back into the central part of the ultrabasic intrusive massif that forms Red Mountain.

The high-grade placers of Squirrel Creek were worked by the Goodnews Bay Mining Co. by means of dragline excavator during the seasons of 1934, 1935, and 1936; but some placers of lower grade remain in the headwater part of the valley and possibly also on bench claims. The ground worked extended from the south end of Discovery claim downstream for 2,600 feet nearly to the south end of claim 3 below Discovery. In this stretch the width of the pay streak ranged from 150 to 550 feet, being narrowest in the medial part of claim 3 below Discovery and widest in the vicinity of Tupper Gulch, a small tributary from the west. This ground was worked in as many as four parallel cuts, but in the vicinity of Tupper Gulch the fourth or most westerly cut was almost of too low grade to be profitable. Some of the placers of Squirrel Creek were of rather high grade, approaching 0.1 ounce of platinum metals to the cubic yard, but the average tenor for the whole pay streak is reported to have been about 0.03 ounce. Plate 9, *B*, shows the valley of Squirrel Creek and the extent of mining operations from 1934 through 1936.

The gravels of the southern end of the pay streak upstream from the mouth of the creek are similar in size and shape to those of Platinum Creek, but at the upper or northern end of the pay streak they are coarse and angular and more like those of Fox Gulch. As on Platinum Creek, the petrographic character of the gravels is the same as that of the rocks found within the drainage basin. The average thickness of the alluvium in Squirrel Creek is about 13 feet, but in the most westerly cut, in the vicinity of Tupper Gulch,



A. BIRD'S-EYE VIEW LOOKING DOWN THE VALLEY OF PLATINUM CREEK.
Shows site of past mining operations on Platinum and Squirrel Creeks.

B. VIEW LOOKING UP THE VALLEY OF SQUIRREL CREEK.
Shows extent of past mining operations.

the thickness increases to about 20 feet. The bedrock of most of the valley of Squirrel Creek is essentially the same as that found on Platinum Creek, but in the northern part of the pay streak, near the line between Discovery claim and claim 1 below Discovery, the contact between the country rock and the ultrabasic intrusive mass of Red Mountain was uncovered; and from this point upstream the ultrabasic rocks form the bedrock. On account of tailings and of sediment in the cut this contact is not now actually visible.

The platinum metals recovered from the valley of Squirrel Creek occurred generally in coarser grains than these same metals found in the valley of Platinum Creek, and nuggets were somewhat more common. The largest nugget found on Squirrel Creek prior to 1937 weighed 1½ ounces. A comparison of the commercial analyses of the platinum metals found on these two creeks shows that the product of Squirrel Creek contains on the average more platinum and less iridium than the product recovered from Fox Gulch and from the western part of the valley of Platinum Creek but less platinum and nearly the same amount of iridium as is found in the eastern part of the valley of Platinum Creek.

SALMON RIVER

No mining was done in the valley of the Salmon River until 1937, but a general idea of the extent of the platinum placers has been obtained from the drilling operations of the Goodnews Bay Mining Co. From the mouth of Medicine Creek the pay streak extends downstream on the Salmon River for at least 2½ miles and has a width ranging from 300 to 1,000 feet. Upstream from the mouth of Medicine Creek insufficient drilling had been done prior to 1937 to delimit the workable ground, but it appears reasonable to expect a downstream continuation of the pay streak of Clara Creek. The configuration of the valley of the Salmon River upstream from the mouth of Medicine Creek is such as to suggest that such a pay streak may lie along the east side of the valley.

Reference has already been made to the V-shaped incision in the bedrock floor of the Salmon River and its tributaries. The upstream limit of this incision has not been traced on this river, but judging from the fact that it extends 2 miles up the valley of Medicine Creek and half a mile up the valley of Platinum Creek, it might be expected to persist up the valley of the Salmon River perhaps as far as Clara Creek. The pay streak of the Salmon River is found on the bedrock of this deep incision as well as on the higher bedrock on both sides of the river. It is also a significant fact that the platinum placers are neither appreciably richer nor leaner in this notch than on the higher bedrock. Drilling has also shown that the alluvium in the Salmon River along the pay streak is from 25 to 50 feet thick.

Some further local details regarding the pay streak on the Salmon River are known from the operations of the dredge that was installed by the Goodnews Bay Mining Co. in the fall of 1937 near the mouth of Platinum Creek. This dredge was built on the west side of the Salmon River on claim 1 below Discovery, about 50 yards southwest of the mouth of Platinum Creek. In the period between November 10 and December 20 it worked northwestward and about parallel to Platinum Creek for a distance of 750 feet, taking a cut 200 to 250 feet wide. The average depth of the gravels within this stretch is about 35 feet. Subsequently, during the season of 1938, the dredge worked upstream in the valley of the Salmon River as far as claim 1 above Discovery and the adjoining bench claim to the west, but the details of these and subsequent operations are not known to the writer.

The proportions of the precious metals recovered in the valley of the Salmon River and in the eastern end of the valley of Platinum Creek are significantly different from those found in the western part of the valley of Platinum Creek or in the valley of Squirrel Creek. In general, the product of the valley of Salmon River and the eastern end of the valley of Platinum Creek is higher in platinum and free gold and lower in iridium and osmium; but the order of these differences is best appreciated by reference to the tables on pages 78–80.

The dredge had not been built at the time of the writer's visit to Goodnews Bay, but its construction was afterwards described by Sawin,[11] from whose paper a part of the following account was taken. The dredge is of the Yuba type, built by the Yuba Manufacturing Co., of San Francisco. The hull, assembled from 33 steel pontoons electrically welded together, measures 130 feet long, 60 feet wide, and 9½ feet deep. The total weight of the hull, machinery, and superstructure is about 1,400 tons. With the digging ladder set at an angle of 45° the dredge can dig 50 feet below water level, and with the ladder held at 25° the hull has about 3 feet of freeboard. The digging ladder is 112 feet long and is equipped with buckets having a capacity of 8 cubic feet. The dredge operates from two spuds, two bow lines, and two stern lines, and has two winches on the starboard side, one of which has eight drums. The other is an independent ladder-hoist winch. The stacker is 140 feet long and, like the digging ladder, is covered and heated to permit operation in subzero weather. The 36-inch stacker belt is made of canvas and rubber. The trommel-screen is 7½ feet in diameter and has a perforated section 26 feet long. The power plant, which is located on the boat, is a McIntosh-Seymour Westinghouse Diesel electric generator rated at 625 kilovolt-amperes.

[11] Sawin, H. A., Bucket dredge installed at Goodnews Bay, Alaska: Eng. and Min. Jour., vol. 139, No. 5, pp. 40–41, 1938.

It delivers high-voltage three-phase current for electric operation throughout.

The dredge began mining operations on November 10, 1937, and worked for 41 days before closing down for the season. In 1938 it began work on April 27, so that it would appear that the working season in this district may be as long as 8 months. It was planned that the dredge should work up the valley of Platinum Creek only to claim 5 below Discovery, where it would turn and come back down the valley of Platinum Creek and into the valley of the Salmon River, where its principal work will be done. The Goodnews Bay Mining Co. plans to work claim 4 and a part of claim 5 below Discovery on Platinum Creek by means of a dragline excavator.

CLARA CREEK

Clara Creek is a western tributary of the Salmon River, entering that stream about 2¾ miles by air line upstream from the mouth of Platinum Creek. Clara Creek heads in the north end of the ultrabasic massif that forms Red Mountain and flows about S. 50° E. from its source to its mouth, a distance of about 1½ miles. The valley of Clara Creek is not well marked, even in its headwaters, and in reality is little more than a straight shallow gulch without tributaries, which is incised in the west wall of the valley of the Salmon River. (See pl. 4, *B*.) The total area drained by Clara Creek is estimated to be less than 1½ square miles.

The longitudinal and lateral limits of the platinum pay streak on Clara Creek are not well known, as little drilling has yet been done in this valley and the only mining operations that had been carried on prior to the end of 1937 were at the eastern end of claim 1 above Discovery upstream. Accordingto Reed [12] earlier mining on a smaller scale was done on Discovery claim and on claims 1, 2, and 3 above Discovery, but this work was confined to a narrow channel in the bed of the creek and did not serve to test the width of the pay streak. It is probable that the pay streak is continuous from the contact of the ultrabasic rocks in the headwaters of Clara Creek downstream to its mouth, with the possible exception of that part of the valley contiguous to the Salmon River, where the platinum-bearing placers may have been disturbed by changes that occurred in the course of the Salmon River at the end of the glacial period. The tenor of the platinum placers on Clara Creek may not at present be definitely stated. Reports of the earlier small-scale mining indicate that some of the placers contained as much as 0.08 ounce of platinum metals to the cubic yard of gravel, but as in the valley of Squirrel Creek, the amount of such ground was small. It is likely that the

[12] Reed, Irving, Mining investigations and mine inspection in Alaska, for biennium ending March 31, 1933, pp. 113–116, Juneau, Territory of Alaska, 1933.

large-scale operations now in progress will disclose an average tenor, including the platinum mined in earlier years, of about 0.02 ounce to the cubic yard of gravel.

In the placer-mining operations of the Clara Creek Mining Co., a cut ranging in width from 100 to 150 feet has been mined from the eastern end of claim 1 above Discovery upstream to the western end of claim 3 above Discovery, where mining terminated at the end of the season of 1937. Throughout most of this distance the operators have mined what they consider to be the south side of the pay streak, with the idea that there is at least as much additional ground to the north that can ultimately be worked. At the west end of claim 3 above Discovery the dragline plant crossed in 1937 to the north side of the pay streak, leaving a block of ground on the south side to be worked later.

The alluvial material on Clara Creek is 10 to 12 feet thick. The upper 2 or 3 feet consists of turf, peat, and dark-colored vegetal material mixed with sand. Throughout most of the valley of Clara Creek the gravel consists of fragments which, though subangular, are of small size, averaging perhaps not more than 3 or 4 inches in diameter. Unlike the conditions found in the valley of Platinum Creek and its tributaries, the gravel of Clara Creek, though consisting in part of material derived from the local bedrock, includes also a considerable quantity of rocks of foreign origin, which undoubtedly are glaciofluviatile gravels derived from a glacier that formerly reached the divide at the head of the Salmon River. At the west end of claim 3 above Discovery the mining operations of 1937 began to uncover large boulders, mainly of chert, as much as 3 or 4 feet in diameter that lay near the upper surface of the alluvial cover. An examination of the north end of the ridge forming Red Mountain discloses the fact that gravel of glacial origin is present from the base to an elevation of 600 feet above the present level of the Smalls River. The spur north of Clara Creek is likewise covered with gravel of glacial origin. These facts explain the heterogeneity of the gravels on Clara Creek. They explain, moreover, the presence of large boulders in the upper horizons of the alluvium at the head of Clara Creek, as these may thus be interpreted as glacial erratics, which subsequently worked down the hillside into the valley.

The bedrock that has been exposed by mining operations in Clara Creek consists of greatly sheared and greatly decomposed rocks of several types whose exact original character is not determinable. Apparently they include chiefly sheared chert, quartzite of cherty origin, quartzite of graywacke origin, tuffaceous rocks, and chlorite schist, the latter being closely related to the sheared chert. The cleavage and schistosity of these rocks appears to be a local phenomenon induced perhaps by stresses attendant upon the intrusion of the ultrabasic rocks to the west. Mining operations in the valley of Clara Creek have shown that the bedrock floor beneath the gravels has an unsymmetrical transverse profile, rising steeply on the south side and gradually on the north side.

The platinum metals on Clara Creek are mainly in the crevices and on the surface of the bedrock. At some places 3 or 4 feet of bedrock has to be removed in order to obtain a high recovery. The platinum metals also occur in the lower horizons of the overlying gravel, but, unlike the conditions on Platinum Creek, enough platinum also occurs in the upper horizons that it is unsafe to strip very far below the surface. Actually, in addition to the surficial turf and vegetal material, only about 2 or 3 feet of the gravel is stripped and dumped to one side, and all the remainder is put through the sluice boxes.

The platinum metals recovered on Clara Creek are rather fine grained, but nuggets are not uncommon; and one nugget weighing about 2 ounces has been recovered. The product differs from that recovered from the valleys of Platinum and Squirrel Creeks and differs markedly from that found in the western part of the valley of Platinum Creek and on Fox Gulch. The content of platinum in the metals of Clara Creek is notably high, but the most striking characteristic is the very low percentage of iridium. The percentages of osmium and rhodium are likewise low. It will also be noticed that the commercial analyses (p. 79) show a much greater proportion of impurities for the Clara Creek product than for the product mined by the Goodnews Bay Mining Co. If both products were recomputed free of black sand, however, the discrepancies in the respective contents of platinum would be even more marked than the above comparison indicates, whereas the other ratios would not be so greatly altered.

The placer-mining methods utilized by the Clara Creek Mining Co. are similar to those previously described for the dragline operations on Platinum Creek. The moss and turf is first stripped off, either with the dragline bucket or by ground sluicing. For digging the gravels a Northwest dragline excavator mounted on a tractor base is used. This has a 55-foot boom and a bucket with a rated capacity of 1¼ cubic yards. The excavator is equipped with a 130-horsepower 6-cylinder caterpillar Diesel engine. The washing plant, which is a rigid unit mounted on skids, consists of a dump box 12 feet square and a 102-foot sluice line of steel sluice boxes 8 feet long and 30 inches wide, into which the dump box discharges. A giant with a 3-inch nozzle is used to clean the gravels in the dump box. The first 64 feet of the sluice line has riffles of manganese steel gratings. The next 3 feet has undercurrents that discharge through the bottom of a sluice box onto a small table mounted below the sluice line. Then follows 16 feet of grating riffles succeeded by 3 feet of undercurrents, which also discharge through the bottom of a sluice box to another submounted table. The last 16 feet of the sluice line consists of more undercurrents. Matting is used both under the undercurrents and on the two tables mounted below the sluice line.

Water for the sluicing operations is impounded by two dams in Clara Creek downstream from the mining operations and in the cut that has already been worked. Most of the mud settles in the upper dam; thus clearer water is yielded from the lower dam. A 115-horsepower 6-cylinder caterpillar Diesel engine drives a centrifugal pump with a 12-inch intake and a 10-inch outlet. This pump delivers to the sluice box 4,200 gallons of water a minute under an 80-foot head, but a 30-horsepower Fairbanks-Morse Diesel engine and a small pump are also used under the dump box to compensate for loss of pressure in the pipe line.

The amount of concentrates recovered here with the platinum metals is as great as on Platinum Creek. At the time of the writer's visit in August 1937 a small Wilfley table and a small Joshua Hendy ball mill were being installed to clean these concentrates. The ball mill is a desirable accessory to the concentrating table in that the concentrates are ground to a fairly uniform size and in that condition are handled much more efficiently by the concentrating table. This grinding also frees the platinum metals that are intergrown with grains of chromite.

PRECIOUS METALS

Studies of the physical and chemical properties of the precious metals and their artificial alloys have been made by many investigators, but much remains to be done, particularly in the study of their natural alloys. It is a well-known fact that pairs and triads of metals, as well as more complex groups, when melted together in different proportions, will solidify to form various mixtures and compounds, according to the existing temperatures and pressures. Thus binary metallic alloys may be mechanical intergrowths of the two metals, atomic mixtures, chemical compounds, or various combinations of all of these phases.

If two or more metals exist in an alloy as individual grains, such that all the grains could be rendered visible by microscopic enlargement, certain physical properties could readily be prophesied from linear relationships existing between the two pure metals. Thus if the specific gravity of each of two metals in an alloy were known, it should be possible, from a chemical analysis, to compute the specific gravity of the alloy. But where atomic or molecular readjustments have taken place, it will not generally be possible thus to compute the specific gravity. Natural gold or platinum alloys do not in general show such linear physical relationships, and for this reason it is known that some or all of the metals in such alloys are not mechanically intergrown. Hence the states in which metals exist in many alloys is indeterminate from microscopic examination alone; and for this reason the alloys of the precious and other metals have been extensively studied by thermal, microchemical, and other laboratory methods.

The relationships existing between metals or other components of a multiple system in gaseous, liquid, or solid states and under varying temperatures and pressures are usually expressed as equilibrium diagrams. If the experimental laboratory work on which such diagrams are built could reproduce the conditions found in nature, the complete history of the formation of the precious metals might be explained. But even under conditions different from those in nature, equilibrium diagrams give some understanding of the conditions under which various metals may occur together. Thus, for gold and silver, Raydt[13] has derived an equilibrium diagram showing a liquidus and a solidus curve without maximum or minimum points, thereby indicating that dry melts of gold and silver will solidify as solid solutions in all proportions from pure gold to pure silver. But such phase relations do not necessarily hold for the natural gold alloys, because other metals are also present, and because the effects of still other components, such as quartz, water, and the so-called mineralizers have not been evaluated. Yet it seems likely that the results thus obtained from dry melts will also apply in some measure to natural alloys of gold and silver, and for this reason placer gold is considered to be in whole or in large part a solid solution of gold and silver. Similar investigations of dry melts of the platinum metals, however, are more likely to apply directly to their natural alloys because these metals are not ordinarily considered to have been deposited from aqueous solutions.

Certain alloys made from pairs and triads of the platinum metals have been investigated as dry melts, but no alloys of all six of the platinum metals are known to have been thus studied. It is, therefore, impossible to state the metallic phases which may exist in such six-fold artificial alloys; and the natural alloys, which also contain iron and other metals, may have still more complex phase relationships. From the inability to compute the true specific gravity of natural platinum alloys from their chemical analyses, as shown on page 76, it is known that neither all nor most of these metals are present as individual grains in the alloys. The presence, however, of the hexagonal metals osmium and ruthenium suggests immiscibility or partial miscibility of these elements in the solid phases of the other platinum metals. Hence osmium and ruthenium may occur as pure and distinct crystallites. On the other hand, the investigations so

[13] Raydt, U., Über Gold-Silberlegierungen: Zeitschr. anorg. Chemie, vol. 75, pp. 58–62, 1912.

far made by metallurgists show that platinum, iridium, rhodium, and palladium, at least in binary and ternary systems, will crystallize from dry melts as solid solutions; and also that platinum and α iron, the principal metal of the dross, form a continuous series of solid solutions. Such investigations also tend to disprove the existence of any chemical compounds of the platinum metals, either as between one another or in combination with iron, copper, or nickel. From theoretical considerations, therefore, it is probable that solid solution plays a predominant role in the natural platinum alloys but that some or all of the osmium and ruthenium may occur as pure crystallites.

The individual grains of the platinum metals, however, were deposited at different sites in the original lodes and probably originated under variable conditions of composition, concentration, temperature, and pressure. Hence, it is to be expected that individual grains of these metals will vary considerably in their chemical composition, though it is unlikely that any one grain could be selected which, on chemical analysis, would prove to be entirely free of any one of the six platinum metals. This variation is clearly apparent, both from an examination of the grains in any one sample and from the great chemical variability found in the product mined at different places in this area. Therefore, this placer platinum must be regarded as an assemblage of different alloys consisting of atomic mixtures, which represent the stable phases that have resulted from the cooling of fluids of different chemical composition under varying physical conditions. A polished section of a nugget from Platinum Creek actually showed two distinct alloys, intergrown with one another, but their chemical composition could not be ascertained.

The presence of atomic mixtures of the platinum metals renders it impossible to identify, even qualitatively, the metals comprising any individual grain of placer platinum by means of any simple physical or chemical tests. The magnetic property, for example, of some placer platinum may or may not be due to the presence of alloyed iron, and in any event the intensity of the magnetic susceptibility can give no quantitative clue to the content of iron. Similarly the pure platinum metals have definite solubilities in various inorganic acids or mixtures of acids, but atomic mixtures of these metals do not necessarily have the solubilities of any of their components. A complete chemical analysis is, therefore, the only means of determining the composition of placer platinum; but the chemistry of the platinum metals is too large a field to be summarized in a geologic report. Without regard, however, to any determinative value, some of the better-known physical properties and constants of the pure platinum metals may be of interest to those concerned with platinum mining. For this reason the following table has been included.

Physical properties of the precious metals

	Atomic Weight	Specific gravity	Melting point (° C.)	Boiling point (° C.)	Hardness (Moh's scale)	Electrical resistivity (ohms per cm.^{3}, 20° C.)	Magnetic susceptibility (mass unit, 18° C.)	Thermal coefficient of linear expansion (20° C.)	Crystallographic system	Atomic radius (cm.)	Workability
Paramagnetic											
Platinum	195.2	21.45	1,755	4,300	4.5	10.5×10^{-6}	1.10×10^{-6}	8.9×10^{-6}	Cubic	1.38×10^{-8}	Malleable and ductile.
Iridium	193.1	22.4	2,350	4,800	6.5	6.0×10^{-6}	$.14 \times 10^{-6}$	6.5×10^{-6}	do	1.35×10^{-8}	Brittle.
Osmium	190.8	22.5	2,700	5,300	7.0	9.0×10^{-6}	$.05 \times 10^{-6}$	6.1×10^{-6}	Hexagonal	1.34×10^{-8}	Do.
Ruthenium	101.7	12.2	2,450	2,800	6.5	10.0×10^{-6}	$.50 \times 10^{-6}$	9.1×10^{-6}	do	1.32×10^{-8}	Brittle when cold, malleable at red heat.
Rhodium	102.9	12.5	1,955	2,500	4.0	5.1×10^{-6}	1.11×10^{-6}	8.4×10^{-6}	Cubic	1.34×10^{-8}	Do.
Palladium	106.7	11.9	1,555	2,200	4.8	10.8×10^{-6}	5.4×10^{-6}	11.8×10^{-6}	do	1.37×10^{-8}	Malleable and ductile but less so than platinum.
Diamagnetic											
Gold	197.2	19.3	1,063	2,600	2.5	2.4×10^{-6}	$-.15 \times 10^{-6}$	14.2×10^{-6}	Cubic	1.44×10^{-8}	Very malleable and ductile.
Silver	107.9	10.5	960	1,950	3.0	1.6×10^{-6}	$-.20 \times 10^{-6}$	18.9×10^{-6}	do	1.44×10^{-8}	Very malleable and ductile but less so than gold.

This table shows some significant relations. Lode or placer gold never occurs pure in nature, being always alloyed with more or less silver. Although a common composition of such alloys is 85 percent of gold, 14 percent of silver, and about 1 percent of dross, yet many variations are known. These relatively simple alloys are composed essentially of two elements, one of which is much heavier than the other, though the sizes of the atoms are identical. Actually the specific gravities of gold and silver have the ratio of 1.84 : 1 and their atomic weights the ratio of 1.83 : 1.

Analogously the platinum metals consist of alloys of six metals, three of which are heavy metals and three are lighter. If the average specific gravity of platinum, iridium, and osmium is compared with the average specific gravity of ruthenium, rhodium, and palladium, the ratio of these two means is 1.81 : 1. A similar mean summation of the atomic weights results in the ratio 1.86 : 1. There seems therefore to be a general physical analogy between gold and platinum alloys; but on the other hand, it should be noted that although the atomic weight of gold is greater than the mean atomic weights of platinum, iridium, and osmium, the specific gravity of gold is less than the mean specific gravity of the three heaviest of the platinum metals. The same generalizations hold true for silver as compared with ruthenium, rhodium, and palladium as a group. The atoms of all the pure platinum metals are smaller than those of gold and silver, and only osmium and rhodium have atoms of approximately the same size.

The melting points of the platinum metals do not correlate with this subdivision of heavier and lighter elements, as one of the heavier elements, platinum, has a lower melting point than all of the metals of the lighter group; but there does seem to be a relation between these two groups and the boiling points, as all the elements of the heavier group have higher boiling points. The other physical properties above tabulated appear to bear no unique relationship to the specific gravities of the platinum metals. Gold is the softest and osmium is the hardest of the precious metals. Silver has the greatest electrical conductivity and palladium the least. All the platinum metals are paramagnetic, but gold and silver are diamagnetic; and of the platinum metals, palladium has the greatest and osmium the least magnetic susceptibility. Osmium and ruthenium are crystallographically hexagonal, but all the other precious metals belong in the cubic system. And finally, gold has the greatest degree of ductility and malleability; but among the platinum metals, platinum stands first and osmium or iridium last in this property, the two latter being actually brittle.

CHEMICAL ANALYSES

The platinum metals recovered in the placer mining operations in this area are platinum, iridium, osmium, ruthenium, rhodium, and palladium. A small amount of free gold is also recovered. Careful analysis of both the platinum metals and the gold has shown that the platinum metals contain no alloyed gold and the gold contains little or no alloyed platinum metals.

As the placer product is inconstant, every shipment of platinum metals must be analyzed in order to determine its intrinsic value, but in marketing the platinum metals the two mining companies of the Goodnews Bay district have utilized different methods. The Goodnews Bay Mining Co. in 1937 sent its product to Ledoux & Co., of New York City, where it was analyzed and held to await the selling order of the company. In this transaction Ledoux & Co. acted only as chemists, assuring both the seller and the purchaser of the purity and grade of the product. But in 1938 the Goodnews Bay Mining Co. had its product analyzed by two independent concerns—D. C. Griffith & Co. and Johnson, Matthey & Co.—and contracted with the latter firm to take its entire output. The Clara Creek Mining Co., on the other hand, sells its product to the Wildberg Bros. Smelting & Refining Co., of San Francisco, who are both analysts and purchasers of the product.

In the sale of these precious metals all the platinum metals and the associated gold are paid for in the ratios of their presence in the product. The silver, on the other hand, which is alloyed with the gold, constitutes such a small proportion of the total product that it is not considered in the composite sales price. As a result of this practice the commercial assays show only the amount of pure gold and no silver. The common elements of the dross—iron, copper, and nickel—are likewise neglected. Hence the commercial assays, though accurate as to the content of precious metals, do not give the complete composition of the platinum and gold alloys but instead contain an item called impurities, which represents all the elements of the dross contained in the platinum metals and the gold, a small amount of silver alloyed with the gold, extraneous metallic impurities, such as solder and lead shot, and the residual black sand, which it is impracticable to remove. Nevertheless, such analyses yield a great deal of information regarding the placer product, and the writer is greatly indebted to the Goodnews Bay Mining Co. and the Clara Creek Mining Co. for their generosity in making available these analyses to the writer and for their permission to publish them.

The analysis of placer platinum metals is a more complex process than the analysis of placer gold, and new methods are currently being discovered, as indicated on page 82. Hence systematic differences may exist in the results obtained by different commercial organizations; and if no attention is paid to such differences, erroneous conclusions may be drawn with regard to the genesis and distribution of the placers. In order to discover if such differences existed, the Goodnews Bay Mining Co. submitted nine identical samples of its product to both Johnson, Matthey & Co. and Ledoux & Co. for analysis; and also 15 identical samples to both Johnson, Matthey & Co. and D. C. Griffith & Co. These were random samples, so that it is the differences between the mean values of these analyses rather than the absolute percentages of the platinum metals that are significant. These results, given below, will serve to show the order of magnitude of the analytical errors in commercial analyses.

Comparative data on commercial analyses

Mean of nine identical samples

	Johnson, Matthey & Co., analysts	Ledoux & Co., analysts		Johnson, Matthey & Co., analysts	Ledoux & Co., analyst
Platinum	73.36	73.81	Palladium	.32	.33
Iridium	10.60	8.81	Gold	1.63	1.56
Osmium	2.18	2.00	Impurities	10.71	12.07
Ruthenium	.17	.11			
Rhodium	1.03	1.31		100.00	100.00

Mean of fifteen identical samples

	Johnson, Matthey & Co., analysts	D. C. Griffith & Co., analysts		Johnson, Matthey & Co., analysts	D. C. Griffith & Co., analysts
Platinum	71.40	71.54	Palladium	.30	.26
Iridium	12.14	12.11	Gold	1.37	1.39
Osmium	2.42	2.47	Impurities	11.19	10.96
Ruthenium	.18	.19			
Rhodium	1.00	1.08		100.00	100.00

All the commercial analyses of the platinum metals mined by the Goodnews Bay Mining Co. in this area prior to the end of 1938, arranged by creeks and roughly in order downstream, are given below. The one commercial analysis furnished by the Clara Creek Mining Co. of the platinum metals recovered from Clara Creek is also presented. The eastern end of the valley of Platinum Creek is really coextensive with the valley of the Salmon River. Moreover, this part of the valley of Platinum Creek was mined by the same dredge that operated in the valley of the Salmon River. For these reasons the analyses of the platinum metals recovered from the eastern end of the valley of Platinum Creek are compiled with those of the Salmon River.

In some of these tables, analyses by Johnson, Matthey & Co., by Ledoux & Co., and by D. C. Griffith & Co. are given. In such tabulations, allowance must be made for the fact that the analyses by Ledoux & Co. are consistently lower in iridium than the analyses by Johnson, Matthey & Co. and by D. C. Griffith & Co. The other differences may or may not be significant.

Commercial analyses of platinum metals

Fox Gulch and Platinum Creek

[Analyses 1-14, by Ledoux & Co.; analyses 28-33 and 35-42, by Johnson, Matthey & Co.]

	28	29	1	2	3	4	5	30	6	7	8	31	9	32	10
Platinum	44. 44	44. 80	56. 25	61. 71	61. 62	61. 38	60. 88	60. 42	59. 73	59. 42	57. 81	58. 16	57. 97	57. 91	57. 75
Iridium	34. 67	32. 75	25. 43	20. 52	19. 43	21. 21	21. 65	21. 70	23. 04	23. 24	23. 52	23. 77	24. 21	24. 24	25. 83
Osmium	6. 60	6. 42	5. 55	4. 34	4. 74	3. 76	4. 09	4. 70	4. 42	4. 74	3. 57	5. 02	3. 58	5. 39	4. 34
Ruthenium	. 55	. 51	. 38	. 31	. 37	. 44	. 48	. 37	. 33	. 37	. 40	. 38	. 49	. 39	. 46
Rhodium	1. 14	1. 00	1. 48	1. 98	2. 01	1. 66	1. 58	1. 32	1. 53	1. 52	1. 93	1. 30	2. 28	1. 44	1. 67
Palladium	. 05	. 10	. 21	. 13	. 24	. 22	. 23	. 22	. 21	. 28	. 10	. 20	. 28	. 20	. 14
Gold	. 05	. 08	Tr.	Tr.	Tr.	. 02	. 02	. 59	. 15	. 24	. 37	. 47	. 28	. 40	. 29
Impurities	12. 50	14. 34	10. 70	11. 01	11. 59	11. 31	11. 07	10. 68	10. 59	10. 19	12. 30	10. 70	10. 91	10. 03	9. 52

	11	12	13	14	33	35	36	37	38	39	40	41	42	Mean
Platinum	56. 65	57. 96	65. 23	66. 95	70. 63	69. 44	70. 00	69. 38	68. 10	70. 03	70. 04	72. 01	72. 13	62. 10
Iridium	24. 31	23. 39	16. 30	16. 54	12. 83	14. 28	14. 06	14. 06	15. 42	14. 23	14. 19	12. 61	12. 28	20. 34
Osmium	3. 42	3. 50	1. 85	2. 88	2. 74	3. 09	3. 05	3. 15	3. 58	3. 09	3. 10	2. 63	2. 60	3. 93
Ruthenium	. 30	. 27	. 19	. 29	. 18	. 23	. 23	. 25	. 26	. 23	. 23	. 21	. 20	. 33
Rhodium	3. 13	1. 68	1. 79	1. 38	1. 03	1. 07	1. 21	. 93	1. 03	1. 17	1. 22	1. 22	1. 07	1. 49
Palladium	. 16	. 26	. 27	. 24	. 29	. 28	. 33	. 30	. 29	. 30	. 31	. 27	. 26	. 23
Gold	. 78	. 54	. 91	. 35	. 46	. 34	. 34	. 45	. 36	. 29	. 29	. 50	. 35	. 32
Impurities	11. 25	12. 40	13. 46	11. 37	11. 84	11. 27	10. 78	11. 48	10. 96	10. 66	10. 62	10. 55	11. 11	11. 26

28-29. Claim 1 above Discovery, Fox Gulch.
1. Discovery claim, Fox Gulch.
2-14. Discovery claim on Platinum Creek to claim 2 below Discovery, arranged in order downstream.
30. Claim 1 below Discovery, Platinum Creek.
31. Claims 1 and 2 below Discovery, Platinum Creek.
32. Claim 2 below Discovery, Platinum Creek.
33. Claim 3 below Discovery, Platinum Creek.
35. Claim 4 below Discovery, Platinum Creek.
36. North bench claim, adjoining claim 4 below Discovery, Platinum Creek.
37-40. Claims 4 and 5 below Discovery, Platinum Creek, and adjoining bench claims to north.
41-42. Claim 5 below Discovery, Platinum Creek, and adjoining bench claim to north.

Squirrel Creek

[Analyses 15-21 by Ledoux & Co.; analysis 34 by Johnson, Matthey & Co.]

	15	16	17	18	19	20	21	34	Mean
Platinum	65. 92	68. 50	68. 35	68. 84	68. 88	72. 33	66. 53	70. 17	68. 69
Iridium	13. 77	12. 73	14. 44	12. 32	15. 63	9. 41	13. 54	13. 70	13. 19
Osmium	3. 75	3. 34	3. 09	3. 19	3. 48	2. 05	3. 98	3. 11	3. 25
Ruthenium	. 46	. 14	. 22	. 14	. 44	. 19	. 27	. 17	. 25
Rhodium	1. 30	1. 52	1. 90	1. 45	1. 04	1. 34	1. 25	1. 21	1. 38
Palladium	. 34	. 29	. 16	. 17	. 48	. 23	. 19	. 28	. 27
Gold	. 16	. 15	. 25	. 16	. 37	1. 21	. 54	. 47	. 41
Impurities	14. 30	13. 33	11. 59	13. 73	9. 68	13. 24	13. 70	10. 89	12. 56

15. Discovery claim and claim 1 below Discovery.
16. Claim 1 below Discovery.
17. Claims 1 and 2 below Discovery.
18. Claims 1 and 2 below Discovery and Tupper Gulch, which adjoins them.
19 and 20. Claim 2 below Discovery.
21. Claim 2 below Discovery and Sinclair fraction.
34. Bench claim adjoining claim 3 below Discovery on the east.

Lower Platinum Creek and Salmon River

[Analyses 22-26, by Ledoux & Co.; analyses 43, 46, 60, 61, 67, 68, 72, 78, and 84 by D. C. Griffith & Co.; all other analyses by Johnson, Matthey & Co.]

	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Platinum	76.34	76.20	76.30	76.15	75.27	75.21	75.26	75.24	74.60	74.42	74.37	74.60	74.52	74.55	71.48	74.09	74.77	73.94	73.32	73.10	72.81	75.46	73.89	74.02
Iridium	9.13	9.91	7.98	8.05	7.53	7.30	7.83	7.75	8.40	7.88	8.02	7.98	7.84	8.15	11.69	9.22	8.42	9.82	10.21	10.34	10.47	8.06	10.10	10.15
Osmium	1.85	1.99	1.65	1.61	1.48	1.43	1.54	1.52	1.60	1.67	1.67	1.72	1.69	1.69	2.39	1.86	1.75	2.04	2.06	2.04	2.07	1.55	1.95	1.87
Ruthenium	.16	.17	.14	.14	.11	.10	.12	.11	.14	.12	.13	.14	.13	.12	.17	.14	.13	.14	.16	.16	.16	.19	.15	.15
Rhodium	1.16	1.17	1.04	1.04	.92	.92	.99	.98	.91	1.09	1.12	1.18	1.07	1.14	1.14	.99	.94	1.03	1.05	1.02	1.02	.91	.90	.91
Palladium	.34	.36	.26	.28	.37	.39	.36	.36	.33	.32	.33	.33	.35	.30	.32	.28	.29	.29	.26	.33	.33	.30	.34	.32
Gold	Tr.	Tr.	2.19	2.03	2.90	3.01	2.42	2.70	3.05	2.48	2.39	2.44	2.81	2.46	2.39	2.57	2.77	2.11	2.23	2.29	2.30	1.88	2.28	2.19
Impurities	11.02	10.20	10.44	10.65	11.42	11.64	11.48	11.34	10.97	12.02	11.97	11.61	11.59	11.59	11.35	10.85	10.93	10.63	10.71	10.72	10.84	11.65	10.39	10.39

	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	22	23	24	25	26	Mean
Platinum	73.59	73.49	73.56	73.62	70.26	70.56	68.76	71.44	70.41	72.52	72.41	72.55	72.53	72.02	70.46	76.00	71.54	71.23	74.58	75.03	72.13	72.94	72.31	73.48
Iridium	10.19	9.95	10.36	10.19	13.06	14.01	14.84	11.78	12.57	10.64	10.97	10.55	10.65	11.03	12.80	6.86	11.00	10.83	9.30	9.04	8.54	8.64	9.14	9.77
Osmium	2.04	1.98	2.05	2.00	2.55	2.73	2.86	2.23	2.49	1.97	1.94	1.93	1.88	1.93	2.30	1.26	2.00	1.88	2.07	1.77	2.13	2.16	2.14	1.93
Ruthenium	.17	.17	.16	.16	.20	.24	.22	.18	.16	.14	.15	.09	.15	.16	.16	.11	.14	.15	.14	.13	.16	.21	.12	.15
Rhodium	1.14	1.14	1.05	1.05	.93	1.15	.90	.65	1.12	.66	.97	.87	.64	.55	.74	.54	.70	.81	1.89	2.02	1.80	1.84	1.83	1.05
Palladium	.34	.22	.33	.33	.26	.24	.23	.26	.24	.29	.25	.31	.30	.31	.30	.32	.31	.28	.32	.33	.27	.28	.29	.31
Gold	2.10	2.49	2.30	2.40	.70	.90	1.16	1.81	1.49	1.80	1.58	2.11	1.78	1.78	1.42	2.67	2.33	3.09	1.62	1.77	2.72	2.44	2.54	2.10
Impurities	10.43	10.56	10.19	10.25	12.04	10.17	11.03	11.65	11.52	11.98	11.73	11.59	12.07	12.22	11.82	12.24	11.98	11.73	10.08	9.91	12.25	11.49	11.63	11.21

43-48. Claim 1 above Discovery, on Salmon River, and adjoining bench claim to west.
49-50. Claim 1 above Discovery, on Salmon River.
51. Claim 1 above Discovery, on Salmon River, and Sliver fraction.
52-53. First tier bench claim north of claim 5 below Discovery, on Platinum Creek; Sliver fraction; Discovery claim on Salmon River and adjoining bench claim to west.
54-57. First tier bench claim north of claim 5 below Discovery, on Platinum Creek.
58-66. First tier bench claim north of claim 5 below Discovery, on Platinum Creek; Discovery claim, on Salmon River; and Sliver fraction.
67-70. Discovery claim, on Salmon River.
71-76. Claim 5 below Discovery, on Platinum Creek, and adjoining bench claim to north.
77. Claim 1 above Discovery, on Salmon River; Sliver fraction; claim 5 below Discovery on Platinum Creek; and adjoining bench claim to north.
78. Discovery claim, on Salmon River; Sliver fraction; and claim 5 below Discovery, on Platinum Creek
79-84. Discovery claim, on Salmon River, and claim 5 below Discovery, on Platinum Creek.
22-26. Claim 1 below Discovery, on Salmon River, and adjoining bench claim to west. Arranged in order downstream.

Clara Creek

[Wildberg Bros. Smelting & Refining Co., analysts.]

	27		27
Platinum	73.29	Rhodium	0.42
Iridium	5.90	Palladium	.56
Osmium	.69	Gold	1.01
Ruthenium	.13	Impurities	18.00

Certain relations are at once apparent from these sets of analyses, but they are still more apparent in the recomputed mean analyses below, which omit the impurities.

Recomputed analyses of platinum metals

	Platinum Creek	Squirrel Creek	Salmon River	Clara Creek
Platinum	69.98	78.55	82.76	89.38
Iridium	22.92	15.08	11.00	7.20
Osmium	4.43	3.72	2.17	.84
Ruthenium	.37	.29	.17	.16
Rhodium	1.68	1.58	1.18	.51
Palladium	.26	.31	.35	.68
Gold	.36	.47	2.37	1.23
Total	100.00	100.00	100.00	100.00

In figure 2 the percentages of platinum, iridium, and osmium are plotted as ordinates against arbitrarily chosen abscissas that divide the distance between Fox and Clara Creeks into three equal intervals. Ruthenium, rhodium, and palladium are plotted in the same way, but with the scale of the ordinates amplified 50 times. From this tabulation and graph, it is apparent that as platinum and palladium increase the other four metals of this group decrease. The rhodium and palladium curves are nonlinear, but the curves of platinum, iridium, ruthenium, and osmium approach closely to linear relationships. The decrements of iridium and osmium are somewhat different, but the decrements of iridium and ruthenium are nearly the same. Collectively these relationships suggest some sort of an inverse metallogenetic relationship between platinum and the group comprising iridium, osmium, and ruthenium. The curves of rhodium and palladium, the one showing decrease and the other increase, are probably also significant. Their departure from linearity suggests discontinuities in the phase relationship between them and the other four metals.

This diagram also brings out a significant geographic relation. A considerable part of the platinum metals recovered from the upper valley of Platinum Creek above the mouth of Squirrel Creek was derived from rocks in the valley of Fox Gulch. Hence if the first, second, and fourth abscissas are considered roughly to represent respectively Fox Gulch, Squirrel Creek, and Clara Creek, it will be seen that there is a regular change in the character of the platinum metals in going northeastward from Fox Gulch along the flank of the ultrabasic intrusive mass. The platinum metals from the lower valley of Platinum Creek and from the Salmon River are a mixture

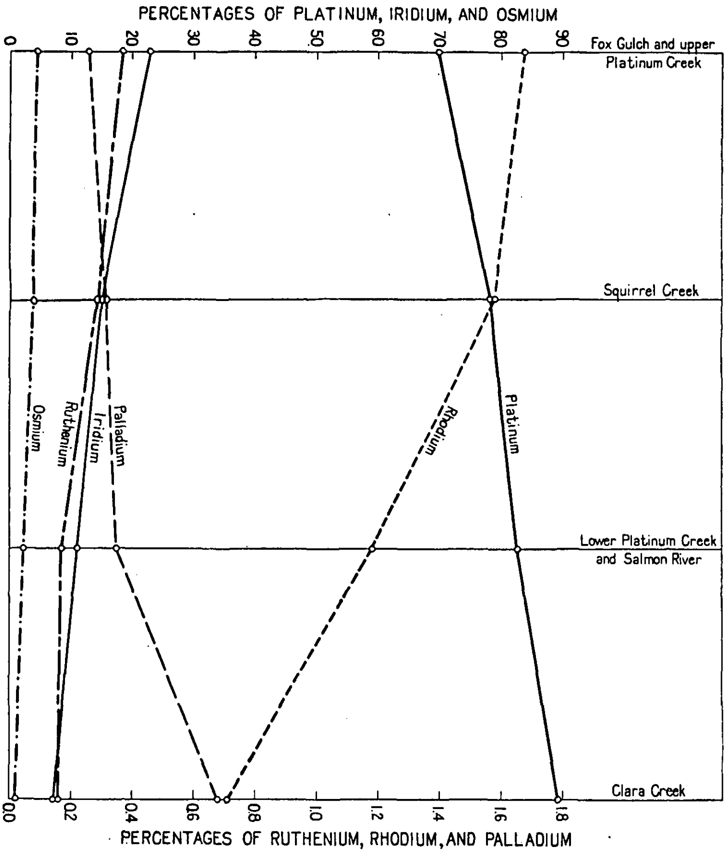


FIGURE 2.—Percentages of platinum metals found in placers along the eastern side of Red Mountain.

derived from many sites along the eastern flanks of Red Mountain, but mainly from the zone between Squirrel and Clara Creeks. It is also known, from analyses of screened portions of these platinum metals, that the larger grains contain less platinum and more iridium than the smaller grains; and as the smaller grains move farther downstream than the larger ones, some of the variations in composition are also explainable on this basis.

In order to learn the entire composition of the platinum metals, two analyses were made in the chemical laboratory of the Geological Survey. One of these, an analysis of material from the lower valley of Fox Gulch corresponding closely to sample 1 of the commercial analyses, was made to determine only the metals of the dross. This analysis was then recomputed free of SiO_2 and MgO, as follows:

Dross of sample from Fox Gulch

[R. C. Wells, analyst]

	Material corresponding to sample 1	Recomputed free of SiO_2 and MgO		Material corresponding to sample 1	Recomputed free of SiO_2 and MgO
SiO_2	0.23		Copper	.39	.39
MgO	Tr.		Nickel	.26	.26
Iron	7.30	7.32			

NOTE:—No gold, silver, cobalt, or manganese was found in the sample. Specific gravity, 18.33, determined by George Steiger.

In the commercial analysis of sample 1 the impurities amount to 10.70 percent. It was now assumed that 7.97 percent of these impurities was dross and that the remaining 2.73 percent represented black sand and other material not a part of the metallic alloy. Therefore commercial analysis No. 1 was recomputed to total 92.03 percent, and was then combined with the recomputed analysis of the dross, with the following result:

Theoretical composition of platinum metals from the lower valley of Fox Gulch

	Commercial analysis No. 1	Theoretical composition		Commercial analysis No. 1	Theoretical composition
Platinum	56.25	57.96	Iron		7.32
Iridium	25.43	26.21	Copper		.39
Osmium	5.55	5.72	Nickel		.26
Ruthenium	.38	.39	Impurities	10.70	
Rhodium	1.48	1.53			
Palladium	.21	.22		100.00	100.00

The second analysis, which is a complete analysis of the sample from Clara Creek, including a recomputation free of MgO and Al_2O_3, is given below:

Complete analysis of platinum metals from Clara Creek

[K. J. Murata, analyst]

	Part soluble in aqua regia	Part insoluble in aqua regia	Total	Recomputed free of MgO and Al_2O_3
Platinum	80.80	0.59	81.39	82.25
Iridium	2.20	3.11	5.31	5.37
Osmium	[1] .53		.53	.54
Ruthenium	[1] .28		.28	.28
Rhodium	1.38	.06	1.44	1.45
Palladium	.14		.14	.14
Iron	9.38		9.38	9.48
Copper	.37		.37	.37
Nickel	.09		.09	.09
Cobalt	.03		.03	.03
MgO	.10		.10	
Al_2O_3	.35		.35	
	95.65	3.76	99.41	100.00

[1] Osmium and ruthenium of soluble and insoluble portions were combined.

NOTE.—No gold, silver, thallium, lead, tin, mercury, chromium, manganese, arsenic, or antimony were found. Specific gravity of sample, 17.20, determined by George Steiger.

In the analyses of the platinum metals of Fox Gulch and Clara Creek, a preliminary treatment was given by immersion in a 1:1 solution of hydrochloric acid, to remove surficial material that was not a proper part of the platinum alloy. With regard to the analytical methods of this analysis, Mr. Murata appends the following note:

The scheme for the determination of the platinum metals published recently by Gilchrist and Wichers [14] was used in the chemical analysis. A preliminary separation from the base metals was effected through a method developed by Gilchrist.[15] Dr. Gilchrist's advice in the application of the details of the method is greatly appreciated. The sample was attacked with aqua regia and the insoluble residue alternately fused with the sodium hydroxide-sodium peroxide flux and with sodium chloride in an atmosphere of chlorine.

Between a fourth and a third of the grains of platinum metals in the sample from Clara Creek are magnetic, though in varying degrees. All the grains, however, are held by a strong electromagnet. Mr. Murata found that the magnetic grains are generally darker in color than the nonmagnetic grains; they also give off an appreciable amount of iron (about 0.4 percent) during the preliminary treatment with hydrochloric acid. Although they tend to be less magnetic after this acid treatment, no relation was found between the total content of iron in the alloy and the magnetic property.

It has previously been stated that the specific gravity of natural platinum alloys cannot be theoretically calculated. In order to show the difference that exists between the true specific gravity and the specific gravity that should exist if the platinum metals existed as a mechanical mixture, as in a eutectic intergrowth, a computation was made from the chemical analysis of the product of Clara Creek. The theoretical specific gravity S for a mechanical mixture of n elements was calculated by means of the following formula

$$S=\frac{(M_1+M_2+M_3+\ .\ .\ .\ +M_n)\ (S_1S_2S_3\ .\ .\ .\ S_n)}{(M_1S_2S_3S_4\ .\ .\ .\ S_n)+(M_2S_1S_3S_4\ .\ .\ .\ S_n)+(M_3S_1S_2S_4\ .\ .\ .\ S_n)+\ .\ .\ .}$$

$$\frac{1}{\ldots+(M_{n-2}S_1S_2\ldots S_{n-3}S_{n-1}S_n)+(M_{n-1}S_1S_2\ldots S_{n-3}S_{n-2}S_n)+(M_nS_1S_2\ldots S_{n-3}S_{n-2}S_{n-1})}$$

where the weights of the n elements are $M_1M_2M_3\ .\ .\ .\ M_n$, and their specific gravities are $S_1S_2S_3S_4\ .\ .\ .\ S_n$.

The result of this computation shows a specific gravity of 18.12, whereas the true specific gravity, as measured by George Steiger, is

[14] Gilchrist, Raleigh, and Wichers, E., Procedure for the separation of the six platinum metals from one another and for their gravimetric determination: Am. Chem. Soc. Jour., vol. 55, pp. 2565–2573, 1935.

[15] Gilchrist, Raleigh, New procedure for the analysis of dental gold alloys: Bur. Standards Research Jour., vol. 20, pp. 745–771, 1938.

17.20. The meaning of the greater volume in the natural alloy, as compared with the volume of a mechanical mixture, is not apparent without detailed laboratory investigation, but it serves at least to show that not all, and possibly none, of the metallic constituents are present as pure metals.

The platinum metals of Clara Creek were also tested spectrographically by George Steiger, of the Geological Survey. Mr. Steiger's statement is as follows:

Three grains of the alloy were tested separately in the spectrograph, by placing each directly in the electrode without any chemical separation. Two of the grains were "non" or very weakly magnetic, the other was easily attracted by a weak magnet. No difference between the grains was detected by the spectrograph. Each grain gave distinct tests for copper and iron, a weak test for arsenic, and a possible test for silver.

Several lead lines were noted in one of the specimens. The specimens were also tested for boron, beryllium, bismuth, cadmium, germanium, antimony, tin, and zinc; negative results were given for all these metals. From magnetic properties already observed, iron content evidently varies to a considerable degree. Copper content may also vary, but no indication of this was observed. These two metals can be easily and accurately quantitatively determined by simple chemical methods, using no larger quantities of material than is found in individual grains.

The complete analysis of the platinum metals of Clara Creek and the theoretical analysis of the product of Fox Gulch show a great range in the different types of platinum alloys found in this area. At the time when the composite analysis of the material from Fox Gulch was made, it represented the minimum in platinum and maximum in iridium and osmium that had been found in any of these alloys. But subsequent mining operations farther northwest in the valley of Fox Gulch, in 1938, have revealed the presence of alloys still lower in platinum and still higher in iridium and osmium. From the facts now available, it is probable that complete analyses would show a range of at least 35 percent in platinum, 30 percent in iridium, 5 percent in osmium, and less significant ranges in ruthenium, rhodium, and palladium. The high percentage of iridium in the placers of Fox Creek is an important economic feature, as the market price of iridium is several times that of platinum, so that the value of the product is thereby considerably enhanced.

Additional data bearing on the composition of the platinum metals was furnished to the writer in 1939 by the Goodnews Bay Mining Co. in the form of two complete analyses of the platinum metals from the valley of the Salmon River.

Complete analyses of metals from Salmon River

[Johnson, Matthey & Co., analysts]

	28	29		28	29
Gold	2.19	2.28	Iron	8.20	8.13
Platinum	74.02	73.89	Copper	.41	.39
Iridium	10.15	10.10	Nickel	Tr.	Tr.
Osmium	1.87	1.95	Arsenic	.03	.04
Ruthenium	.15	.15	Sulphur	.09	.11
Rhodium	.91	.90	Chromite	.11	.18
Palladium	.32	.34		98.59	98.60

Eliminating from these two analyses the gold and chromite and assigning enough iron to make the necessary molecules of pyrite and arsenopyrite, which are then discarded, a recomputation to 100 percent results as follows:

Recomputed analyses of metals from Salmon River

	28	29		28	29
Platinum	77.15	77.18	Iron	8.45	8.37
Iridium	10.58	10.55	Copper	.43	.41
Osmium	1.95	2.04	Nickel	Tr.	Tr.
Ruthenium	.16	.16			
Rhodium	.95	.94		100.00	100.00
Palladium	.33	.35			

These two complete analyses, when compared with the complete analysis of the product of Clara Creek and with the theoretical analysis of the platinum from Fox Gulch, tend to confirm the relations between platinum, osmium, and iridium that were deduced from the commercial analytical data. It will also be noted that the content of iron in these two analyses is intermediate between the amounts shown in the complete analyses of the products of Fox Gulch and Clara Creek. This suggests that the proportion of iron in the alloys increases northeastward from Fox Gulch along the flank of the ultrabasic mass.

The gold found with the platinum metals also leads to some significant inferences. From the beginning of the field work, it was believed that some of the gold recovered with the platinum metals, particularly on Clara Creek and on the Salmon River, was from a foreign source, was transported to the head of the valley of the Salmon River, and was there deposited in the glacial outwash deposits. These deposits were subsequently reworked by fluviatile action, and the gold was thus added to the preexisting placers in the valley of the Salmon River. Some of the gold, however—for example, in Fox Gulch, Squirrel Creek, and Platinum Creek above the mouth of Squirrel Creek—was not introduced by glacial action, as no glacial ice from the north penetrated into these valleys. The gold in these valleys is therefore of local origin and, as previously shown, may be connected genetically with the dikes of sodic granite and syenite that cut the ultrabasic rocks. As these sodic intrusives are believed to be differentiates of the basic magma, it was thought that the dross of this gold alloy might show a relation with the dross of the platinum metals. Accordingly, an analysis was made in the laboratory of the Geological Survey of a hand-picked sample of the gold from Squirrel Creek. The results of this analysis are given below:

Complete analysis of placer gold from Squirrel Creek

[E. T. Erickson, analyst]

	Analysis	Recomputed free of Pt, Cr_2O_3, Al_2O_3, SiO_2, and insoluble material
Gold	83.90	87.99
Silver	10.42	10.93
Platinum, if present, not over	.01	----------
Copper, very small, not over	.002	.002
Iron	.96	1.07
Nickel	.007	.008
Cr_2O_3	.002	----------
Al_2O_3 and SiO_2	.43	----------
Insoluble in aqua regia [1]	1.73	----------
	97.461	100.000

[1] Including 0.06 of iron and no chromium.

NOTE.—No lead or bismuth was found in the sample. Specific gravity of sample, 13.32, determined by George Steiger.

The analyst has interpreted the chromium not as an alloyed metal but as Cr_2O_3 intergrown or included with some of the grains of gold in the form of chromite ($FeO.Cr_2O_3$). This is justified by the fact that no alloyed chromium was found in the complete analysis of the platinum metals. In general copper and iron constitute the principal metals of the dross alloyed with placer gold, but the relative proportions of these two metals vary greatly. In this particular analysis iron is the dominant metal of the dross, and only a minute amount of copper is present. Nickel, on the other hand, forms a small proportion of the dross and is about four times as plentiful as copper. And finally, the presence of Cr_2O_3 shows that some of the gold must have occurred in bedrock either intergrown with chromite or in contact with it. These facts are considered adequate to relate this gold genetically with the chromite and therefore by indirection with the platinum. In this connection it is also worth mentioning that this placer gold is held weakly by a strong electromagnet, though pure gold is known to be diamagnetic.

GENESIS OF PLACERS

The complete geologic history of an ore deposit, or of any detrital deposits derived therefrom, can seldom be given, and the platinum placers described in this bulletin are no exception to this general rule. In the Goodnews Bay district the lode material is either of too low grade to form a deposit of commercial value or the higher-grade ore, if such existed, has been completely removed by erosion. Similarly, insofar as the placers are concerned, many critical facts at present unknown cannot be known until all of the deposits have been opened up by mining. Nevertheless, sufficient facts have been deduced or inferred in the preceding pages to warrant a general statement of the principal events in the long history of the formation of these placers.

BEDROCK SOURCES

In the foregoing description of the geologic features of the area south of Goodnews Bay, it has been shown that Red and Susie Mountains are composed of ultrabasic rocks and that Red Mountain, except for a peripheral zone, is made up largely of a variety of peridotite known as dunite. The platinum placers are localized mainly in the valley of Platinum Creek and its tributaries, in the valley of Clara Creek, in the valley of the Salmon River, downstream from the mouths of these two streams, and in other gulches that drain the eastern side of Red Mountain. In other parts of the world the platinum metals are known to be associated generally, though not exclusively, with ultrabasic rocks. Therefore, as the platinum placers are localized in valleys that drain the flanks of Red Mountain, there can be little doubt that the dunite and related rocks of Red Mountain are the bedrock source of the platinum metals now being mined.

The platinum metals, however, have not been found in place in Red Mountain, nor does a chemical analysis of the dunite show any traces of them; but it has already been shown that platinum is not likely to be detected in the amount of dunite that is utilized in making a chemical analysis. On the other hand, some of the larger nuggets of platinum metals found in the placers are intergrown with chromite, and chromite is known to constitute about 0.4 percent of the dunite of Red Mountain. Moreover, an analysis of the pebbles of chromite that constitute a part of the placer concentrates shows that this chromite contains about 0.05 ounce of platinum metals to the ton. It is therefore believed that most of the platinum metals in the placers are genetically associated with the chromite that occurs in the dunite. A part of the platinum metals, however, particularly those deposited near the periphery of the ultrabasic intrusive mass, may possibly be of hydrothermal origin; and in this environment, the platinum metals may occur in contact with or enclosed within the neighboring country rock.

In the description of the ultrabasic rocks, the hypothesis has been mentioned that the dunite originated by the separation and sinking of crystals of olivine from a cooling magma. Most of the iron and chrome ores, having a limited miscibility in the magma, also separated at this or an earlier stage in the process of cooling. It has been inferred, however, that in this area the intrusive bodies of ultrabasic rock, though generally lenticular in shape, were not originally horizontal, but approximated a vertical position from the time they originated and were subsequently tilted to their present positions. It therefore follows that the dunite, chromite, and associated platinum metals were probably localized in the lower parts of lenticular but upright intrusive masses, either within the intrusive masses or along their borders so that as these horizons were subsequently bared to erosion, the platinum metals began to be freed from their bedrock sources. The ultrabasic rocks of intrusive masses that have not been deeply eroded may not therefore contain much platinum. This is a possible explanation for the lack of platinum in the stream gravels in the vicinity of Susie Mountain.

From the localization of the placers on the east side of Red Mountain it might be inferred that the bedrock source of the platinum metals likewise was localized on this side of the mountain. This is probably true, but in the discussion of the Quaternary deposits it has been shown that the country west of Red Mountain was once the site of one distributary lobe of the Goodnews glacier. Therefore, even if platinum metals had likewise occurred on the west side of Red Mountain, it is improbable that any placer deposits would now be present on that side, as glacial action tends to dissipate rather than to concentrate metallic elements in gravels. Moreover, not only are the streams on that side of the mountain small, but insufficient time has probably elapsed since the retreat of the glacier for the formation of Recent platiniferous deposits of commercial grade.

LIBERATION OF PRECIOUS METALS

In the description of the igneous rocks of this area it was inferred from indirect evidence that the ultrabasic rocks were intruded some time later than the middle part of the Mesozoic era—possibly in the Cretaceous or early Tertiary period. It was also inferred that a superjacent mass of ultrabasic rocks, aggregating in thickness perhaps 1,000 feet, has been removed from the site of Red Mountain. Allowing for the fact that these crystalline rocks were intruded at a considerable distance below the ancient land surface, it seems probable that overlying sedimentary and igneous rocks, with an aggregate vertical thickness of at least 2,000 feet, have been eroded from the site of Red Mountain since the ultrabasic rocks were intruded.

The mean rate of denudation for the whole United States has been estimated by Dole and Stabler[16] to be 1 inch in 730 years, or about 0.0001 foot a year. At this rate, an average denudation of 2,000 feet could be effected in 20,000,000 years, or in less than half the time that is considered to have elapsed since the beginning of the Tertiary period. But in the recent stages of the denudation of Red Mountain, and perhaps in some of the earlier stages, this site was a mountainous one, where erosion may have been considerably accentuated. On the other hand, 2,000 feet is considered the minimum vertical thickness of the rock cover above the present surface of Red Mountain, and a greater thickness would lengthen the time required for the total denudation. All these inferences are admittedly highly speculative, but taken together they lead to the belief that the ultrabasic rocks were probably exposed to erosion long before the beginning of the Pleistocene epoch and possibly as early as mid-Tertiary time. Hence it is equally probable that a large part of the platinum metals were freed from their bedrock sources in pre-Pleistocene time, though, of course, the processes of liberation have continued to the present day.

ACCUMULATION OF PLACERS

As soon as the superjacent sedimentary rocks were removed and the underlying ultrabasic rocks were eroded sufficiently to expose the platiniferous zones, the platinum metals began to accumulate in the streams that then drained Red Mountain. These ancient drainage channels were the ancestors of the present streams, and their head-water courses may have been somewhat different from those of the present day. In their lower courses, however, these older streams must have departed greatly from the plan of the present stream courses in order to have excavated broad valleys, such as the eastern end of Platinum Creek. Such lateral migrations of streams give rise at some places to a wide placer pay streak; yet at others, particularly where the valleys are narrow, the gravels have been reworked concurrently with the lateral migration, thus to a large degree obliterating the traces of the older channels.

In the area around Red Mountain, the precious metals are believed to have been liberated from their bedrock sources at sometime during the second half of the Tertiary period. It is not to be expected that the various positions of the ancient stream channels and the history of the erosion, deposition, reworking, and further deposition of the

[16] Dole, R. B., and Stabler, Herman, Denudation: U. S. Geol. Survey Water-Supply Paper 234, p. 84, 1909.

stream gravels of that remote date could be deciphered. In other words, this early alluvial history antedates the geomorphic record; but at sometime near the beginning of the Pleistocene period these platiniferous gravels had already accumulated as placers at approximately the sites where they now exist. Their subsequent transmutations may be generally deduced from the geomorphic record previously presented.

In the earliest physiographic stage of which the geomorphic record gives a clue, platiniferous gravels were probably distributed in the valleys of Platinum Creek and its tributaries that drain Red Mountain; in the valley of Clara Creek and in gulches lying between Clara and Platinum Creeks; and in the main valley of the Salmon River from the mouth of Clara Creek downstream for some undetermined distance south of the mouth of Platinum Creek. Of these three general localities the valley of Platinum Creek between the mouths of Fox Gulch and Squirrel Creek is one site at which there has been recognized the original bedrock floor that existed at this earliest recorded alluvial stage. Likewise, the gravels overlying this stretch of bedrock have probably been less disturbed since their final deposition than at the other localities cited, though this statement does not imply that they have not been reworked to some extent since their initial deposition. In the valley of Clara Creek the bedrock that has been uncovered by mining may likewise represent the bedrock of the earliest physiographic stage, as suggested by its high degree of surficial alteration. But the overlying gravels are likely to have undergone more reworking and redeposition than in the valley of Platinum Creek. Certainly the normal course of erosion in the valley of Clara Creek was subsequently disturbed by glacial action.

The valley of the Salmon River and the eastern part of the valley of Platinum Creek show the first major erosion of these ancient platiniferous gravels. It has already been deduced that the base level of erosion was lowered at some time in the early Pleistocene and that Salmon River was thereby rejuvenated. In the early stages of this rejuvenation the gravels were first eroded and subsequently the bedrock was incised. Such a process must have worked progressively upstream, so that it may well be doubted if a continuous bedrock gorge from the headwaters of the Salmon River to its mouth ever existed. Even under conditions of rejuvenation, sedimentation was probably in progress in the southern part of the valley while bedrock gorges were being carved in the headwater tributaries. But the net result of the whole process of rejuvenation was the eventual reworking of all the gravels at the site of the bedrock incision and possibly also of a part of the gravels lying on either side of the gorge. But if all the bedrock floor of Salmon River or any large part of it had been bared during this period of rejuvenation, some impoverishment of those areas in platinum metals should be expected, with a corresponding enrichment at the site of the bedrock incision. Yet the drilling records of the Goodnews Bay Mining Co. show no such phenomenon, from which it must be concluded that the gorge at its successive stages in the valley was a narrow incision, both in bedrock and in the overlying gravels. Hence it is inferred that the precious metals of the early gravels were merely let down to a lower altitude on a new bedrock floor with a small but undetermined vector of downstream movement. Some estimate of the magnitude of this downstream vector may be obtained when the southern part of the valley of the Salmon River is dredged; for if this vector is one of appreciable magnitude the pay streak should persist downstream in the bedrock gorge farther than it does on the bedrock bench above the gorge.

The cycle of erosion initiated by the rejuvenation was not completed, as the bedrock gorge was not extended into the headwaters of the various tributaries of Platinum Creek. But to exactly what stage alluviation had progressed in the southern end of the valley of the Salmon River when the physiographic cycle was terminated is not known. Possibly the bedrock gorge in the southern end of the valley was by that time partly or wholly filled with reworked gravels. In any event, rejuvenation was finally halted by some cause, and the most probable one seems to be the advent of glaciation in the headwaters of the Salmon River and along the west side of Red Mountain. The glaciation, as heretofore shown, tended to raise local base levels of erosion, so that sedimentation on a greatly accentuated scale began to be the dominant process throughout the valley of the Salmon River. It has also been inferred that the headwater drainage of the Smalls River was at this time added to that of the Salmon River; and it is certainly to be expected that the flow of water would be still further augmented by melting ice at the head of the Salmon River. The erosional effects of this greater volume of water cannot be properly evaluated, but judging from the analagous condition where an increased volume of water is fed into the headward part of a valley for hydraulic mining operations the effect was mainly to distribute effectively and rapidly the additional debris of glacial origin, without a great deal of reworking of the preexisting gravels farther downstream. The principal economic effect of this process was the introduction into the valley of the Salmon River of gold, which was contained in the glacial deposits and with them was distributed downstream. In this downstream movement of the gold the additional volume of water was probably an effective agent.

The subsequent geomorphic history has heretofore been given. So far as known, the effects of the later processes have not been such as to disturb the deeply buried gravels in the Salmon River Valley nor in the tributary streams, such as Platinum and Clara Creeks. The bed of the Salmon River is now far above bedrock, and even in the shallower gravels of Platinum and Clara Creeks the present volume of water is insufficient, even in times of flood, to disturb the lower strata of these gravels. Hence the alluviation of the valley of the Salmon River and its tributaries by glacial outwash represents the final stage in the reworking of any of the principal platiniferous gravels. The distribution of the platinum metals in the lower horizons of the older pay-streak gravels also indicates that there has been little subsequent enrichment of the pay streak in Recent time, not necessarily because all the platinum metals of Red Mountain have been eroded, but more probably because the span of late Pleistocene and Recent time has been inadequate to liberate and concentrate new deposits.

ADVICE TO PROSPECTORS

The investigations set forth in the preceding pages lead to some inferences that should be of value to those engaged in the search for new deposits of platinum metals. In the Goodnews Bay area, as in many other parts of the world, platinum metals are genetically associated with intrusive rocks of ultrabasic character, such as peridotite and perknite. Moreover, this association is at most places a very intimate one, in that the platinum metals are usually found within ultrabasic masses rather than in vein processes extending outward from the intrusive rocks. Therefore the first significant suggestion is that a careful search be made for such bodies of ultrabasic rocks.

Ultrabasic rocks may not always be easily identified by the prospector. Such rocks under Alaskan climatic conditions are almost sure to weather to a yellowish-brown color, which from a distance appears reddish or reddish-brown. But this feature alone does not suffice for an identification, as gabbro, diabase, and basalt under favorable conditions may likewise weather in much the same way. Hence the true character of the ultrabasic rocks must be sought beneath the surficial veneer of iron ores.

Peridotites and perknites differ from one another in several respects. The term peridotite refers to ultrabasic rocks that consist dominantly of olivine and subordinately of pyroxene or amphibole and contain practically no feldspar. A perknite, on the other hand, is an ultrabasic rock that consists dominantly of pyroxene or amphibole, with some olivine and other accessory minerals, and little or no feldspar. Olivine, the principal constituent of peridotites, is particularly susceptible to a type of replacement that occurs at some depth below the surface and leads to the development of serpentine. Therefore, in samples collected below the surficial veneer of iron ores, peridotites may show either olivine or serpentine or both. Olivine usually occurs in ultrabasic rocks as green or yellowish-green crystals large enough to be recognized by the naked eye; and once this mineral has been seen it is rather easily recognized. Serpentine, on the other hand, occurs in many forms and is not always easily distinguished from similar minerals, such as chlorite; but when it occurs as a replacement of olivine, it usually traverses the olivine in characteristic irregular cracks that are likewise easily recognized once they have been seen. The perknites, on the other hand, consist of minerals that are less likely to be easily recognized by the prospector. Probably the surest way for a prospector to recognize the ultrabasic rocks is to equip himself with some small samples from typical outcrops of these rocks.

In a region covered with timber or brush, however, one of the surest ways to recognize the presence of ultrabasic rocks, particularly the peridotites, is by the absence or scarcity of vegetation. These rocks contain few of the chemical elements needed for the growth of plants and therefore are relatively bare and desolate.

As gold is associated with granitic rocks, so are the platinum metals associated with ultrabasic rocks. Although granitic and ultrabasic rocks are the ultimate sources respectively of gold and platinum metals, yet these precious metals are present in appreciable quantities only in a relatively small number of such intrusive rocks. Hence their occurrence does not necessarily imply that the precious metals are sure or even likely to be present. On the other hand, such intrusive masses are certainly the best sites for prospecting.

Granitic intrusive rocks are far more plentiful in the crust of the earth than ultrabasic intrusive rocks; and platinum metals are much scarcer than gold. It may not be stated with assurance that the percentage of gold derived from granitic rocks is less than the percentage of platinum derived from ultrabasic rocks, but this is also probably true. And, it is known from more than a century of experience that platinum metals occur mainly in a disseminated form in bedrock, so that lodes of such metals are very rare. It is probable that the conditions in the earth's crust that produce the differentiation of ultrabasic minerals from more siliceous magmas are unique and therefore probably local. From these facts and inferences, it follows that the best place to search for ultrabasic rocks is in the general vicinity of similar rocks that have already been recognized. Certainly such areas should be carefully scrutinized before going far afield. Yet it is nevertheless true that commercial placers of the platinum metals are much rarer than gold placers and that the prospector for platinum placers is much less likely to be rewarded with success than the prospector for gold placers.

Another factor of dissimilarity in the occurrence of gold and platinum metals should also be emphasized, because it is a favorable one for the platinum prospector. Gold occurs mainly in veins or other secondary processes, which may lie within a granitic mass, along its borders, or even at some distance from the site of intrusion. Platinum metals, on the other hand, are most likely to be found within ultrabasic intrusive masses or along their margins. Moreover, gold ores may occur at some distance from their parent rock and may therefore be found at some vertical distance from a granitic body. As a result of this, gold mineralization has been recognized at many localities where no granitic rocks appear at the surface, because those rocks have not yet been bared to erosion. Platinum metals, on the other hand, are likely to occur in the lower strata of ultrabasic rocks, so that if important deposits of the metals exist in an area, the ultrabasic rocks are almost certain to crop out. Hence if platinum metals occur in a region, the parent rock and therefore the best sites for prospecting are more likely to be evident from the bedrock geology.

One geologic factor that applies to prospecting for both gold and platinum placers is glaciation. It is believed by the writer that most of the placer gold in Alaska, whether it now occurs in preglacial or in postglacial gravels, was freed from its bedrock sources in preglacial time. Therefore many placers existed in Alaska before the ice age, and there is no good reason to believe that the granitic rocks in one part of Alaska yielded more gold than in another part. Yet at the present time most of the important gold placers are confined to the Yukon and Kuskokwim Valleys and to Seward Peninsula. The explanation of this distribution is that the widespread regional glaciation of southern and southeastern Alaska has operated to scour out and dissipate the preexisting placers. The placers of southern Alaska that were not thus destroyed were either in valleys transverse to the main movement of the ice or were otherwise reconcentrated from gold-bearing glacial till of more or less local origin. The gold placers of interior and western Alaska, on the other hand, are in unglaciated areas and have not been disturbed by ice.

Hence in prospecting for placers containing the precious metals, it is most desirable to concentrate the work in areas that have not been regionally glaciated. The Goodnews Bay district is bordered on the east by a region that has been intensely glaciated and within which

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no commercial placers have yet been found. Tongues of ice moved westward and southwestward from this ancient ice cap down the trunk valleys in the direction of Bering Sea; and some of these, as in the valley of the Goodnews River, reached salt water. But many of the tributary valleys, especially the parts close to the sea, were affected only by alpine glaciation or were unglaciated. Alpine glaciation should not be such a deterrent to the placer prospector as regional glaciation, because glaciers of the alpine type may not have completely dissipated the preexisting placers; and even if such disruption of the placers has occurred, some of the glacial till may still be preserved in the valleys wherein it originated, so that the present streams may have been able to reconcentrate the precious metals, thus forming Recent placers. The valley of the Salmon River was favorably situated in that it was not glaciated at all. From these facts it follows that the distribution and character of any glaciers that may have existed in a region constitute a geologic factor of great importance that should be considered in all prospecting operations. The chances of success in finding placers of the precious metals will be greatly increased if the prospector will restrict his work to areas that are entirely unglaciated; and if this is not feasible, then the less glaciation an area shows the greater will be the chances of success.

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