

Orientation Geochemical Soil Survey at the Nixon Fork Mines, Medfra Quadrangle, Alaska

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CONTRIBUTIONS TO ECONOMIC GEOLOGY

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*A study to determine effective
soil-sampling techniques for
reconnaissance geochemical
prospecting in the Nixon Fork
district*



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**ORIENTATION GEOCHEMICAL
SOIL SURVEY AT THE
NIXON FORK MINES,
MEDFRA QUADRANGLE, ALASKA**

By **BRUCE L. REED** and **ROGER L. MILLER**

ABSTRACT

Gold lodes in the Nixon Fork area occur as small contact metamorphic deposits in limestone within a few hundred feet of a quartz monzonite contact. Bedrock is extensively covered by overburden, but soil sampling has revealed anomalous metal concentrations related to the lodes. Arsenic, antimony, copper, lead, and silver are the best pathfinder elements for gold. Arsenic, copper, lead, and antimony generally increase with soil depth. Silver is enriched in the A horizon. Gold is present in C-horizon samples in amounts up to 16 parts per million as far as 400 feet downslope from some lodes. Anomalous metal content in C-horizon soils is generally reflected in the A-horizon soils. Sampling of A-horizon soils would be an effective method for reconnaissance geochemical prospecting in this area.

INTRODUCTION

Gold placers were discovered in the Nixon Fork area in 1917. During the following year the source of the gold was located, and several lode claims were staked. The lodes occur as small contact metamorphic deposits in limestone along the contact with a quartz monzonite stock; the deposits generally occur within a few hundred feet of the igneous contact. The total recorded production from the several small lodes in the area is \$1.3 million (Herreid, 1966). The mines have been essentially inactive since 1933, although limited operations were attempted in 1960.

The area surrounding the Nixon Fork mines is similar to other gold-producing districts in south-central Alaska in that it is ex-

tensively covered by overburden. Vegetation consists of a mixed growth of spruce, cottonwood, birch, willows, and alder as well as numerous species of wild flowers, mosses, and grasses. Geochemical soil surveys would seem to be particularly applicable in those areas where outcrops are sparse and where other exploration methods are relatively expensive or ineffective. The purpose of this orientation survey was to obtain data on the abundance and distribution of certain metals in soil horizons overlying both mineralized and unmineralized terrain to determine the key elements that reflect mineralization and the most practicable soil horizon for sampling.

Mr. Theodore Almasy, McGrath, Alaska, was most helpful in familiarizing the writers with the Nixon Fork mines and assisting in the collection of the data, and he extended his hospitality and help in many other ways.

LOCATION AND ACCESSIBILITY

The Nixon Fork mines are between Nixon Fork and the North Fork of the Kuskokwim River, about 35 miles northeast of McGrath (pl. 1). McGrath serves as the hub of south-central Alaska, having airline service with Anchorage and Fairbanks as well as barge service on the Kuskokwim River. A small trading post is at Medfra (pl. 1), which has a 2,200-foot silt-grass airfield. Medfra is also supplied by barges on the Kuskokwim River. A supply road, built in the 1920's, from Medfra to the Nixon Fork mines has not been maintained for many years and at present is unsuitable for wheeled vehicles. An airstrip about 800 feet long is located on a ridge about 1 mile south of the Nixon Fork mines (pl. 1). This strip is in fair condition and can be used by "Cub"-type aircraft or, prudently, by aircraft of the Cessna 180 class.

SUMMARY OF GEOLOGY

A reconnaissance geologic map of the Nixon Fork area is shown on plate 1. Recent geologic maps for the region surrounding the Nixon Fork mines are not available, and plate 1 is essentially the early reconnaissance work of Brown (1926) supplemented by aerial photograph interpretation. The geology near the Nixon Fork mines (pl. 1) is modified slightly from Herreid (1966). Descriptions of the geology of the Nixon Fork area and of the lode and placer deposits are given in reports by Martin (1922), Brown (1926), Mertie (1936), White and Stevens (1953), Jasper (1961), and Herreid (1966). Only a brief summary, based largely on the above reports, is given below.

The oldest and most common rock type in the area is a complexly folded Paleozoic limestone. The limestone, 5,000–7,000 feet thick, is white to dark gray, is thin to thick bedded, and contains thin interbeds of shale, chert, and calcareous sandstone. Fossils of Ordovician, Silurian, and Devonian(?) age are present in this carbonate unit (Brown, 1926, p. 102–105). Near contacts with intrusive rocks, the limestone is metamorphosed to calc-silicate marble. This limestone is probably equivalent to the north-trending Paleozoic carbonate rocks in the southern Alaska Range 60 miles to the south (Reed and Elliott, 1968).

Cretaceous rocks consist of a monotonous sequence of medium- to dark-gray graywacke, argillite, shale, and siltstone with local beds of conglomerate. These rocks are at least 5,000 feet thick, have well-developed slaty cleavage, and are hornfelsed near contacts of granitic stocks.

Late Mesozoic or early Tertiary stocks of quartz monzonite and granite cut the Paleozoic and Cretaceous rocks. An age of 66.9 ± 2 million years was measured on biotite from the stock at the Nixon Fork mines (Marvin Lanphere, written commun., 1970). Quartz latite porphyry locally occurs along the borders and also as dikes within the quartz monzonite stock at the mines. These porphyry phases are believed to represent chilled border zones (Brown, 1926) and late differentiates of the magma (Herreid, 1966).

The sedimentary rocks are complexly folded into northeast-trending structural features. The area of the Nixon Fork mines probably is a breached northeast-trending fold domed by the underlying intrusive. The northeast-trending linear features shown on plate 1, traced from aerial photographs, locally may have controlled emplacement of the intrusive rocks. Brown (1926, p. 120–123) proposed that the Paleozoic limestones have been thrust northwestward over Cretaceous rocks. The thrust was subsequently folded and pierced by granitic stocks. Erosion has exposed fensters of Cretaceous rocks below the thrust plate. On aerial photographs, the small area of Cretaceous(?) rocks shown on the northwest fork of Soda Creek appears similar to the fenster northeast of the Nixon Fork mines; however, that area has not been field checked. The thrust plate appears to be terminated to the north by the Iditarod-Nixon Fork fault zone, a major fault zone in south-central Alaska with probable right-lateral movement (Grantz, 1966). Cretaceous sedimentary rocks crop out north of the fault zone (pl. 1).

The gold lodes at the Nixon Fork mines are small, but locally rich, contact metamorphic deposits in limestone and generally oc-

cur within a few hundred feet of the quartz monzonite contact (pl. 1). The chief ore minerals are auriferous pyrite and chalcopyrite. Locally, extensive oxidation has resulted in the release of gold from the sulfide minerals and consequent enrichment in the oxidized zone.

MATERIALS SAMPLED AND ANALYTICAL METHODS

The soils in the area sampled are residual. On moderate to steep slopes, the soils have undergone downslope movement as shown by the soil anomalies discussed later and by the displaced rock fragments. In general, the soils are immature and do not have well-developed horizons. This is especially true on the steeper slopes where soils are shallower and contain abundant rock fragments. The A horizon is generally 2–10 inches thick, black, and rich in humic materials. The B horizon is moderately well developed only on flat or gently sloping areas and commonly has a noticeable change in color or texture. In most areas the color of this intermediate horizon is orange brown to brown. The depth, color, and other characteristics of the C horizon are influenced by the terrain and underlying bedrock. Areas underlain by quartz monzonite are characterized by a coarse-grained grayish-yellow “granitic” layer extending 3–5 inches above bedrock in which quartz, feldspar, and mica fragments are clearly visible. The C horizon of soils overlying limestone is typically a fine light-olive-gray silt.

Soil samples were taken with a 4-inch metal auger to a maximum depth of 4 feet. Samples from the A horizon were taken from black soil 2–5 inches below the roots of the grass or moss. Roots and undecomposed organic matter were excluded from these samples. Samples from the B horizon were taken where a layer with color or textural change between the A and C horizons was apparent. Where the B horizon was poorly developed, part of the C horizon may have unintentionally been included in these samples. Care was taken to collect C-horizon samples 2–6 inches above bedrock; however, in some places small rock fragments prevented the auger from penetrating to bedrock, and samples from the lowest horizon may include part of the B horizon. Where soil profiles were not developed, samples were taken only from the dark organic soil below moss or grass roots.

Samples were collected in rectilinear grids surveyed by tape and compass and by pace and compass. Samples were also taken on traverse lines along previously cut claim lines and along lines surveyed by pace and compass. Data for the samples collected from different horizons on rectilinear patterns are presented as geo-

chemical maps and as histograms. Data for samples collected at different horizons on traverse lines are presented as profile curves. Because the auger was occasionally stopped by rock fragments, it was not possible to collect a lower soil horizon at every sample location, a problem which accounts for the absence of these data for some of the curves. The soil samples were dried at temperatures below 40°C, sieved, and the minus 80-mesh fraction analyzed.

To determine background values of bedrock, samples of the most common rock types in the area were collected for analyses. Care was taken to select fresh specimens, and weathered surfaces of the samples were cut off with a rock saw. Owing to lack of exposures, most of the samples collected are float, but are believed to have been locally derived.

All samples were analyzed for 30 elements by the six-step semi-quantitative spectrographic method. The precision of a reported value is approximately plus 100 percent or minus 50 percent. Because the necessary sensitivity was not attained by the spectrographic method, the following elements were analyzed by wet chemical or instrumental methods: Gold by atomic absorption (Thompson and others, 1968); arsenic by the confined spot procedure (Almond, 1953; Ward and others, 1963, p. 40-44); and antimony by the procedure described by Ward and others (1963, p. 38-40). Roger L. Miller analyzed the samples for the last three elements.

RESULTS

This study indicates that arsenic, antimony, copper, lead, and silver are the best pathfinder elements for detecting gold mineralization in the Nixon Fork area, and thus these are the principal elements discussed in this report. Data for iron, manganese, and calcium are included in the profile curves because the mobility of many elements in the secondary dispersion cycle is affected by pH (lime) and by the absorptive capacity of hydrous Fe and Mn oxides (Jenne, 1968). Zinc in amounts of 200 ppm (parts per million) or more (limit of detection 200 ppm) was present in only five samples, and it was not detected in any samples containing the highest concentrations of the pathfinder elements listed above. Bismuth may also be a diagnostic element in geochemical soil surveys in the Nixon Fork area, for it was found (spectrographic limit of detectibility: 10 ppm) only in the samples containing the highest values for the pathfinder elements.

Mercury was determined by the mercury vapor detector (Vaughn, 1967). High concentrations of organic matter interfere

Table 1.—Analyses of nonmineralized bedrock samples from the Nixon Fork mines area

[Analyses by six-step semi-quantitative spectrographic method (except for gold, arsenic, and antimony)—analysts: K. J. Curry, J. M. Motooka, and D. G. Siems. Gold was by atomic absorption method (Thompson and others, 1958); arsenic was by the confined spot procedure (Almond, 1958; Ward and others, 1963, p. 40–44); antimony was by the procedure described by Ward and others (1963, p. 38–40).—analyst for all three: R. L. Miller. Analyses are reported to the nearest number in the series 0.1, 0.16, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, **, etc. The precision of values is approximately plus 100 percent or minus 50 percent. N—not detected; L—present but below determination limit]

Sample	Field No.	Tag No.	Rock type	Percentage										Parts per million									
				Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	Hg			
1	68AR15	AJT271	Quartz monzonite	3	1	1	0.7	500	N	<.02	20	700	3	N	N	20	30	30	0.06				
2	68AR232	AJT280	Granodiorite	3	3	3	.7	20	N	<.02	20	1,000	1	N	N	30	70	30	.09				
3	68AR232C	AGC176	Quartz monzonite	3	1.5	1.5	.3	500	N	<.02	10	700	1.5	N	N	15	30	7	.02				
4	68AR232C	AJT273	Altered feldspar porphyry	1	1.1	1.3	.2	500	N	<.02	50	20	2	N	N	N	5	10	.12				
5	68AR232C	AJT270	White marble	1	7	15	.01	700	L	<.02	L	N	N	N	N	N	N	7	.22				
6	68AR57A (2)	AJT275	Altered limestone	1.5	5	>.02	.05	700	L	80	<.02	1,000	300	1	N	N	20	5	.2				
7	68AR386	AJT274	Graywacke	10	.07	.15	.5	500	N	80	<.02	N	50	1	N	N	20	50	30	.9			
8	68AR386B	AJT275	Argillite	10	.2	.05	.7	2,000	N	80	<.02	150	1,000	2	N	N	15	200	50	1.8			
9	68AR47A	AJT276	Argillite	3	.02	.05	.7	30	N	80	<.02	15	100	L	N	N	100	7	1.5				
Limit of detectability				0.05	0.02	0.05	0.002	10	0.5	0.02	10	20	1	10	20	5	5	5			

Sample	Field No.	Tag No.	Rock type	Parts per million										Remarks	
				Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Zn			
1	68AR15	AJT271	Quartz monzonite	N	20	10	4	10	N	200	N	200	N	Float.	
2	68AR232	AJT280	Granodiorite	N	L	70	1	16	N	500	L	300	L	Do.	
3	68AR232C	AGC176	Quartz monzonite	N	L	30	2	10	L	300	L	300	L	Do.	
4	68AR106	AJT279	Altered feldspar porphyry	N	20	N	N	3	L	N	N	N	N	Float from prospect pit; chiefly quartz, sericite, and kaolinite(?).	
5	68AR28	AJT270	White marble	N	N	N	N	2	N	100	N	100	N	Float; approximately 70 percent dolomite, 30 percent calcite.	
6	68AR57A (2)	AJT278	Altered limestone	N	N	5	10	8	N	200	N	200	N	Float from prospect pit; chiefly calcite with minor chlorite.	
7	68AR386	AJT274	Graywacke	5	N	70	N	6	10	N	N	500	N	Iron oxide filled fractures.	
8	68AR386B	AJT275	Argillite	N	10	30	N	6	15	N	N	200	Do.		
9	68AR47A	AJT276	Argillite	N	N	20	N	10	L	N	100	N	Do.		
Limit of detectability				5	10	5	10	.....	5	10	.....	200			

with the determination of mercury by this method. In the A horizon and in some of the deeper horizons, the organic content of the soil is quite high and may constitute more than half of the total sample. However, because the organic content is relatively constant from sample to sample, the differences in mercury content may be significant and thus are reported here.

BEDROCK SAMPLES

Analyses of bedrock samples collected to determine background values in local rock types are given in table 1. The location of these samples is shown on plate 1. Although care was taken to select fresh specimens, the samples of argillite and graywacke were badly fractured and contained thin seams filled with iron oxide material that may account for some of the higher metal values in these samples.

The range of values, in parts per million, for the principal elements of interest for different rock types is summarized below:

<i>Rock type</i>	Ag	As	Au	Cu	Pb	Sb
Intrusive rocks	<0.5	<10-80	<0.02	7-30	<10-30	1-4
Metamorphosed limestone	<0.5	<10-80	<.02	5-7	<10-10	2-8
Argillite and graywacke	<0.5	80	<.02	7-50	<10	6-10

With the exception of arsenic and antimony, the values for the pathfinder elements are close to average background values for similar rock types elsewhere (Turekian and Wedepohl, 1961).

AREA A

A rectilinear sampling grid, in which samples were taken at 50-foot intervals downslope from the Whalen glory hole, is shown in figure 1 and is located on plate 1. The grid was laid out at this location to determine whether anomalous metal patterns were present in soils downslope from the Whalen glory hole that would reflect the mineralized rock. The dotted line in figure 1 represents the approximate contact between the limestone and granitic intrusive rocks as determined from rock fragments in the lowest soil samples. Geochemical maps showing the distribution of As, Sb, Cu, Pb, Ag, and Au in the A and C horizons are shown on plate 2. Histograms are given for each of the above metals.

Background and threshold levels, in parts per million, for this area, based on a qualitative appraisal of geochemical maps and histograms on plate 2, are given below. Owing to the particulate

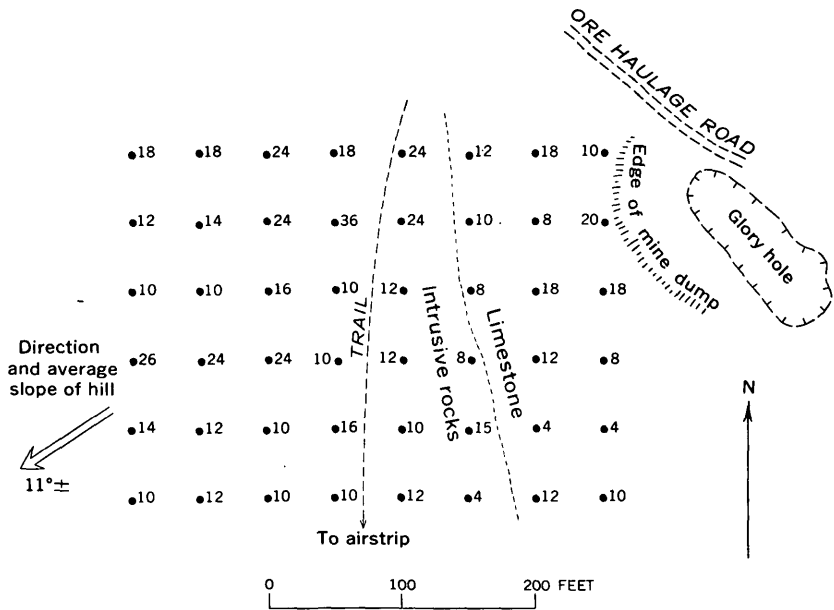


FIGURE 1.—Rectilinear sampling grid of area A. Numbers adjacent to sample localities (dots) indicate depth, in inches, to lowest soil sample. Geochemical contour maps for Ag, As, Au, Cu, Pb, and Sb in the A- and C-horizon soils are shown on plate 2.

nature of gold in soils, gold is not included; however, as an approximation, it seems that values of 0.05 ppm Au or greater should be considered anomalous.

	As		Ag		Cu		Pb		Sb	
Soil horizon	A	C	A	C	A	C	A	C	A	C
Background	20	20	0.7	0.5	50	70	50	50	8	10
Threshold	30?	40	1.5?	1	100	200	70?	70	10	20

From inspection of the geochemical maps (pl. 2), it is readily apparent that in the deepest soil samples the geochemical contours outline a well-defined pattern of anomalous values downslope from the mine dump. The width of the anomalous train ranges from slightly less than 100 feet to about 175 feet. How far the train continues in the downslope direction has not been determined, but the shape of the contours at the southwest edge of the grid suggests that it may continue for at least an equal distance (about 400 ft) in the downslope direction.

The shape of the anomalous metal patterns in the soil suggests that they were formed by downslope creep of metal-rich soil and detritus. The fact that the anomalies are more intense in the C

horizon suggests that contamination by mining activities did not produce or seriously modify the pattern detected. The shape of the train and the fact that placer gold was mined in Holmes Gulch, three-fourths mile downslope from area A (pl. 1), suggest that the gold occurs as clastic fragments in the soil, as may also some of the other metals. Furthermore, it is difficult to explain as mine contamination the consistently high gold values in the deeper horizon samples 100–300 feet downslope from the mine dump. A second sample,¹ not shown on the geochemical maps, was taken about 15 feet from the location of the highest gold value (10 ppm); its gold content was 16 ppm. On the other hand, the C-horizon sample closest to the dump yielded only 0.3 ppm gold, whereas the A horizon from this sample location yielded 3.2 ppm. The high, but local, gold values in the A horizon near the dump may well reflect contamination due to mining activities. This may also be true for the other high metal values in the A horizon near the dump.

A feature of some of the C-horizon patterns is a second anomaly developed about 200 feet downslope from the mine dump. This second anomalous zone is not present on the lead map, but it is particularly well outlined by the isopleths for 8 ppm Au, 2.5 ppm Ag, 1,000 ppm Cu, 30 ppm Sb, and 40 ppm As. Considering the angle of slope, these metal values would be expected to increase upslope toward the metal source. The presence of this secondary high may reflect another area of metallization which fortuitously falls within the geochemical train of the Whalen lode, a lateral enrichment due to the combined effects of weathering and soil creep or to lateral migration of metal-rich water from the Whalen lode. The possibility that this secondary high is related to another area of metallization could easily be tested by shallow trenching, as the depth to bedrock in this area is probably about 2 feet.

The high lead and moderately high antimony values in both horizons at the southwestern part of the grid are offset about 100 feet northwest of the metal train defined by the other elements. Both these metals are relatively immobile, and the offset may reflect a corresponding increase of lead and antimony in the underlying bedrock.

Analyses, in parts per million, of two grab samples from the glory hole dump are as follows:

¹ To check the validity of the sampling, additional samples were taken at a few localities. The metal content did not vary appreciably; however, the lowest values reported are shown on the geochemical maps.

Sample	Ag	As	Au	Bi	Cu	Hg	Pb	Sb	Zn	Remarks
10.....	10	100	9.4	1,000	20,000	0.08	70	35	300	Copper-stained skarn.
11.....	30	1,500	6.4	30	20,000	.30	150	100	700	Do.

In addition to gold and copper, the samples are relatively rich in silver, arsenic, bismuth, and antimony. The zinc content in these samples is more than twice that of lead; however, in the soil samples from area A, zinc is present (>200 ppm) in only one sample because of possible ground-water leaching. Lead, on the other hand, has a relatively limited dispersion pattern and is enriched in the soil. Bismuth in amounts up to 70 ppm is present in all the samples along the crest of the main geochemical high. This suggests that bismuth also may be a useful indicator element in this area. Geochemical maps for iron and manganese were prepared, but showed no well-defined patterns.

With the exception of arsenic and gold, the geochemical maps of A-horizon samples reflect, in general, the metal patterns shown by the deepest horizons. The two values of 60 ppm arsenic on the east side of the grid remain unexplained. The 1.2 ppm gold content of the sample in the southwestern part of the grid may reflect downslope mechanical dispersion of the high gold content found in the C horizon in the area of this sample.

In the A horizon the antimony pattern is narrower and less intense than the pattern shown in the deepest horizon. Copper, on the other hand, shows a slightly wider, but also less intense, pattern in the A horizon. The silver pattern in the A horizon is more intense and slightly wider than the pattern shown by the C horizon. The higher silver values along the axis of the geochemical anomaly and the greater number of samples in which silver values were detected indicate that silver is concentrated in the organic soils. Enrichment of silver in the A horizon has also been noted at Cobalt, Ontario, (Boyle and Dass, 1967) and at the Thunder Bay district, Ontario, (Boyle, 1968). The geochemical maps thus suggest that sampling the A horizon for copper and silver would be an effective method of geochemical prospecting in this area.

The distribution of mercury (fig. 2) in the A and the C horizons shows no similarity to the patterns in the geochemical maps shown on plate 2. The high mercury values in the northeastern and southeastern part of the grid occur in areas of low metal values for the pathfinder elements, and there is no relation to the intense gold anomaly shown in the deeper horizon samples. The mercury values, which range from 0.1 to 1.5 ppm, are high when compared with average background values of 0.01–0.1 ppm mercury in soils

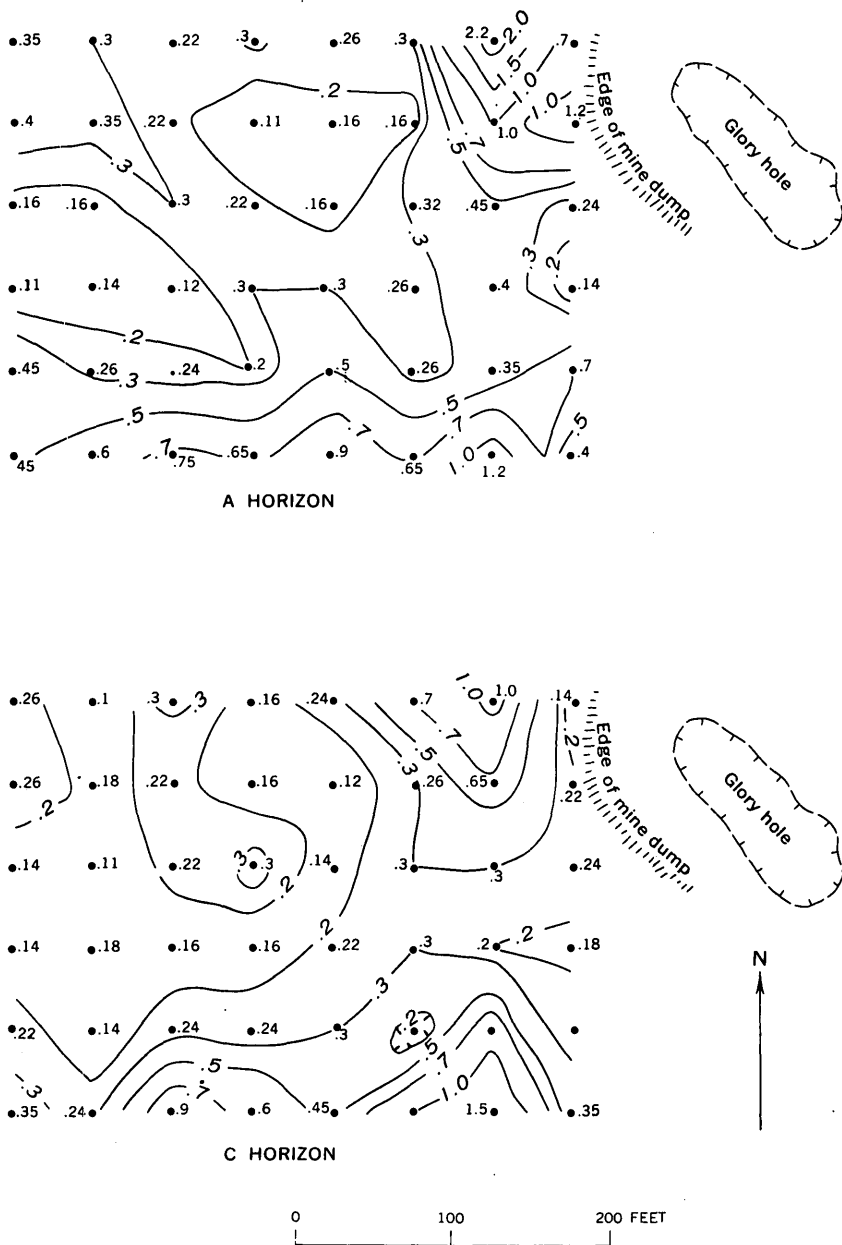


FIGURE 2.—Geochemical maps of area A showing distribution of mercury in the A- and C-horizon soils. Numbers adjacent to sample localities show mercury content in parts per million.

near other deposits of mercury, gold-silver, lead-zinc, copper, and molybdenum (Brown, 1967). It is possible that the area sampled represents only a part of a larger mercury halo associated with the Whalen lode or with the limestone-intrusive contact.

Herreid (1966, p. 14), in describing a soil-sampling traverse along the trail in area A (pl. 1), noted that the "soil samples taken near the glory hole*** are not anomalous." It is possible that his sample interval (approximately 200 ft) missed the anomaly. It may also be that his field method using cold ammonium citrate was not effective in extracting the metal content of the soils.

AREA B

Three soil-sampling traverse lines were laid out in an approximate east-west direction and one in a north-south direction in an area underlain by quartz monzonite (pl. 1; fig. 3). The purpose of this sampling grid was to obtain background information on the metal content of soils overlying quartz monzonite. The ground surface in area B slopes gently to the north. The sample interval was approximately 150 feet, and the distance between the three lines was about 300 feet (fig. 3). The central line lay along a N. 85° W. claim line. The Keen shaft, immediately north of the area sampled (fig. 3), is reported to have been sunk on a 4-foot-wide vein consisting of banded quartz, arsenopyrite, and minor pyrite (Martin, 1922, p. 160). Analyses, in parts per million, of three grab samples from the dump near the shaft are given below:

Sample	Ag	As	Au	Cu	Hg	Pb	Sb	Zn	Remarks
12.....	0.7	1,000	0.02	700	1.1	30	15	<200	Altered quartz monzonite.
13.....	3.0	>10,000	6.2	150	1.6	300	200	<200	Banded quartz, with arsenopyrite.
14.....	15	>10,000	8.0	700	0.5	300	150	<200	Do.

Suggested background values, in parts per million, for area B are given below. For comparison, the values for these elements in quartz monzonite are also given.

Soil horizon	Ag	As	Cu	Hg	Pb	Sb
A.....	<0.5	40?	20	?	30	3
B.....	<.5	50?	30	.3	30	4
C.....	<.5	60?	50	.4	30	5
Quartz monzonite ¹	<0.5	<10-20	7-30	0.02-0.06	10-30	2-4

¹ Samples 7, 8 and 9, table 1.

The geochemical maps for area B (pl. 3) show that with the exception of arsenic and mercury, the metal values for the other

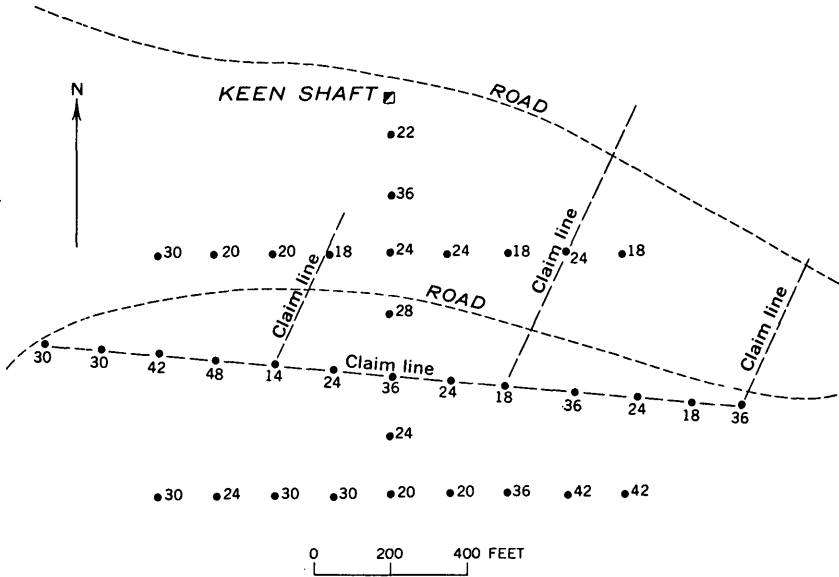


FIGURE 3.—Sampling grid of area B. Numbers adjacent to sample localities (dots) indicate depth, in inches, to lowest soil sample. Geochemical maps for As, Cu, Hg, Pb, and Sb in the C horizon are shown on plate 3.

elements are low. Arsenic in the C horizon ranges from 40 to 600 ppm, two to 30 times the amount found in bedrock samples of the quartz monzonite (samples 1 and 3, pl. 1; table 1) and in uncontaminated soils (1–10 ppm, Warren and others, 1964). On the northern east-west traverse line, the 80-ppm arsenic contour in the C horizon defines a zone approximately 500 feet wide. This zone splits into two south-trending prongs which continue to the south edge of the area sampled. The east ridge is the more prominent of the two. Although the mercury, antimony, copper, and lead content of the soils is low, the highest values for these metals fall generally within the area defined by the high arsenic values. Silver (not shown on pl. 3) was detected in all the C-horizon samples in the northern arsenic high defined by the 100 ppm arsenic contour. Gold was not detected in any samples from area B.

The distribution of iron, calcium, manganese, and the pathfinder elements in the A, B, and C horizons are shown in the form of histograms on plate 4. The histograms show, in general, that iron, calcium, manganese, arsenic, antimony, and copper contents increase with depth. Silver shows an inverse relation: it is detected in more A-horizon samples than B-horizon samples, and in more B-horizon samples than C-horizon samples. Lead does not show any systematic distribution with depth. Mercury is strongly con-

centrated in the A horizon and shows a slight increase in the C horizon relative to the B horizon. Warren, Delavault, and Barakso (1966) also have noted that soils in British Columbia having a high organic or clay content may be expected to contain significantly more mercury than the average for the whole soil profile. As is the case for area B and as will be shown in some of the profiles discussed later, mercury in A-horizon samples is five to 10 times more abundant than in C-horizon samples.

The high arsenic values in the soils are of interest, inasmuch as the altered quartz monzonite specimens, which macroscopically contain no metallic minerals, yielded 1,000 ppm arsenic (grab sample 12). The two samples with visible arsenopyrite yielded 6.2 and 8.0 ppm gold. Thus arsenic may be a good pathfinder for gold, and the patterns shown on plate 3 may reflect a suboutcropping vein. Other areas in the quartz monzonite may also have a high arsenic content, as suggested by five spring sediment samples collected a few hundred feet north of the gold placer working on Encio Gulch (pl. 1). These samples contained 700–1,500 ppm arsenic, although the metal content for the other pathfinder elements in these samples was within normal background values.

Owing to the spread of high mercury values (pl. 4), no background value is assigned to this element in A-horizon soils. The background values for silver, copper, lead, and antimony in the soils are close to values for unmineralized quartz monzonite. Soils in this area appear to have an anomalously high arsenic content; background values are twice as high as the values for arsenic in uncontaminated soils overlying quartz monzonite. Both arsenic and mercury show a twofold and tenfold increase respectively when compared with bedrock values for these elements in unmineralized quartz monzonite.

PROFILE C-C'

A 3,400-foot traverse was made across graywacke-argillite, quartz monzonite, and a small segment of the limestone (pls. 1, 5). Most of the samples were taken 3–5 inches above bedrock at intervals of approximately 150 feet. The purpose of this traverse was to provide information for background values for quartz monzonite and the graywacke-argillite sequence and to determine if the limestone-quartz monzonite contact would be reflected by metal values in the overlying soil. Float from a few prospect pits (not shown on pl. 1) at the east end of the traverse near the contact of limestone and the intrusive body show minor copper staining, but

elsewhere along the traverse there is no evidence of bedrock metal-
lization.

With the exception of a high mercury value of 1 ppm 850 feet from the west end of the profile, the metal values for the path-
finder elements over the argillite and graywacke are low and probably represent background values. The sample at the west end of the profile was taken at a depth of 4 inches and consisted of dark organic soil. The high mercury content of this sample (1 ppm) probably reflects biochemical concentration of this element. Iron, calcium, manganese, arsenic, and copper values are slightly higher in soils overlying quartz monzonite than in soils overlying argillite and graywacke. Iron and manganese show a sharp increase in soils as compared with bedrock values (table 1). The limestone-quartz monzonite contact is reflected by a downslope increase in arsenic, antimony, copper, lead, and mercury. Suggested back-
ground values, which are similar to those for area A, for the path-
finder elements along this profile are given below. For comparison, the bedrock values are included.

	Ag	As	Cu	Hg	Pb	Sb
C-horizon soils over argillite and graywacke ...	0.5	20	50	0.3(?)	30	3
Bedrock ¹	<0.5	80	7-50	.9-1.5	<10	6-10
C-horizon soils over quartz monzonite .....	.5	30	70	.3(?)	50	3
Bedrock ²	<.5	<10-80	10-30	.09-.12	10	1-3

¹ Samples 7, 8, and 9, table 1.

² Samples 2 and 4, table 1.

PROFILE D-D'

The D-D' traverse was made north to south across a limestone roof pendant (pls. 1, 5). Samples were taken at the maximum possible depth at intervals of 150 feet. Limestone cut by altered feldspar porphyry dikes and several prospect pits showing minor copper staining are present along the traverse line.

Inasmuch as most of the lode gold deposits are found in limestone adjacent to the quartz monzonite contact, local high metal values might be expected along this profile. However, with the exception of the high antimony, copper, and lead values which reflect the limestone-quartz monzonite contact at the north end of the traverse, none of the metals appears anomalously high when compared with metal values in area A (pl. 2). Bedrock was not reached in the two samples at the north end of the profile. That the soil at these two locations is rich in humic material to a depth of at least 30 inches probably accounts for the high mercury values for these samples.

Samples were not taken near the glory hole because of expected contamination and lack of soil near the mine workings. Samples along the ridge on either side of the glory hole do not, however, have anomalous concentrations of any of the pathfinder elements. This suggests that any "halo" present in the soils around the glory hole is quite small and that downslope creep is the most likely cause of the anomalous train of metal values near the glory hole in area A (pl. 2).

PROFILE E-E'

Metal values for samples taken at 150-foot intervals along a 2,850-foot traverse that crosses the limestone-intrusive contact are shown on plate 5. The traverse is along a claim line and downslope from several small lodes (pl. 1).

Regional threshold values for the profiles are suggested by the samples 300–600 feet from the west and east ends of the traverse. The local threshold values, shown by the curves for iron, manganese, arsenic, antimony, copper, and lead along the central part of the profile, correspond to a zone of mineralization in the limestone west of the intrusive (pl. 1). High gold, lead, copper, antimony, and arsenic values downslope from the Highgrade shaft probably represent creep from this lode, inasmuch as placer gold has been mined from Crystal Gulch (Brown, 1926, p. 138). Other peak values probably represent creep from the lodes farther upslope (pl. 1) or may possibly represent contamination from the ore haulage roads. However, considering the depth of the deepest samples and the fact that A-horizon samples show lower metal values than C-horizon samples, the latter possibility seems somewhat remote. If the metal values found in the eastern part of the local threshold represent creep from the Garnet and Inclined shafts (pl. 1), then soil sampling is effective in detecting anomalous concentrations of metals at least 700 feet downslope from their source.

The single high lead (500 ppm) and mercury (3.5 ppm) peaks at the east end of the traverse remain unexplained. They are not sympathetically related to other pathfinder elements. High lead values in C-horizon samples are generally reflected by high values in the A horizon. This is not the case for the 500 ppm lead from the C horizon, and thus the value may be erratic. It is also noteworthy that A-horizon samples for mercury show a twofold to tenfold increase in metal content relative to the C horizon, but neither horizon reflects the local threshold so well shown by the other indicator elements. This spread in mercury content in the

A and C horizons is noticeably reduced, however, in the four samples at the west end of the profile, which show a decrease in iron and manganese content and an increase in calcium.

With the exception of mercury, the A-horizon samples reflect, in a general way, the metal content more emphatically shown in C-horizon samples. The metal content of soils of intermediate depth are essentially the same as those taken 2–4 inches above bedrock. Although silver was not detected in any samples of this traverse, sampling the A horizon for copper, antimony, arsenic, and lead would have been as effective in locating the anomalous metal concentrations as would sampling the C-horizon soils.

PROFILE F-F'

The 4,600-foot F-F' traverse was made along a claim line 1,500 feet northeast of and parallel to profile E-E'. Samples were taken at 150-foot intervals; the profile curves are shown on plate 5. The purpose of this traverse was to establish background information on the distribution of metals in soils overlying limestone.

The curves show low background values for all the pathfinder elements. Separate peaks rise sharply, however, above the regional threshold. Approximately 1,500 feet from the east end of the profile, high values of antimony (30 ppm), lead (200 ppm), and silver (1 ppm) and higher than background values for copper and arsenic may reflect metallization associated with the limestone-intrusive contact or perhaps soil creep from the lode at the Crystal shaft (pl. 1). The source of the metals for the two sets of peaks near the center of the profiles, one represented by arsenic (80 ppm), copper (500 ppm), and mercury (1.8 ppm) and the other by arsenic (80 ppm) and antimony (20 ppm), is not known. Peaks for manganese reflect rather well the anomalous values for the indicator elements. Silver values are low (0.5–0.7 ppm), but are present where peak values for the indicator elements occur.

The last six samples at the east end of the profile are very high in organic material, a fact which again appears to be reflected in the high mercury values. Mercury values for A-horizon soils in this traverse do not, however, show as strong an enrichment compared with C-horizon samples as do the previously discussed soils. Possibly this is characteristic of soils overlying limestone, as a similar trend was noted in the limestone at the west end of profile E-E'.

Suggested background values, in parts per million, for the pathfinder elements in C-horizon soils overlying limestone are given as follows:

	Ag	As	Cu	Pb	Sb
C-horizon soils over limestone	0.5	20	20	30	5

PROFILE G-G'

Soil samples were taken at 150-foot intervals for 1,500 feet along a claim line that crosses quartz monzonite and a narrow septum of limestone (pls. 1, 5). An area stripped of soil is present where the traverse line crosses the limestone. Copper staining is present in some float from this area.

Two C-horizon samples contain high arsenic and antimony values; otherwise metal values for this profile are within background values found in soils overlying quartz monzonite in area B and profile C-C' (see respective tabulations). The high antimony and arsenic content in the two C-horizon samples is not reflected in the A-horizon samples and are unlike samples taken at similar depths in profile E-E' (pl. 5), where high arsenic and antimony are found in both horizons.

Silver and gold are present in both the A and C horizons on either side of the stripped area. Possibly contamination from old mine workings is responsible for the 0.6 ppm gold in the A horizon, but the gold and silver content in the C horizon immediately down-slope from the limestone contact probably reflects enrichment of these metals near the contact.

SUMMARY AND CONCLUSIONS

Gold lodes in the Nixon Fork area occur as small, but locally rich, contact metamorphic deposits in limestone, generally within a few hundred feet of the quartz monzonite contact. Although bed-rock is extensively covered by overburden, the soil is generally less than 3 feet deep. Geochemical anomalies in near-surface soil are genetically related to the gold lodes, and their detection by geochemical prospecting is an efficient way of exploring for suboutcropping lodes. The most effective pathfinder elements in detecting gold lodes are copper, lead, arsenic, antimony, and silver. Suggested background values, in parts per million, for these elements in the C horizon overlying various rock types are summarized below:

	Ag	As	Cu	Pb	Sb
C-horizon overlying—					
quartz monzonite	0.5	20-30	50	50	4-5
limestone .....	.5	20	20	30	5
graywacke-argillite .....	.5	20	50	30	3

Gold is present in the deepest soil horizon for distances of at least 400 feet downslope from some lodes. The normal gold content of the soils is below the limit of detection (0.02 ppm). The erratic distribution of gold in the soils due to its particulate nature makes difficult the assignment of anomalous value for the metal. Consistent values of 0.05 ppm or greater are, however, probably anomalous and should prompt investigation of the source.

Mercury exhibits strong enrichment in the A horizon. Its values are about 10 times higher than background values for mercury in C-horizon soils of other base- and precious-metal deposits.

Silver also shows enrichment in the A-horizon soils, and anomalies in this horizon may have a greater contrast than those in the deeper horizon. Silver was not detected in most of the samples, as the spectrographic limit of detectability (0.5 ppm) falls at the upper limit for the background silver content in soils (Boyle, 1968).

The poor spectrographic sensitivity for zinc (200 ppm) makes it difficult to study its usefulness as a pathfinder. Zinc was not detected in soil samples containing as much as 1,500 ppm Cu, 150 ppm Pb, 40 ppm As, and 40 ppm Sb, and thus probably it is of rather low abundance in the lode deposits (for example, area B) or has been widely dispersed by ground water. Zinc, therefore, does not appear to be a suitable indicator element in this area.

Molybdenum does not seem to be a good indicator element in these soils, for it is present (up to 7 ppm) in only a few samples and is not systematically related to any of the mineralization.

The geochemical soil anomalies for all the pathfinder elements except silver are strongest in the deeper soil horizons. Anomalies in the deepest samples are, however, also generally reflected in the A horizon. Thus, sampling of the A horizon would be an effective method for reconnaissance geochemical prospecting in this area. Advantages of A-horizon sampling are as follows: The sampling can be done easily; silver is concentrated in this horizon; and copper and lead are effective indicator elements for this horizon. Caution should be used, however, in interpreting results, since this horizon is subject to contamination by surface agents. Anomalous values should be checked by sampling deeper soil horizons if surface contamination is suspected.

The shape of the soil anomalies is influenced by the topographic control of soil creep. Soils 100 feet from the glory hole along the crest of the ridge are low in metal content, but anomalous metal is found in soils as far as 400 feet downslope from the lode. Because the gold lodes in the Nixon Fork area are characteristically

small, sampling intervals along ridges should be fairly short, about 50–75 feet, and intervals on slopes should probably not be greater than 150 feet. Anomalous values should be checked by a grid of samples on 50-foot centers.

Initially, reconnaissance soil sampling for gold lodes in the Nixon Fork mines area should be carried out in the limestone within a few hundred feet of the limestone-quartz monzonite contact. Recently published aeromagnetic maps (Anderson and others, 1969) for an area lying between Nixon Fork and the North Fork of the Kuskokwim River (pl. 1) indicate the presence of other concealed plutonic rocks that probably cut limestone at relatively shallow depths. Soil sampling could determine if these limestone-intrusive contacts are metallized. As well as providing a basis for geochemical soil surveys in the Nixon Fork mines area, this study may also provide guidelines for similar reconnaissance surveys in other mining districts in south-central Alaska that are characterized by a paucity of bedrock exposures.

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