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A Columbium-Bearing Regolith on Upper Idaho Gulch, Near Tofty, AK

By J. Dean Warner, C. L. Mardock, and D. C. Dahlin

UNITED STATES DEPARTMENT OF THE INTERIOR

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PREFACE

This is one of a series of Bureau of Mines reports that present the findings of reconnaissance-type mineral assessments of certain lands in Alaska. These reports include data developed by both industry and government studies.

Assessing an area for its potential for buried mineral deposits is a difficult task because no two deposits are identical. Moreover, judgments prior to drilling, the ultimate test, frequently vary among evaluators and continue to change as a result of more detailed studies.

Included in these reports are estimates of the relative favorability for discovering mineral deposits similar to those mined elsewhere. Favorability is estimated by evaluation of outcrops, and analyses of data, including mineralogy, geochemistry, and evaluation of rock-forming processes that have taken place. Related prospects and the environment in which they occur are subjectively compared to mineral deposits and environments in well-known mining districts. Recognition of a characteristic environment allows not only the delineation of a trend but also a rough estimate of the favorability of conditions in the trend for the formation of minable concentrations of mineral materials.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	lb	pound
cps	count per second	min	minute
ft	foot	mm	millimeter
ft^2	square foot	pct	percent
ft^3	cubic foot	ppm	part per million
ft^3/st	cubic foot per short ton	s	second
G	gauss	st	short ton
g	gram	wt pct	weight percent
in	inch	yr	year

A COLUMBIUM-BEARING REGOLITH ON UPPER IDAHO GULCH, NEAR TOFTY, AK

By J. Dean Warner,[1] C. L. Mardock,[2] and D. C. Dahlin[3]

ABSTRACT

In 1984, as part of a project to evaluate Alaskan occurrences of certain critical and strategic minerals, the Bureau of Mines investigated a columbium-bearing regolith on upper Idaho Gulch, near Tofty, AK. The regolith is derived from weathering of a dolomitic marble and consists mostly of iron oxide minerals with accessory apatite, zircon, xenotime, rutile, monazite, and the columbium minerals aeschynite, columbite, and ilmenorutile. Two regolith lenses contain 340,000 lb of columbium resources at an average grade of 0.07 pct. Calculated composite concentrates from two regolith samples (approximately 200 lb each) contained 53 and 57 pct of the columbium at grades of 0.97 and 0.86 pct, respectively. In each case the grade could be improved to 1.1 pct Cb with a sacrifice of 9-pct recovery.

The regolith's mineralogy, trace-element geochemistry, and similarity to descriptions of other columbium-enriched regoliths suggest that the underlying marble may be a carbonatite. The lack of associated alkalic igneous rocks and the stratiform nature of the regolith, however, may be interpreted as evidence for sedimentary origin of the marble. The marble and regolith are a lode source for some of the minerals in the Idaho Gulch placer deposit.

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INTRODUCTION

In 1984, the Bureau of Mines investigated a columbium-bearing regolith on upper Idaho Gulch, near Tofty, Hot Springs mining district, Alaska. The regolith is a residual weathering product of marble. It was originally identified in 1956 by the Bureau as a result of investigations to locate lode sources of tin, columbium, tantalum, chromium, and radioactive minerals found in placer gold deposits of the Tofty area. Approximately 12,000 ft of trenching, comprising 40 trenches, and 1,400 ft of diamond drilling were completed in the headwaters of Idaho Gulch at that time. The results of this early study, which were not published, indicated trace amounts of columbium and tantalum were present, but concluded that the regolith was not a lode source for heavy minerals found in placer deposits of the area.

Conversely, the 1984 investigation indicates that uniformly low-grade concentrations and minor resources of columbium but no tantalum are present in the regolith. The regolith may represent residue overlying a carbonatite and is a likely lode source for some of the heavy minerals occurring in the placer deposit on Idaho Gulch.

This investigation was conducted as part of a Bureau project to assess Alaskan reserves or resources of certain critical and strategic minerals, including those containing columbium (*1*).[4] The United States relies entirely on foreign sources of columbium, which is used mainly in heat- and corrosion-resistant alloys by the metallurgical and aerospace industries (*2*). The resources identified in this report represent approximately 6 pct of the United States annual demand for primary columbium (*2*).

[4]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

ACKNOWLEDGMENTS

Although this report primarily presents results of recent investigations, it also incorporates and relies heavily on unpublished data generated by the 1956 Bureau investigation in the Idaho Gulch area conducted by R. P. Maloney (deceased) and B. I. Thomas (retired), mining engineers with the Bureau of Mines. The report also benefited from discussions with D. M. Hopkins and R. M. Chapman, geologists with the U.S. Geological Survey, concerning the regional geology of the Tofty area. Discussion with D. T. Smith, geologist with the Alaska Division of Geological and Geophysical Surveys, helped clarify ideas about carbonatites. Field work was assisted by D. D. Southworth, graduate student, University of Alaska, Fairbanks, and by J. Y. Foley, physical scientist, Bureau of Mines, Fairbanks, AK. The logistical assistance of Robert Burgess, a placer miner at Tofty, is gratefully acknowledged.

LOCATION AND ACCESSBILITY

Tofty is located 95 miles west-northwest of Fairbanks, AK, about 15 miles northwest of the village of Manley Hot Springs, from which it is easily reached by gravel road (fig. 1). Manley Hot Springs is accessible by road or air throughout the year from Fairbanks and by river barge during the summer months from the railroad center at Nenana. The area investigated is located about 1.5 miles west of Tofty at the 800-ft elevation in Idaho Gulch. This area lies on the U.S. Geological Survey Tanana A-2 quadrangle (1:63,360 scale).

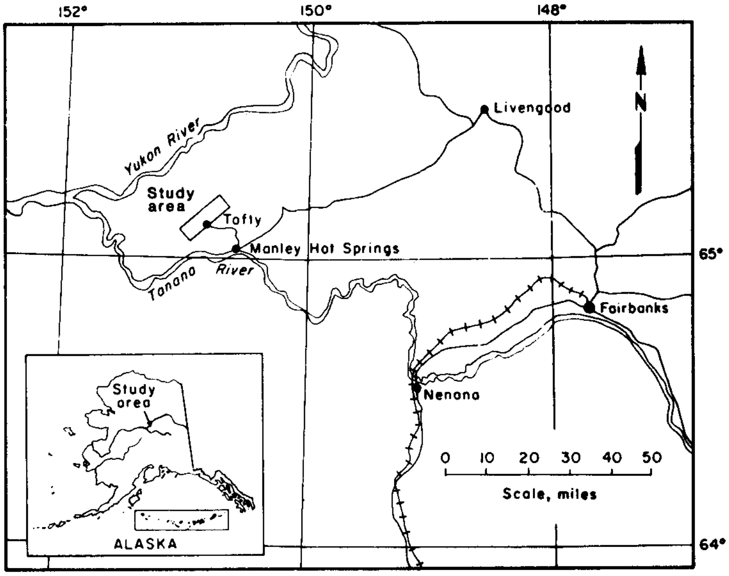

Figure 1.—Location of study area.

PHYSIOGRAPHY

Tofty is located in the southwestern portion of the Yukon-Tanana upland physiographic division (*3*), near the confluence of the Yukon and Tanana Rivers. The terrain around Tofty is extremely subdued, characterized by gently sloping, northeast-trending hills, occasional subcircular rounded mountain tops, and broad asymmetric valleys (fig. 2). This area is entirely blanketed by vegetation and a thick mantle of perennially frozen loess covers all the valleys and lower portions of the hills.

Figure 2.—Aerial view of Idaho Gulch showing trenches.

LAND STATUS

The Tofty area lies on Federal lands administered by the Bureau of Land Manaagement and is open to mineral entry. Ninety-five unpatented Federal placer mining claims cover most of the lower portions of the creeks near Tofty. The area investigated, however, was not claimed at the time of the investigation (August 1984).

PREVIOUS INVESTIGATIONS

Shortly after the discovery of gold in 1907, cassiterite (SnO_2) was identified in placer concentrates from the Tofty area (*4-6*). Placer deposits containing cassiterite were found to lie within a northeast-trending belt, extending between Woodchopper Creek, to the southwest, and Cooney Creek, to the northeast, that informally became known as the Tofty tin belt (fig. 3). Subsequent studies of the tin-bearing placer deposits, spurred on by World War II and postwar tensions, were performed by Thorne and Wright (*7*), Wayland (*8*), Thomas and Herdlick,[5] and Thomas (*9*). No lode source of cassiterite has ever been reported.

Columbium and rare-earth-element minerals have also been identified in placer concentrates from the Tofty tin belt. In 1934, Waters (*10*) identified the columbium mineral aeschynite [$(Ce,Ca,Fe,Th)(Ti,Cb)_2(O,OH)_6$], as well as zircon, pyrite, magnetite, ilmenite, monazite, xenotime, apatite, anatase, tourmaline, and barite in concentrate samples from placer mines on Deep Creek, Sullivan Creek, and Cache Creek. The identification of these minerals was confirmed by Moxham, in 1954, who also identified two previously unreported minerals, ellsworthite [uranpyrochlore $(U,Ca,Ce)_2(Cb,Ta)_2O_6(OH,F)$] and columbite [$(Fe,Mn)(Cb,Ta)_2O_6$] (*11*). Moxham found the greatest concentrations of the three columbium minerals and zircon and monazite in concentrates from placers on Idaho, Miller, and Harter Gulches. In 1955, The Bureau[6] confirmed Moxham's and reconfirmed Water's mineral identifications. The 1955 investigation also found from 0.2 to 7.0 pct Cb_2O_5 in concentrates from test pits in tailings and from 0.15 to 1.8 pct Cb_2O_5, as well as 0.6 to 0.25 pct CeO_2, anomalous concentrations of lanthanum, and trace concentrations of yttrium in concentrates from churn drill holes on Miller and Idaho Gulches.

[5]Preliminary investigations of tin and radioactive minerals in gold placer deposits near Tofty, Yukon River Region, Alaska (BM-4606-1, 1955), performed by the Bureau of Mines for the U.S. Atomic Energy Commission.

[6]Work cited in footnote 5.

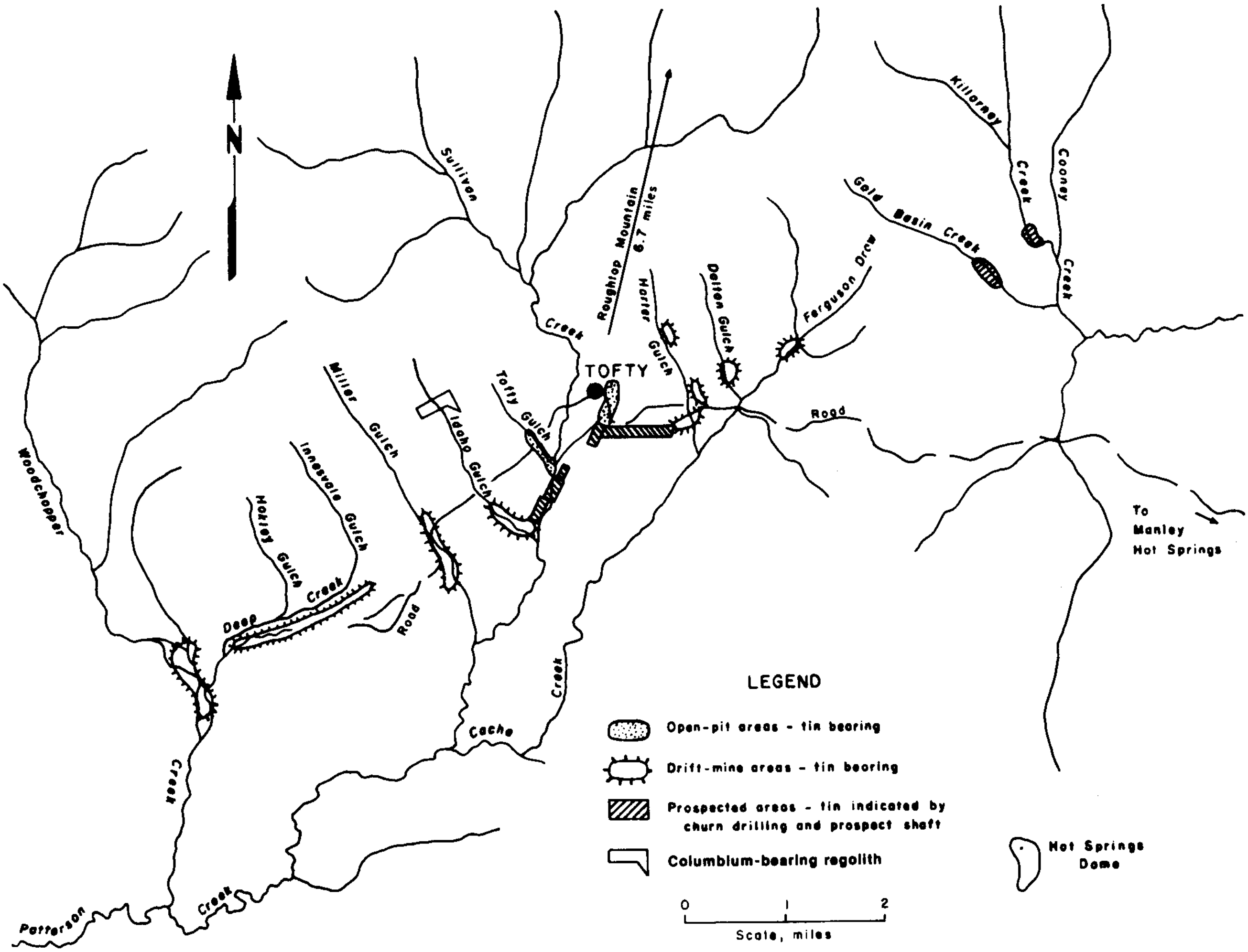

Figure 3.—Tofty tin belt, Alaska.

In 1956, the Bureau, in an attempt to locate lode sources of the placer minerals, trenched on upper Idaho Gulch and identified two bodies of radioactive ferruginous regolith (figs. 2-3). Subsequent detailed sampling and diamond drilling defined two northwest-dipping, northeast-striking lenses of material containing trace amounts of columbium, phosphorus, and zirconium, among other metals, but no uranium, which was the principal interest of its study. The results of the lode investigations on Idaho Gulch were never published, but are partially incorporated in this report.

In 1984, as part of a current Bureau project to investigate critical and strategic minerals in Alaska, Southworth (*12*) reanalyzed concentrates from channel samples of tailings collected in 1956 by Thomas, for columbium. Southworth found that most samples contained between 0.2 pct and 4.5 pct Cb with higher values generally in gravels from the vicinity of Deep Creek, Miller Gulch, and Idaho Gulch. Using placer reserve figures from Thomas (*9*) and Wayland (*8*), Southworth calculated an inferred reserve of 100,000 lb Cb_2O_5 within the Tofty placer deposits.

BEDROCK GEOLOGY OF THE TOFTY AREA

Bedrock outcrops in the Tofty area are rare; most geologic observations have been limited to now-inaccessible drift-mine exposures and sparse road cuts or inferred from placer cobble lithologies. In general, however, much of the area is underlain by a succession of graywacke, quartzite, siltstone, shale, slate, slaty argillite, and polymictic comglomerate that has been interpreted as being a portion of a Mesozoic-age flysch basin that extends approximately 150 miles northeastward from the Tanana River to north of Livengood (*13-16*). These rocks exhibit local low grade (zeolite facies) metamorphism and severe deformation (*17*). Roadcut and trench exposures near Tofty and on Idaho Gulch show that bedding strikes east-northeast and dips moderately to steeply northwest; however, small hand-specimen to outcrop scale isoclinal folds are locally common.

Minor amounts of serpentinized and chloritized ultramafic and mafic rock with locally associated graphitic slaty to schistose rock are exposed along the northwest margin of the flysch basin (*13*). These rocks may have either been tectonically emplaced or partially intruded within the basal flysch unit. Alternatively, some of the ultramafic, mafic, and metasedimentary rocks may underlie the flysch and be exposed in erosional windows.

Magnetite-apatite bearing limestone, similar to that identified on upper Idaho Gulch in this report, is described by Wayland on Harter Gulch (*8*). The relationship of this rock to other units is unknown; carbonate rocks are not reported elsewhere within the flysch belt.

The Mesozoic flysch is cut by two intrusions in the Tofty area. A biotite granite pluton with local felsic segregations and associated tourmaline crops out on Hot Springs Dome, southeast of Tofty, and a monzonite and quartz-monozonite composite pluton crops out on Roughtop Mountain, northeast of Tofty (fig. 3). The intrusion on Roughtop Mountain shows a Late Cretaceous radiometric age of 92 ± 10 million yr, the intrusion on Hot Springs Dome has an early Tertiary radiometric are of 62 ± 3 million yr (*13*).

NATURE AND EXTENT OF PRESENT INVESTIGATIONS

During this investigation, data from nine trenches and nine diamond drill holes compiled by the Bureau in 1956 were reevaluated. The reevaluation comprised reanalyses of available samples, selective reexcavation of the trenches, and relogging of available core. Information resulting from the 1956 investigation is presented and acknowledged where appropriate. Figure 4 shows locations of trenches and drill holes and mapped extent of the regolith. Modified 1956 drill logs and geologic cross sections constructed from drill data are presented in appendix A.

Additional methods used during this study include selective sampling of the 1956 trenches; optical, radiometric, scanning electron microscope (SEM), microprobe, and X-ray diffraction (XRD) studies of mineral compositions; and magnetic, radiometric, and soil sampling surveys over a 500- by 1,900-ft grid area (outlined on figure 4).

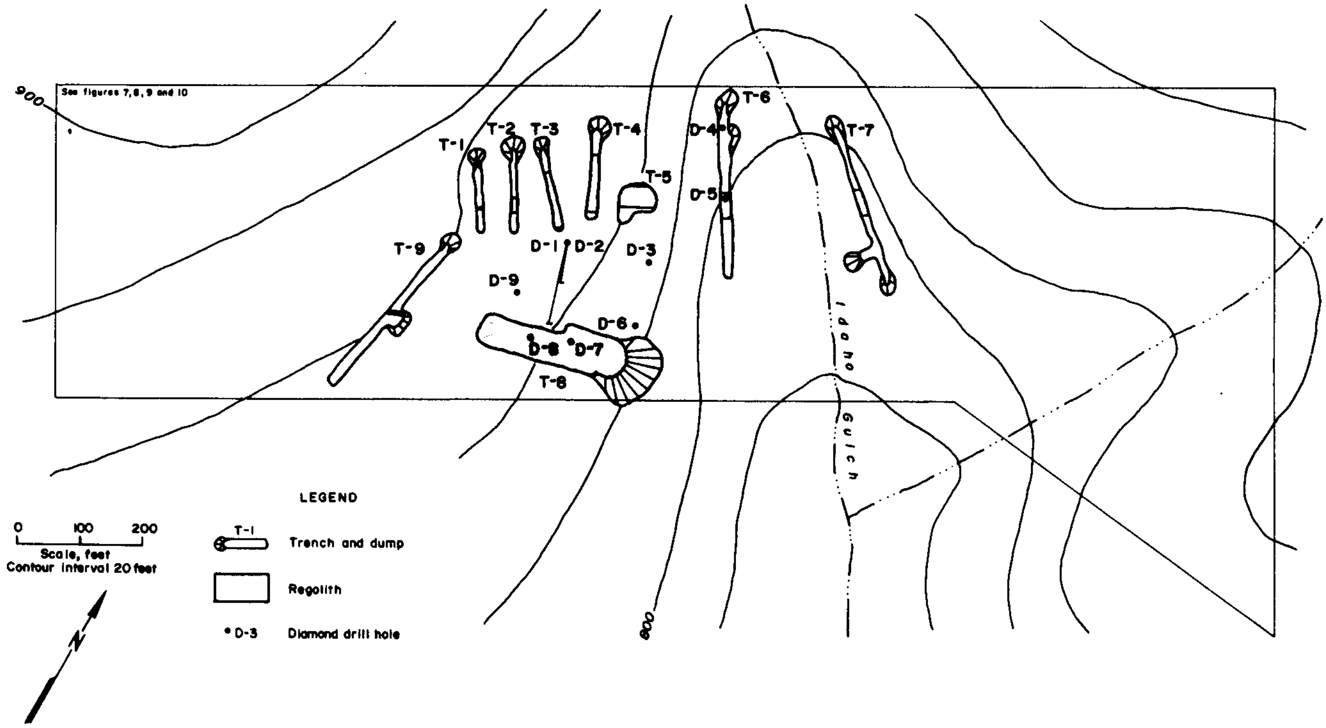

Figure 4.—Locations of trenches and drill holes and mapped extent of the regolith.

GEOLOGY OF THE REGOLITH

Two bodies of iron-rich regolith were identified on upper Idaho Gulch by Bureau trenching in 1956. Subsequent drilling indicated the regolith forms conformable lenses within the N 60° E trending wallrock units. The lenses grade downward into, and apparently have been derived by chemical weathering of dolomitic marble (figs. A-1—A-6). In plan view, both lenses are irregular in shape, varying in thickness from 3 to 80 ft. The northwestern lens is partially exposed by trenching over a strike length of 620 ft and dips approximately 50° to the northwest (fig. A-6). The southeastern lens is partially exposed over about 350 ft of strike length and dips between 40° and 50° northwest (figs. A-1—A-4). In 1956, both lenses were mapped as pinching out to the southwest, but open ended to the northeast (fig. 4).

Cross sections in figures A-1 through A-5 show that the southeastern regolith lens ranges in thickness from 17 to 28 ft, averaging 23 ft at trench T-8, and persists downdip for between 100 and 250 ft. The regolith, where intersected approximately 100 ft downdip in drill holes D-9, D-1, and D-6, has true thicknesses of 12, 16, and 23 ft, respectively. The increase in drill-intersected thicknesses suggests that the southeastern regolith lens may be thicker and extend deeper northeast of the trenches and diamond drill holes.

The northwestern regolith lens is approximately 31 ft thick at trench T-6 but is of unknown thickness at distances less than 200 ft downdip (fig. A-6). Where intersected at 200 ft downdip in drill hole D-3, the northwestern regolith lens consists of thin, discontinuous zones in dolomitic marble.

The footwall of the regolith grades into marble at distances of as little as 50 ft downdip in some drill holes; the regolith is generally absent at distances greater than 200 ft downdip (figs. A-3 and A-6). Because both the hanging wall and footwall were only observed in drill hole D-3, the attitude and shape of the marble body is unknown.

The marble consists of coarse, granular ankeritic (composition determined by XRD analysis) dolomite and calcite with up to 10 pct disseminated and banded rounded magnetite and euhdral to rounded pyrite grains and up to 5 pct disseminated rounded apatite crystals. In this rock, pyrite commonly replaces magnetite. Minor amounts of biotite, some of which is partially replaced by chlorite, are also present and a trace amount of zircon occurs.

Drilling and trenching indicate the regolith and marble occur within a succession of probable intermediate grade (greenschist facies) metasedimentary and metaigneous(?) rocks consisting of variable amounts of quartz, muscovite, sericite, chlorite, and graphite and locally minor amounts of talc, serpentine, dolomite, calcite, magnetite, or pyrite. Lack of outcrop and poor core recovery from drilling preclude detailed correlations between the various rock types. In general, however, the footwalls and lower few feet of the hanging walls of both regolith lenses consist of calcareous chlorite-sericite ± talc ± quartz phyllite and schist and the section of hanging wall beginning a few feet above each lens consists of siliceous muscovite-graphite schist (cross sections A-2, A-3, and A-5 through A-7, appendix A). The footwall of the regolith lens in drill hole D-7 consists of a nonfoliated chlorite-sericite-quartz rock that may represent a metamorphosed mafic igneous rock.

MINERALOGY AND PETROGRAPHY OF THE REGOLITH

Most of the regolith consists of a moderate amount of pebble- to cobble-size rock fragments in a dark chocolate brown to brownish orange earthy matrix composed largely of sooty and specular hematite, exotic limonite, small fragments of limonitic boxworks after pyrite, goethite, and hematitic magnetite.

The most common rock type consists of a dark red spongelike matrix of siliceous hematite with up to 40 pct rounded to angular 0.5- to 2-mm apatite grains and trace amounts of euhedral zircon crystals. Cross-cutting veinlets of goethite and chalcedony and patches of limonitic boxworks after pyrite are also common. This hematite-rich rock grades into a less common, more siliceous rock consisting of up to 40 pct euhedral to broken subhedral and finer rounded apatite and irregularly shaped hematitic magnetite grains with minor euhedral to angular zircon crystals or fragments in a matrix of iron-stained finely crystalline quartz. Rounded grains of carbonate, chert, and chlorite schist (?) also occur as inclusions in this rock.

Other rocks found in the regolith include massive vuggy goethite and yellowish-orange porous limonite within which are rounded fragments of kaolinitized phyllite(?) and veinlets of goethite, hematite, quartz, chalcedony, carbonate, and apatite.

Near its wallrock contacts, the regolith is more yellow-orange in color and is composed mostly of limonitic clay. Secondary(?) apatite occurs as bluish gray to white botryoidal masses along fractures in fragments of earthy, porous limonite in these areas. An apple-green clay containing a chromiferous member of the montmorillonite-beidellite series and possible traces of anatase[7] is associated with limonitic kaolinite in the footwall of the southeastern regolith lens in trench T-8.

Geochemical, radiometric, optical microscope, microprobe, and SEM examination of the minus 20-mesh fraction of concentrates panned from regolith samples[8] indicate the regolith also contains trace to minor amounts of apatite, zircon, monazite, xenotime, brewsterite(?), columbium-bearing rutile, which may locally alter to ilmenorutile, and the columbium minerals aeschynite and columbite. Results of analyses of concentrate samples are presented in table 1, and ranges of mineral content in samples are listed in table 2. Apatite occurs as fine bluish-white grains with a composition (determined by XRD analysis) intermediate between the hydroxyl

[7]Identification of anatase and clay minerals in 1956 by H. D. Hess, formerly of the Bureau of Mines, Albany, OR.

[8]A test procedure for characterization of the Tofty regolith concentrates is described in appendix B.

Table 1.—Results of analyses[1] of samples of pan-concentrated regolith, parts per million

Sample[2]	Cb	Sn	Ta	Ce	La	Nd	Y	Description
5	5,700	<50	<100	1,000	400	<500	<10	Heaping pan reduced to 10.6 g.
9	9,000	<50	100	1,000	400	<500	20	Heaping pan reduced to 29.4 g.
15	100	<50	<100	ND	ND	ND	<10	Heaping pan reduced to 20.4 g.
30	300	<50	<100	ND	200	ND	ND	2 heaping pans reduced to 34.7 g.

ND Not detected.

[1]Cb, Sn, and Ta analyses by X-ray fluorescence; Ce, La, Nd, and Y analyses by emission spectrography (other rare-earth elements not detected). Analyses by the Bureau's Reno Research Center, Reno, NV.

[2]Samples are numbered clockwise starting with trench T-2. Gaps between sample numbers listed here correspond to samples listed in tables 3 and 4.

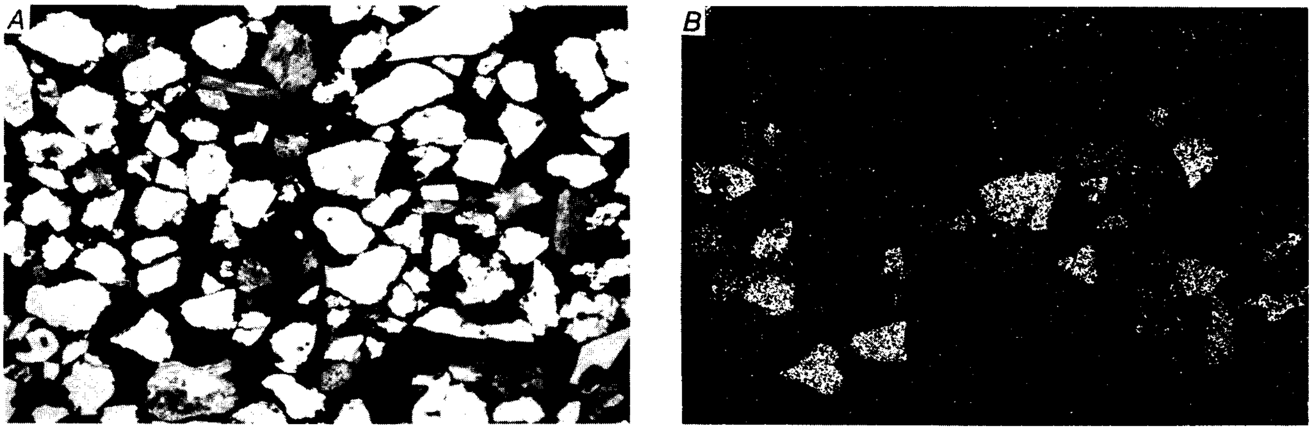

Figure 5.—Scanning electron microscope photomicrograph (*A*) and columbium X-ray scan (*B*) of columbium-rich portion of regolith concentrate.

Table 2.—Estimated ranges for mineral content in minus 20-mesh fraction of samples of pan-concentrated regolith,[1] weight percent

Mineral		Mineral	
Goethite	30-40	Feldspar	1-4
Quartz	11-16	Monazite	2-4
Aeschynite	7- 9	Columbite	2-4
Magnetite	8-10	Xenotime	Tr
Rutile (Cb-bearing)	4- 6	Brewsterite (?)	Tr
Zircon	6-15	Apatite	Tr
Fe-Mg silicates	1- 5	Rock fragments	Tr

Tr Trace.
[1]Samples 5, 9, 15, and 30.

($Ca_5(PO_4)_3OH$) and fluor ($Ca_5(PO_4)_3F$) endmembers of the apatite solid solution series. Although apatite is locally abundant in the regolith, its relatively low specific gravity makes it a rare constituent of the concentrates. Zircon occurs as 0.1- to 0.5-mm, clear euhedral and yellowish subhedral bipyramidal crystals or crystal fragments with poorly developed prism faces. Microanalysis indicates monazite to be of the high-cerium and high-lanthanum and low-yttrium and low-thorium variety and locally intergrown with columbite.

An SEM photomicrograph and columbium X-ray scan of the columbium-bearing portion of a regolith concentrate is shown in figure 5. Aeschynite occurs as dark reddish brown to black, approximately 0.1-mm angular, flattened prismatic orthorhombic crystals with a general composition, based on four analyses, of $(Ca_{0.25\text{-}0.53}\ Fe_{0.08\text{-}0.46}\ Ce_{0.04\text{-}0.27}\ Mn_{0\text{-}0.03}\ Ba_{0\text{-}0.08}\ Th_{0\text{-}0.14}\ Ag_{0\text{-}0.14})\ (Cb_{0.53\text{-}0.90}\ Ti_{0.10\text{-}0.47})_2O_6$. Aeschynite is the bright phase in figure 5*A* with the less intense columbium signals in figure 5*B*; a closeup of the aeschynite is shown in figure 6. Columbite is also a bright phase in figure 5*A*, but has the more intense columbite signals in figure 5*B*. The columbite is the high-iron, low-manganese variety and has a composition of $(Fe_{0.9}\ Mn_{0.09}\ Ca_{0.01})\ (Cb_{0.95}\ Ti_{0.05})_2O_6$.

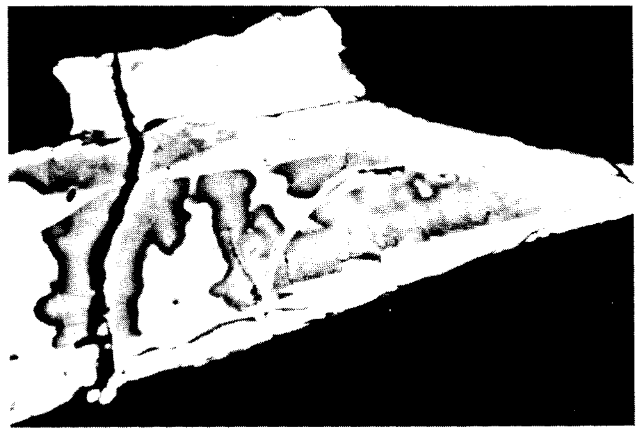

Figure 6.—Scanning electron microscope photomicrograph of broken aeschynite grain from regolith concentrate.

REGOLITH SAMPLING

METHODS AND RESULTS

In 1984, samples of regolith and specimens of rocks were collected from trenches on upper Idaho Gulch for geochemical analyses. The wider trenches, T-5 and T-8, were mapped and sampled in detail (figs. 7-8). Vegetation cover and sloughing of trench walls prevented detailed mapping and sampling of other trenches; only a few samples were collected from trenches T-2, T-3, and T-4 (fig. 9).

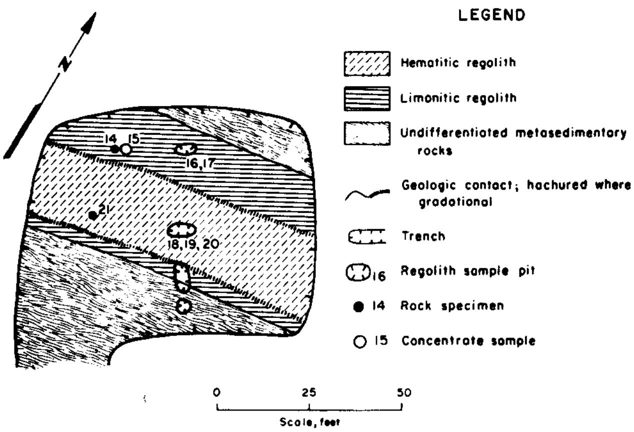

Figure 7.—Locations of samples collected in trench T-5.

Regolith samples were collected from 3- to 4-ft-deep pits (figs. 7-9). One pit was excavated in each of trenches T-2, T-3, and T-4 and a series of pits were dug in each of trenches T-5 and T-8. A vertical channel sample and a bottom sample were collected from each pit.

Regolith samples and rock specimens were crushed, split, pulverized, and analyzed by the Bureau's Reno (NV) Research Center. Regolith samples were analyzed for columbium, phosphate (P_2O_5), zirconium, and zinc by X-ray fluorescence (XRF), tin by atomic absorption (AA), and 42 elements plus rare-earth elements by emission spectrography. Results and methods of analyses are presented in tables 3 and 4 and appendix C. Owing to the sensitivity of the analytical techniques used, some variations exist among the results presented for some individual samples.

Samples of regolith collected from pits in trenches T-2, T-3, T-4, T-5, and T-8 contain <50 to 1,200 ppm Cb, 0.14 to 21.4 pct P_2O_5, <100 to 900 ppm Zr, 200 to 1,200 ppm Zn, and not detected to 900 ppm La (table 3). Low columbium values in samples from the pit in trench T-3 are likely not representative of regolith as their yellow-white color suggests that sloughed bank material was included in the samples.

Regolith samples also contain 0.07 to >6 pct Ba, 7 to >10 pct Fe, 0.3 to >10 pct Mn, 3 to 4,000 ppm Sr, 2,000 to 20,000 ppm Ti, 50 to 6,000 ppm Cr, and 100 to 3,000 ppm Ni (appendix C). Relatively higher values of columbium, phosphate, zirconium, lanthanum, and strontium are restricted to samples from pits excavated in the red-brown

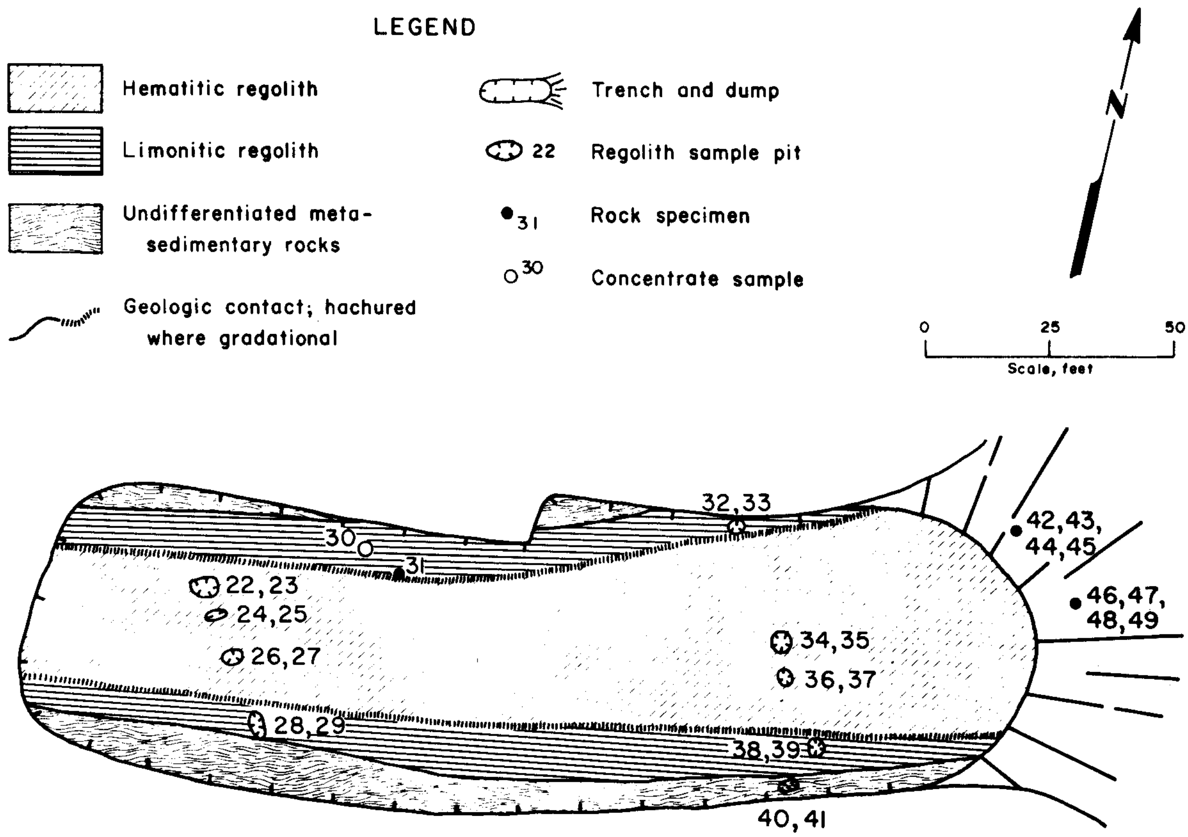

Figure 8.—Locations of samples collected in trench T-8.

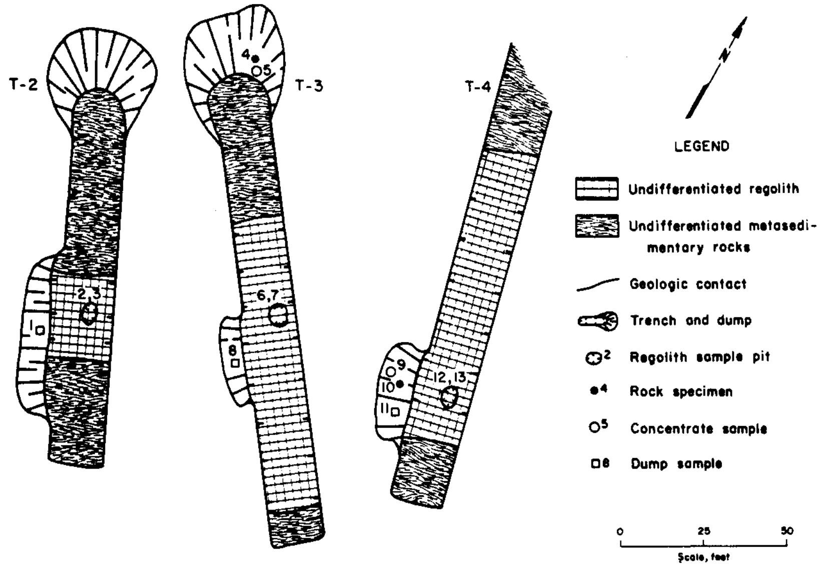

Figure 9.—Locations of samples collected in trenches T-2, T-3, and T-4.

Table 3.—Results of XRF analyses[1] of regolith samples, in parts per million except as noted

Sample	Cb	La[2]	P_2O_5[3]	Zr	Zn	Sample type and/or description
			TRENCH T-2			
1	<50	NA	0.19	300	NA	3-ft channel of dump, material is well mixed and silty.
2[4]	1,000	NA	1.95	800	NA	From bottom of pit, hematitic regolith.
3[4]	1,200	NA	2.03	800	NA	3.5-ft vertical channel in sample 2 pit.
			TRENCH T-3			
6[4]	72	NA	NA	NA	NA	From bottom of pit, includes sloughed bank material.
7[4]	<50	NA	NA	NA	NA	3-ft vertical channel in sample 6 pit.
8	<50	NA	0.14	300	NA	3-ft-long, 10-in-deep channel of dump.
			TRENCH T-4			
11	300	200	0.82	400	400	4.5-ft-long, 1-ft-deep channel of dump.
12[4]	600	400	11.7	700	600	From bottom of pit, hematitic regolith. Bulk sample A[5] collected from this pit.
13	500	200	7.3	900	300	3.5-ft vertical channel in sample 12 pit.
			TRENCH T-5			
16	<50	ND	0.17	<100	500	From bottom of pit, limonitic regolith.
17	<50	ND	.26	200	400	4-ft vertical channel in sample 16 pit.
18	1,000	900	7.1	900	300	From bottom of pit, hematitic regolith. Bulk sample B[6] collected from this pit.
19	700	400	.5	800	300	4-ft vertical channel in sample 18 pit.
20	100	ND	.8	300	300	Sample of clay from adjacent to footwall of limonitic regolith.
			TRENCH T-8			
22	300	ND	9.0	700	400	From bottom of pit, hematitic regolith.
23	400	ND	8.1	700	400	4-ft vertical channel in sample 22 pit.
24	500	ND	1.12	200	600	From bottom of pit, hematitic regolith.
25	700	200	1.68	400	500	3-ft vertical channel in sample 24 pit.
26	1,000	400	10.4	800	300	From bottom of pit, hematitic regolith.
27	700	200	10.4	700	400	3-ft vertical channel in sample 26 pit.
28	<50	NA	.26	300	200	1.5-ft channel of limonitic clay-rich regolith.
29	<50	NA	.94	<100	250	Composite of top 1 ft of sample 28 pit.
32	300	ND	.90	100	1,200	From bottom of pit, hematitic regolith.
33	400	40	2.60	500	900	3-ft vertical channel in sample 32 pit.
34	800	90	1.92	500	1,100	From bottom of pit, hematitic regolith.
35	900	90	1.79	700	1,100	3.5-ft vertical channel in sample 34 pit.
36	300	400	21.4	900	300	From bottom of pit, hematitic regolith.
37	300	200	20.4	900	300	2.5-ft vertical channel in sample 36 pit.
38	<50	ND	.79	200	200	From bottom of pit in graphite phyllite.
39	100	ND	1.47	200	300	Channel in limonitic clay-rich regolith above sample 38.
40	58	ND	.69	200	400	From bottom of pit.
41	100	ND	1.06	300	500	2.5-ft vertical channel in sample 40 pit.

NA Not analyzed ND Not detected.
[1]Performed by the Bureau's Reno Research Center, Reno. NV; Sn analyzed by AA, but not detected.
[2]No other rare-earth elements detected in samples, except sample 36 contains 40 ppm Y. Analyses by emission spectrography, Reno Research Center.
[3]Percent.
[4]Samples 2, 3, 6, 7, and 12 also contain 2.083, 2.445, 0.05, 0.06, and 0.107 ppm Au and 1.431, 1.528, 10.6, 4.0, and <0.3 ppm Ag, respectively. All other Au and Ag values at or below detection limit. Au and Ag determined by inductively coupled plasma analyses.
[5]Head analysis of 0.093 pct Cb.
[6]Head analysis of 0.120 Cb.

Table 4.—Results of analyses,[1] in parts per million, and descriptions of rock specimens

Sample	Cb	Sn	Ta	Au	Ag	Ce	La	Y	Description
4	<100	<50	<100	<0.007	<0.3	ND	ND	ND	10 pct rounded to angular apatite grains within matrix of siliceous iron oxides. Cut by chalcedony veinlets.
10	200	<50	<100	.016	.370	ND	ND	<10	Grab from dump. Mostly red-brown earthy hematite.
14	<100	<50	<100	<.007	<.3	ND	ND	<10	Orange, limonite-rich clay. Grab sample.
21	1,200	<50	<100	<.007	<.3	ND	400	20	Earthy, hematitic matrix cut by chalcedony veinlets. Representative of rocks in trench T-5.
31	200	<50	<100	<.007	<.3	ND	200	<10	4 pct rounded weathered apatite in a dark red earthy hematitic matrix cut by veinlets of goethite.
42	<100	<50	<100	<.007	<.3	ND	90	20	Dark, angular maroon-colored patches in a punky limonitic matrix. Disseminated magnetite blebs also present.
43	300	<50	<100	<.007	<.3	2,000	900	20	Rounded quartz grains in a weathered limonitic matrix. Cut by veinlets of quartz, carbonate, and secondary apatite.
44	200	<50	<100	<.007	<.3	ND	40	40	Dark-red to orange siliceous iron oxide matrix cut by some veinlets of drusy quartz.
45	700	<50	<100	NA	NA	ND	200	20	Blebs of limonite and magnetite in an iron-stained siliceous matrix.
46	400	<5	NA	0.007	0.3	<500	90	40	40 pct euhedral to angular subhedral and finer rounded apatite, irregular to rounded magnetite, and minor euhedral zircon in an iron-stained siliceous matrix.
47	200	<5	NA	<.007	<.3	<500	90	40	Rounded apatite and hematite-magnetite grains, minor angular zircon crystals, and rare fragments of chert or schist (?) in a matrix of coarse recrystallized quartz and iron oxides.
48	200	<5	NA	.020	.894	<500	200	40	Massive fine exotic limonite with rounded 3- to 7-mm fragments of clay after phyllite (?), cut by veinlets of goethite.
49	87	<5	NA	<.007	<.3	<500	ND	40	5 pct rounded apatite grains in a punky siliceous hematite matrix cut by veinlets of goethite.
50	<50	9.1	NA	<.007	<.3	<500	ND	40	Massive vuggy goethite.

NA Not analyzed. ND Not detected.
[1]Cb and Ta analyses by XRF; Sn by AA (5-ppm detection limit) or XRF (50-ppm detection limit); Au and Ag analyses by inductively coupled plasma analyses. Rare-earth analyses by emission spectrography—only Ce, La, and Y detected except sample 42 also contained 1,000 ppm Nd. Analyses by the Bureau's Reno Research Center, Reno, NV.

hematitic regolith whereas a small number of high values of zinc, titanium, barium, chromium, and nickel are present in samples collected from both the hematitic regolith and yellow-orange limonitic regolith.

Rock specimen sample locations are also shown in figures 7, 8, and 9. Because specimens were generally collected from float, analyses are interpreted to be representative only of the specimen and not the deposit grade. Ten of fourteen specimens contained between 200 and 1,200 ppm Cb with traces of cerium, lanthanum, yttrium, or silver; three samples contained traces of gold and one sample contained detectable concentrations of tin; no tantalum was detected (table 4). The highest columbium concentration (1,200 ppm) was found in a specimen of earthy hematite cut by chalcedony veinlets.

Results of analyses for columbium in channel samples collected in 1956 from trench T-8 are presented in table 5 and sample locations are shown in figure 10. The analyses are in good agreement with those from samples collected from pits in 1984 and generally range between 300 and 700 ppm Cb with one value of 200 ppm and one of 1,000 ppm.

Results of columbium analyses in 1956 of sludge samples of regolith from drill holes are presented in table 6. Similar to results of analyses of samples from trenches, between 0.01 and 0.10 pct Cb was detected in all samples.

Results of analyses of three composite samples of marble from drill hole D-4 are presented in table 7. Between 257 and 731 ppm Cb as well as elevated concentrations of phosphate, lanthanum, zirconium, and cerium are present in the samples. These columbium concentrations are very similar to those found in samples of regolith. Unfortunately, no other drill core containing marble is available for analyses.

Table 5.—Results of XRF analyses[1] for columbium in channel samples collected from trench T-8 in 1956

Sample	Cb, ppm	Channel length, ft	Sample	Cb, ppm	Channel length, ft
51	300	8.8	61[2]	700	6.3
52	600	9.5	62	400	7.3
53	400	7.0	63	300	10.4
54	300	9.3	64	300	6.9
55	200	10.0	65	300	9.95
56	400	7.4	66	400	9.80
57	300	7.4	67	300	13.00
58	400	5.8	68	700	8.80
59	300	7.5	69	400	7.60
60[2]	1,000	6.3			

[1]Performed by Bureau's Reno Research Center, Reno, NV, in 1984.
[2]Analysis by unspecified chemical techniques in 1956.

Table 6.—Results of 1956 emission spectrographic (S) and chemical (C) analyses[1] for columbium in sludge samples of regolith

Drill hole	Interval, ft	Cb, pct S	Cb, pct C
D-1	133.2-138.1	0.01-0.10	<0.1
	138.1-143.3	.01- .10	<.1
D-7	6.8- 19.3	.01- .10	<.1
D-9	70.0- 89.4	.01- .10	NA

NA Not analyzed.
[1]Analyses performed by Bureau's Reno Research Center, Reno, NV.

Table 7.—Results of analyses[1] of composite samples of marble from drill hole D-4, parts per million except as noted

Sample	Interval, ft	P_2O_5[2]	Cb	La	Zr	Y	Ce
70	174-196	1.32	257	327	653	21	529
71	196-225	1.86	731	219	190	21	373
72	225-245	2.74	416	927	277	26	1472

[1]P_2O_5 analyzed by emission spectrography, other elements by XRF; performed by Bondar-Clegg, Lakewood, CO.
[2]Percent.

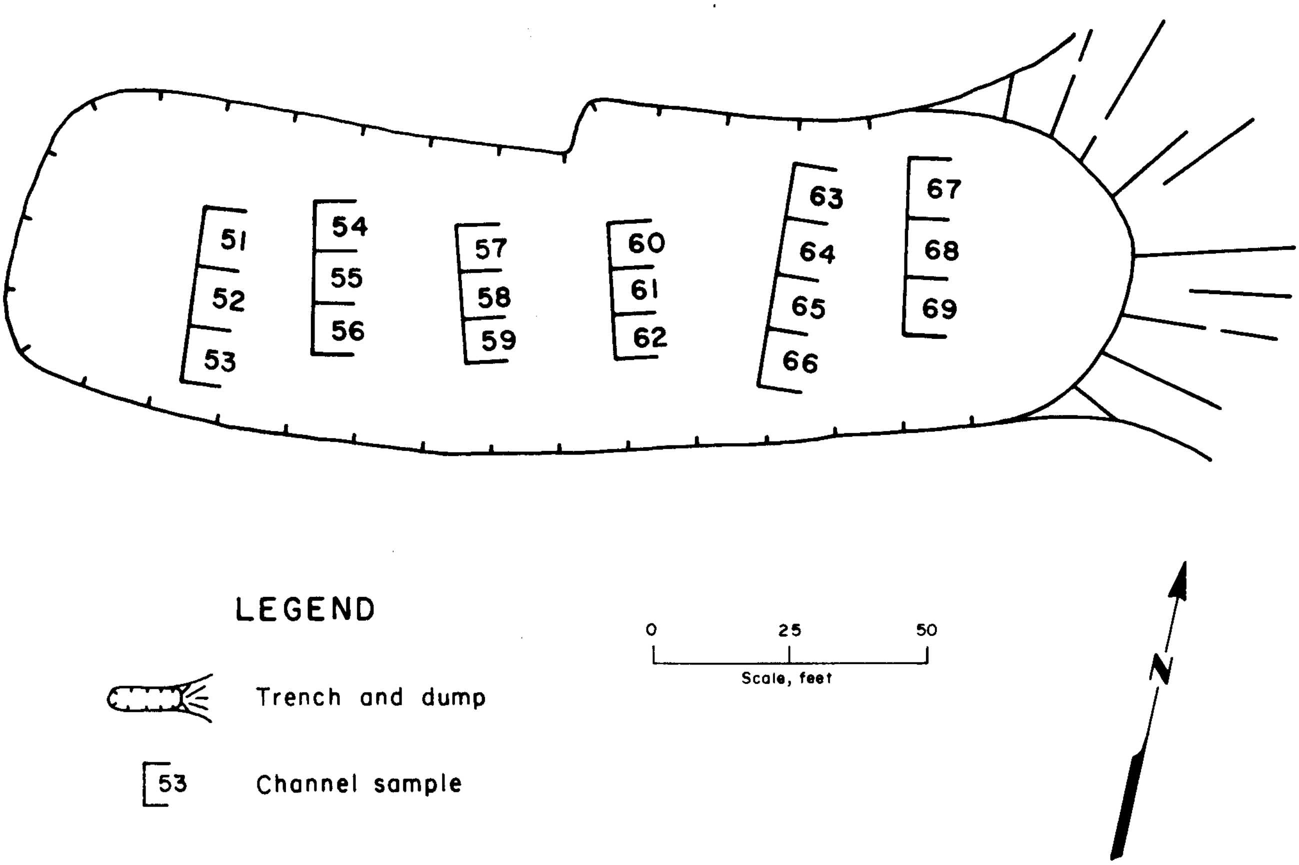

Figure 10.—Locations of 1956 channel samples in trench T-8.

INTERPRETATION

The average grade of the hematitic regolith on upper Idaho Gulch is probably between 0.04 and 0.07 pct Cb. Channel samples from trench T-8 contain from 200 to 1,000 ppm Cb. The weighted average of those values is 0.04 pct Cb over 160 ft comprising six channel samples with lengths varying from 19.9 to 39.2 ft. Sixteen of eighteen samples collected from pits in the hematite-rich portions of the regolith contain between 300 and 1,200 ppm Cb and average approximately 725 ppm Cb; 12 of these samples contain columbium in excess of or equal to 500 ppm. Spectrographic and chemical analyses performed in 1956 also show between 0.01 and 0.10 pct Cb in drill hole sludge samples of regolith. Columbium values similar to those in the hematitic regolith samples are also present in samples of marble.

In contrast, five of nine samples collected from pits in clay-rich limonitic regolith contain less than 50 ppm Cb and the remaining four samples contain from 50 to 100 ppm Cb.

The presence of columbium and the mineralogic similarities between rock specimens and regolith suggest that the specimens are essentially undecomposed or silicified equivalents of the regolith. Many of these rocks fit the description of "boulders of cellular iron-stained apatite-rich material" at Magnet Cove, AR, which is a well-studied, columbium-bearing carbonatite deposit (*18*, p. 43). At Magnet Cove, rocks with mineralogy and fabric similar to those in the regolith on Idaho Gulch grade downward into a magnetite-apatite-perovskite-bearing marble that contains approximately 300 to 400 ppm Cb. These values are very similar to those found in the marble on Idaho Gulch (table 7).

MAGNETIC, RADIOMETRIC, AND SOIL SAMPLE SURVEYS ON UPPER IDAHO GULCH

METHODS AND RESULTS

Magnetic, radiometric, and soil sample surveys were conducted over the area known, or projected, to overlie ferruginous regolith on upper Idaho Gulch (fig. 4). Magnetic and radiometric measurements were taken at 25-ft intervals on 17 northwest-trending 500- to 900-ft-long lines spaced 100 to 200 ft apart. Soil samples were collected at 25-ft intervals on seven 500-ft-long lines spaced 200 ft apart. Survey lines are oriented N 30 W, perpendicular to the trend of the regolith lenses. Figures 11, 12, and 13 are contour maps showing the results of the three surveys. Results are also tabulated in appendix D.

The magnetic survey was performed using a Geometrics UniMag 11, model G-846 portable proton magnetometer.[9] Measurements were corrected for diurnal variations with time-variation graphs constructed from repeated measurements at a single station. All measurements were taken facing N 30 W, perpendicular to the strike of the regolith lenses.

High concentrations of magnetite in the regolith produce strong positive magnetic responses. At intensities above 56,600 gammas, two 1,200-ft-long, N 60 E-trending areas, which merge to the southwest, are defined (fig. 11). Magnetic profiles are generally asymmetric, with steep positive slopes to the southeast and gentle negative slopes to the northwest. Peak magnetic intensities are offset to the northwest of the regolith, correlating with the northerly dip of the lenses.

Total-count gamma-ray radiation was measured using a Scintrex model G15-5 gamma-ray spectrometer. Measurements were taken at hip level over 10-s intervals. Trace amounts of radioactive minerals, including zircon, monazite, apatite, and aeschynite, in the regolith produce radiation measurements between 100 and 250 cps in trenched areas (fig. 12). Two larger irregularly shaped northeast-trending and six other smaller areas with higher radiation values were delineated.

Soil samples were collected at depths of 2.5 to 3.0 ft with a hand auger. Approximately 0.5 lb of sample material was placed in a paper envelope, dried, and screened to minus 80 mesh. Samples were analyzed by the Bureau's Reno (NV) Research Center for columbium, P_2O_5, and zinc by X-ray fluorescence.

Most soil samples consisted of gray-brown, clay-rich silt, but some also contained limonite and rock fragments and were yellow-orange to red. Organic contents of samples ranged widely, but generally were low. Much of the soil in the surveyed area is windblown silt without a developed profile, however some of the samples containing rock chips or hematite staining may contain residual material derived from bedrock.

Drilling and a test pit at the midpoint of soil sample line 10,000 NE show that the silt ranges from 3 to 9 ft and averages approximately 5 ft in thickness. The presence of rare bedrock outcrops near Idaho Gulch suggests that the silt cover thickens away from the gulch.

The large concentrations of apatite in the regolith are reflected by soil samples with anomalously high P_2O_5 concentrations. P_2O_5 soil values above a threshold of 0.3 pct define two 25- to 125-ft-wide anomalous areas that are coincident with and extend beyond the known extent of the regolith (fig. 13).

In contrast to P_2O_5 concentrations, anomalously large columbium or zinc concentrations were limited to samples that were collected either from trenched areas or that contained iron-stained material derived from buried regolith. Five of seven detected columbium values occur within samples collected from regolith exposed in trenches; the other two samples were noteworthy for their orange-red color. Zinc values above 240 ppm also are limited to samples collected from trenched areas or that contain iron-staining derived from regolith.

INTERPRETATION

The magnetic, radiometric, and soil sample surveys produced complementary results indicating that the two regolith lenses extend along strike for approximately 1,200 ft. The two lenses may join to the southwest. Asymmetric magnetic responses offset from the surface expression of the regolith suggest a moderate to steep northwest dip of the two lenses.

Comparison of the data indicates that soil P_2O_5 concentrations define the area underlain by regolith better than does radiation, but neither defines the extent of the regolith as well as its magnetic signature. Higher radioactivity is generally restricted to exposed portions of the regolith.

It is likely that away from the trenched areas and Idaho Gulch, all three surveys were seriously hindered in detecting the regolith by the greater thicknesses of silt cover. There is good probability that the lenses may continue undetected along strike, especially to the northeast.

[9]Reference to specific products does not imply endorsement by the Bureau of Mines.

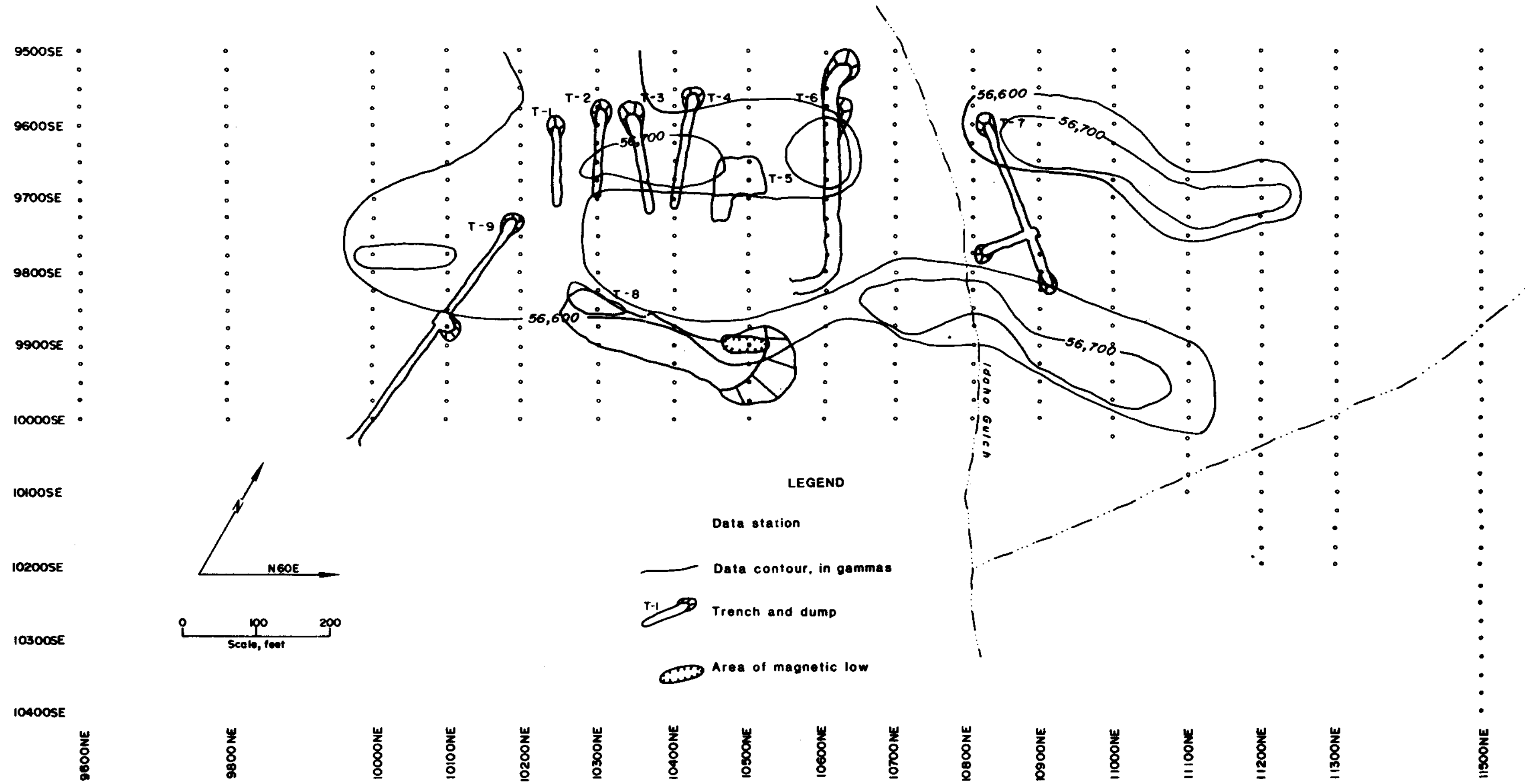

Figure 11.—Residual magnetic intensities within surveyed area on upper Idaho Gulch.

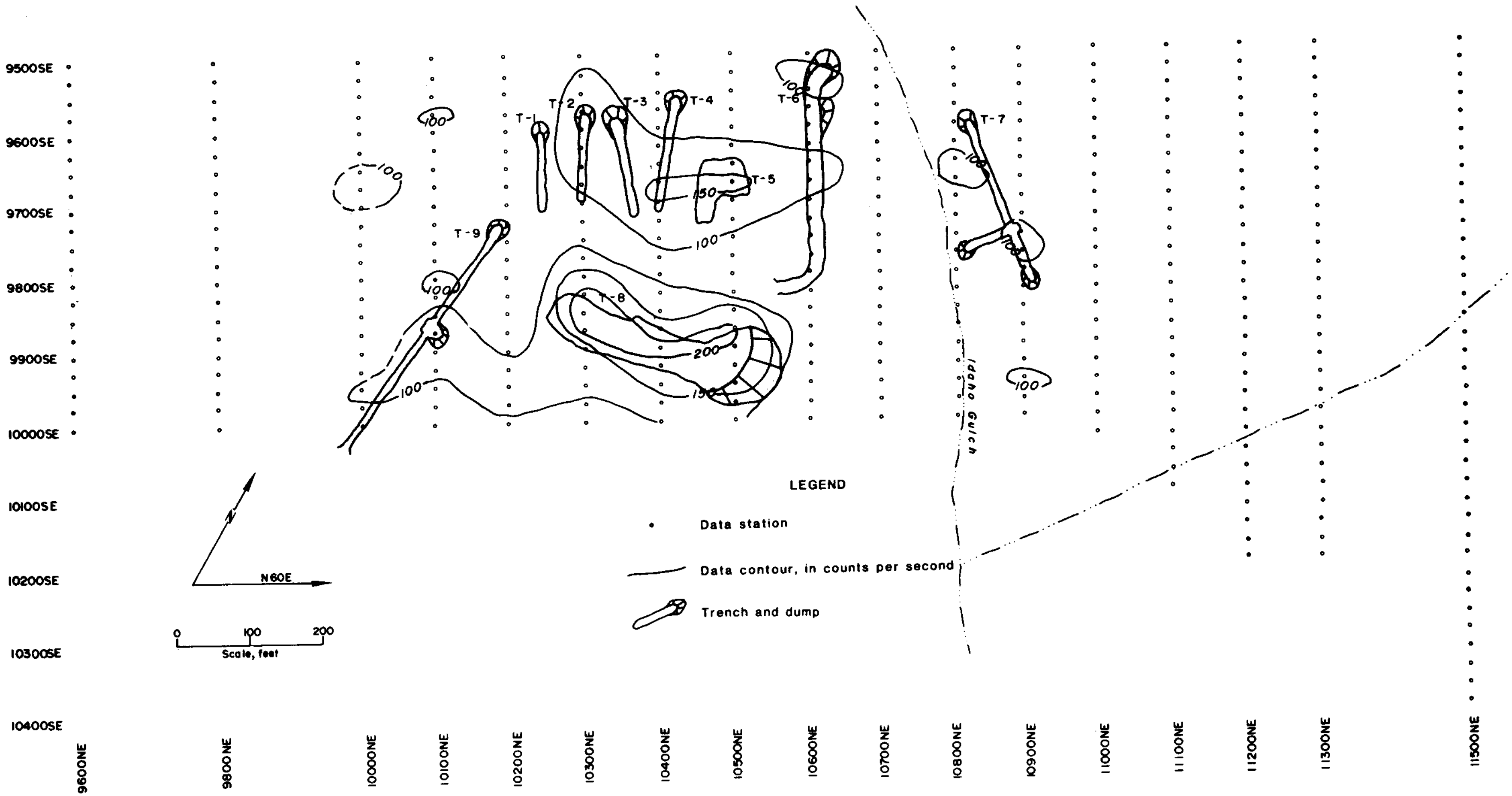

Figure 12.—Total-count gamma-ray radioactivity within surveyed area on upper Idaho Gulch.

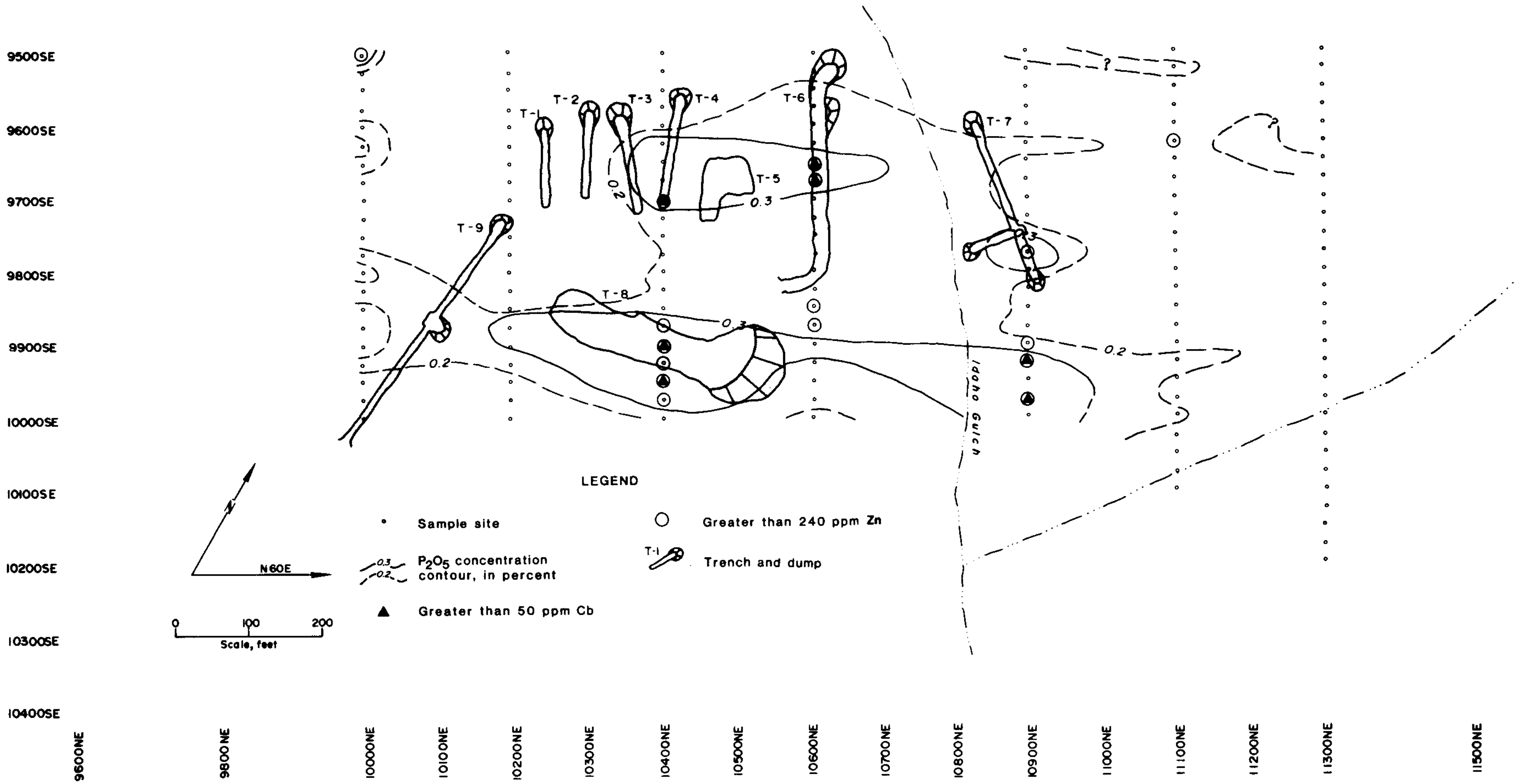

Figure 13.—Columbium, zinc, and P_2O_5 concentrations in soils within surveyed area on upper Idaho Gulch.

COLUMBIUM RESOURCES

Approximately 340,000 lb of indicated and inferred columbium resources are present within the known and inferred extent of the regolith lenses on uper Idaho Gulch. According to standard guidelines, set by Bureau of Mines and U.S. Geological Survey (*19*), this columbium comprises approximately 30,000 lb of indicated and approximately 310,000 lb of inferred resources.

The indicated resource comprises that portion of the southeastern regolith lens exposed in trench T-8 and intersected in drill holes D-1, D-2, D-3, D-6, D-7, and D-8. Drill hole intersections show that this lens decreases from an average thickness of 23 ft at the surface to an approximate average of 17 ft at 100 ft downdip. Given the 6,900 ft^2 surface area and 40° north dip of the hematitic regolith in trench T-8, and assuming that the average thickness decreases by 50 pct at 150 ft downdip, the volume of hematitic regolith represented by that exposed in trench T-8 is approximately 500,000 ft^3. At a measured[10] tonnage factor of 23.5 ft^3/st and a minimum grade of 0.07 pct Cb,[11] a minimum of approximately 30,000 lb of indicated resource is present.

The inferred columbium resource comprises the remaining known or projected regolith. The average apparent thickness, as measured in trenches, over the remaining 2,200 ft of strike length is approximately 50 ft. Subtracting 40 pct of this to account for an approximate average amount of unmineralized limonitic regolith, and given an approximately 45° northerly dip of the regolith lenses, the average true thickness is 22 ft. Assuming a weathering pattern similar to that in trench T-8 where the regolith decreases in thickness by 50 pct at 150 ft downdip, then the volume of inferred hematitic regolith is approximately 5.25 million ft^3. At a tonnage factor of 23.5 and a grade of 0.07 pct Cb, a minimum of approximately 310,000 lb of inferred columbium resource is present.

The regolith also contains zirconium and P_2O_5 resources. Seven of eight 1984 channel samples collected in pits contain 700 to 900 ppm Zr (table 3). At an average concentration of approximately 0.07 pct Zr and a total regolith tonnage of approximately 245,000 st, an inferred zirconium resource is approximately 340,000 lb. P_2O_5 values in the same eight samples range from 0.5 to 20.4 pct. The average of these values is 6.5 pct P_2O_5; discounting the high and low values, the average is 5.2 pct P_2O_5. At a concentration of 5 pct P_2O_5 and a total regolith tonnage of 245,000 st, an inferred P_2O_5 resource is approximately 12,250 st.

Good potential also exists for large additional resources of columbium in the dolomitic marble underlying the regolith. At an average grade similar to that of the regolith, the marble may contain several times the identified resource.

[10]Tonnage factor determined on dried, compacted material; all analyses are also on a dry basis.

[11]The average grade was determined previously in the text to be between 0.04 and 0.07 pct Cb. Head analyses of 0.12 and 0.093 pct Cb on two 200-lb samples of the regolith suggest the higher value may be more accurate.

BENEFICIATION OF COLUMBIUM FROM THE REGOLITH

Two large bulk samples of regolith, each weighing approximately 200 lb, were collected from trenches on upper Idaho Gulch for columbium beneficiation studies. Sample A was collected from trench T-4 from the same pit as samples 12 and 13 and had a head analysis of 0.09 pct Cb. Sample B was collected from trench T-5 from the same pit as samples 18 and 19 and had a head analysis of 0.12 pct Cb.

Figure 14 illustrates the procedure used to beneficiate the two samples. The samples were screened and ground in stages to pass 65 mesh and then tabled on a slime deck to produce a rougher concentrate, coarse tailings (those that settled and banded on the deck), and fine tailings (those that washed off the deck without settling). The rougher coarse tailings were screened and reground in stages to pass 150 mesh and then retabled in a scavenger step. A scavenger concentrate, coarse tailings, and fine tailings were produced. The rougher and scavenger concentrates were combined and scrubbed at 50 pct solids for 10 min in a 1:2 volume HCl-H_2O solution (13 pct HCl by weight) to remove iron oxide staining from the mineral surfaces. The scrubbed concentrate was washed and decanted four times and then treated by magnetic separation. A hand magnet was used to remove magnetite and other highly magnetic material. The remainder was slurred and pumped through a high-intensity wet magnetic separator with a grooved-plate configuration at eight power settings. The magnetic field strength varied from approximately 500 G with the hand magnet to about 9,500 G at the maximum power setting.

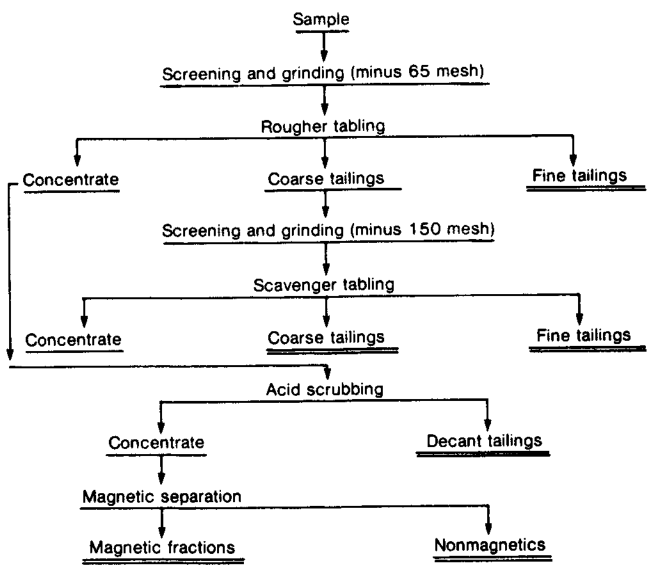

Figure 14.—Flow diagram of columbium beneficiation procedure.

Tables 8 and 9 show the results of beneficiation of samples A and B. A calculated composite concentrate from sample A contained 57 pct of the columbium at a grade of 0.86 pct Cb. A calculated composite concentrate from sample B contained 53 pct of the columbium at a grade of

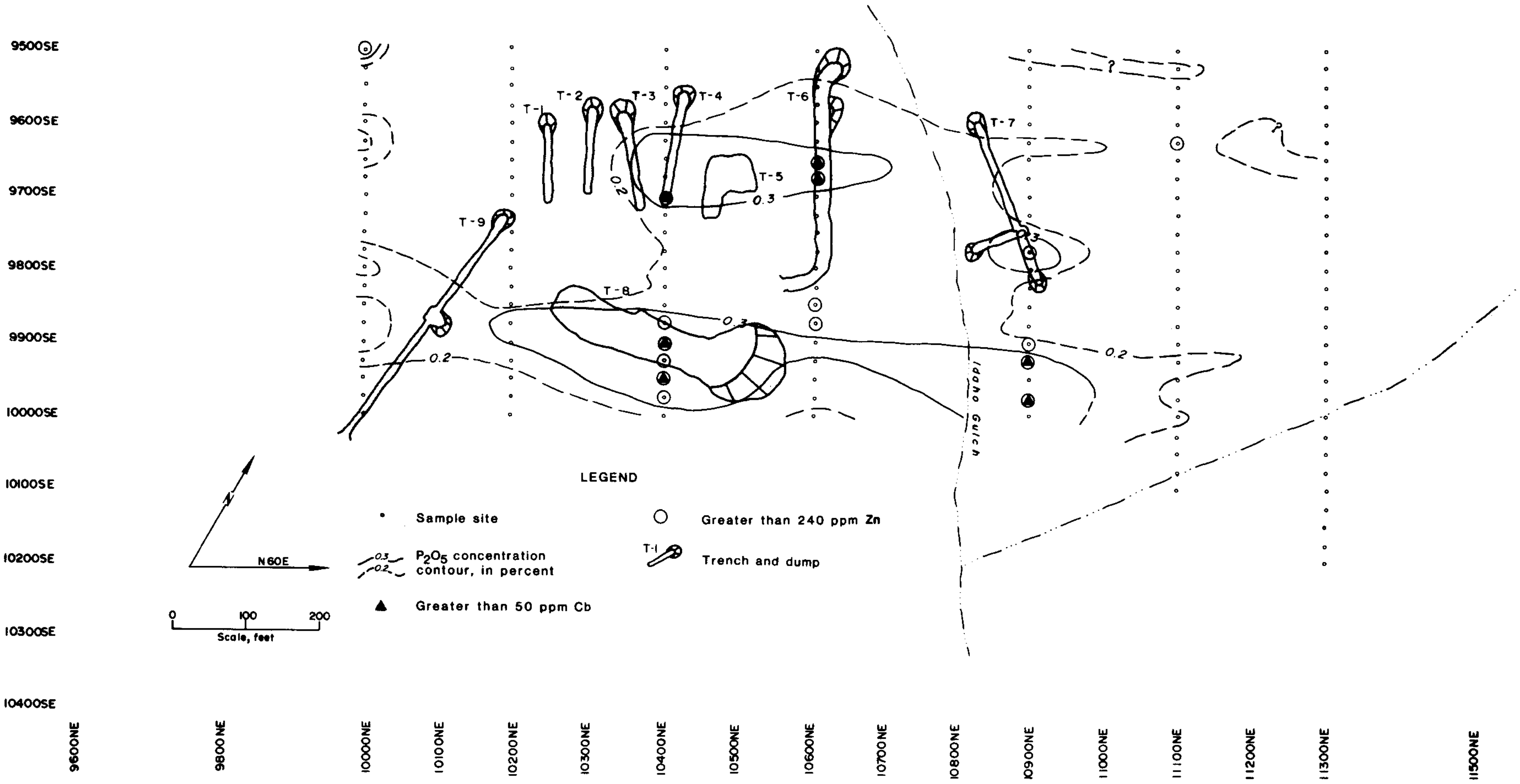

Figure 13.—Columbium, zinc, and P_2O_5 concentrations in soils within surveyed area on upper Idaho Gulch.

Table 8.—Gravity and magnetic concentration of sample A

Product	wt pct	Analysis, pct			Distribution, pct		
		Cb	Zr	Sr	Cb	Zr	Sr
Rougher and scavenger concentrates:							
Magnetics:							
With hand magnet[1]	0.4	0.06	0.03	0.03	0.3	0.2	<0.1
At 700 G.	.1	.09	.04	.09	.1	<.1	<.1
At 1,500 G.	.3	.42	.09	.15	1.2	.6	.1
At 2,200 G.	.3	1.06	.13	.25	3.3	.7	.1
At 4,000 G.	1.6	1.06	.17	.47	17.3	5.2	1.3
At 6,200 G.	1.0	1.01	.33	.73	10.4	6.3	1.2
At 7,600 G.	.4	1.10	.27	.64	4.3	2.0	.4
At 8,700 G.	.8	1.12	.67	.98	8.7	9.8	1.3
At 9,500 G.	.4	1.15	.26	.70	4.2	1.8	.4
Nonmagnetics at 9,500 G.	1.9	.42	1.39	1.99	7.8	48.1	6.1
Weight loss from acid scrubbing	2.9	NA	NA	NA	NAp	NAp	NAp
Subtotal	10.1	NA	NA	NA	57.6	74.7	10.9
Rougher table fine tailings	47.5	.04	.02	.39	18.7	17.5	30.2
Scavenger table coarse tailings	27.3	.06	.01	.97	16.2	5.0	43.3
Scavenger table fine tailings	15.1	.05	.01	.63	7.5	2.8	15.6
Composite or total	100.0	.10	.05	.61	100.0	100.0	100.0
Calculated composite concentrate[2]	6.7	.86	.60	1.00	57.2	74.5	10.9

NA Not analyzed. NAp Not applicable.
[1]Additional analysis: 63.6 pct Fe.
[2]Mathematical combination of magnetics at 1,500, 2,200, 4,000, 6,200, 7,600, 8,700, and 9,500 G, and nonmagnetics at 9,500 G.

Table 9.—Gravity and magnetic concentration of sample B

Product	wt pct	Analysis, pct			Distribution, pct		
		Cb	Zr	Sr	Cb	Zr	Sr
Rougher and scavenger concentrates:							
Magnetics:							
With hand magnet[1]	0.3	0.02	<0.01	<0.01	0.1	<0.1	<0.1
At 700 G.	.1	.11	.02	.02	.2	<.1	<.1
At 1,500 G.	.2	.65	.04	.04	1.2	.3	.1
At 2,200 G.	.6	1.03	.05	.09	4.7	1.0	.3
At 4,000 G.	.7	1.16	.07	.11	7.0	1.7	.5
At 6,200 G.	1.8	1.07	.09	.15	15.8	5.6	1.6
At 7,600 G.	.6	1.07	.08	.15	5.2	1.7	.5
At 8,700 G.	.9	1.06	.11	.20	7.8	3.5	1.1
At 9,500 G.	.5	1.05	.11	.18	3.9	1.7	.5
Nonmagnetics at 9,500 G.	1.5	.65	.34	.52	7.7	17.4	4.5
Weight loss from acid scrubbing	2.3	NA	NA	NA	NAp	NAp	NAp
Subtotal	9.5	NA	NA	NA	53.6	32.9	9.1
Rougher table fine tailings	45.1	.05	.02	.11	18.3	31.4	29.4
Scavenger table coarse tailings	32.9	.08	.02	.24	21.1	22.9	46.7
Scavenger table fine tailings	12.5	.07	.03	.20	7.0	12.8	14.8
Composite or total	100.0	.12	.03	.17	100.0	100.0	100.0
Calculated composite concentrate[2]	6.8	.97	.14	.22	53.3	32.9	9.1

NA Not analyzed. NAp Not applicable.
[1]Additional analysis: 62.0 pct Fe.
[2]Mathematical combination of magnetics at 1,500, 2,200, 4,000, 6,200, 7,600, 8,700, and 9,500 G, and nonmagnetics at 9,500 G.

0.97 pct Cb. In each case the grade could be improved to 1.1 pct Cb with a sacrifice of 9 pct in recovery.

The concentrates also contained zirconium and strontium. The calculated composite concentrate from sample A contained 74.5 pct of the zirconium and nearly 11 pct of the strontium with grades of 0.60 pct and 1.00 pct, respectively. The concentrate from sample B contained nearly 33 pct of the zirconium and 9 pct of the strontium with grades of 0.14 pct and 0.22 pct, respectively.

DISCUSSION

ORIGIN OF THE REGOLITH

The ferruginous regolith on upper Idaho Gulch is derived from chemical weathering of the underlying dolomitic marble. Most of the constituents of the regolith, including apatite, zircon, and a mixed assemblage of iron oxide minerals, are also found downdip in the less weathered marble. Columbium minerals and monazite have not been found in the marble; however, analyses show the marble contains trace amounts of columbium, cerium, and P_2O_5.

The origin of the marble is not as clear. Beds of limestone, dolomite, or marble are unknown elsewhere within the extensive Mesozoic flysch belt (*17*). The marble and possibly associated metasedimentary wall rocks could be older than the flysch and correlative to a unit of Paleozoic-age limestone, dolomite, argillite, phyllite, metachert, and quartz-mica and chlorite schist that is exposed west of Tofty near the Yukon River (*17*). Near Tofty, this material could either occur as fault-bounded slivers intercalated within the flysch, or underlie the flysch and be exposed in an erosional window. Significantly, apatite, which is characteristic of the marble on upper Idaho Gulch, has not been identified in the Paleozoic-age carbonate rocks west of Tofty.

Alternatively, the marble and regolith on upper Idaho Gulch may represent a carbonatite and its residual weathering product. Calcite, ankeritic dolomite, biotite, fluorapatite, monazite, xenotime, magnetite, pyrite, anatase, hematite, zircon, columbium-bearing rutile, ilmenorutile, columbite, and aeschynite are present in the regolith and/or marble. This mineralogy closely resembles that of the apatite-magnetite variety of carbonatite as described by Pecora (*20*). Similarly, the trace element composition of the marble and/or regolith closely resembles that of carbonatites (table 10). Particularly close agreement for level of concentration of trace elements exists for barium, titanium, and P_2O_5.

Magnetite and P_2O_5 and to a lesser extent, columbium and zirconium, are concentrated in the regolith to levels above those in the parent marble (table 10). This upgraded material is directly comparable to upgraded concentrations of magnetite, P_2O_5, columbium, and zirconium in residual soils overlying the Sukula carbonatite complex in southeastern Uganda (*21*), in "apatite-francolite regolith" overlying the Sokli carbonatite complex in Finland (*22*), and elsewhere (*23*).

The overall interpreted regional geologic setting and the rock assemblages found on upper Idaho Gulch are not overwhelmingly similar to those of classic carbonatite occurrences (*20, 24*). In particular, no alkalic igneous rocks or alkali-rich alteration halo have been identified in the Tofty area. However, it is possible that the marble intruded along the structurally complex northwestern margin of the flysch basin and that any associated alkalic rocks or alteration halo either remain hidden beneath the extensive silt cover or have not yet been exposed by erosion. Alternatively, poorly exposed and preserved occurrences of serpentinized rock in the vicinity of upper Idaho Gulch may represent metamorphosed mafic alkalic rocks.

The grade and tonnage of the identified columbium resource on upper Idaho Gulch is considerably lower than that in exploitable columbium-bearing carbonatites worldwide. However, uneconomic columbium grades similar to or lower than those on upper Idaho Gulch have been identified in carbonatites elsewhere. Specifically, at Magnet Cove, AR, only 6 of 21 samples of the carbonatite exposure in Kinsey Quarry contained detectable columbium with concentration ranging between 0.01 and 0.07 pct (*18*). Additionally, it should be noted that the extent of the marble that underlies the regolith on upper Idaho Gulch is unknown, and that only three samples of marble have been analyzed. Therefore there is a possibility for yet undiscovered, possibly higher grade columbium resources in the Tofty area.

SOURCES OF PLACER MINERALS

The bedrock source of the tin belt placer minerals is unknown. Wayland (*8*) outlines two hypotheses to explain possible origins. One suggests the northeast alignment of placer deposits reflects the trend of an ancient stream channel that has been reworked by younger streams. In this hypothesis, the placer minerals would have been derived from a source outside of the tin belt. The other hypothesis proposes that the placer constituents were derived from sources within the tin belt and that the placer deposits were formed from virtual in-place weathering. Wayland concludes that the second theory probably best explains the origin of the cassiterite, but that "the monazite, aeschynite, apatite, and zircon can be accounted for under either hypothesis" (*8*, p. 403).

This investigation shows that a source for some of the placer minerals lies within the tin belt, northwest of the existing placer deposits. High concentrations of radioactive minerals and columbium in placer gravels on Idaho Gulch likely result from erosion of ferruginous regolith on upper Idaho Gulch. High concentration of radioactive minerals and columbium in tailings piles on Miller and Deep Creeks and the reported presence of apatite- and magnetite-bearing dolomite on Harter Gulch (*8*) likewise suggest additional lode sources in the headwaters of those creeks.

Table 10.—Trace-element abundances and variations in reported (*20*) carbonatite deposits and marble and regolith on upper Idaho Gulch, percent

Trace element	Reported carbonatite	Marble[1]	Regolith[2]	Trace element	Reported carbonatite	Marble[1]	Regolith[2]
Ce[3]	0.02 - ?	0.06 -0.24	0 - 0.20	Zr	0.001-0.02	0.02-0.065	0 - 0.09
Ba	.05 -10.0	NA	.5->6.0	Ti	.10 -3.0	NA	.2 - 2.0
Sr	.50 - 2.0	NA	0 - .40	P_2O_5	.10 -6.0	1.32-2.74	.14-21.4
Cb	.001- .5	.025- .073	0 - .12				

NA Not analyzed.
[1]Only 3 samples collected (see table 6).
[2]See tables 2 and 3.
[3]Includes all rare-earth elements.

SUMMARY AND CONCLUSIONS

Two parallel N 60 E trending, northwest-dipping lenses of slightly radioactive iron-rich regolith were identified on upper Idaho Gulch in 1956 and investigated in 1984 by the Bureau of Mines. The regolith contains major amounts of magnetic and nonmagnetic iron oxide minerals, abundant apatite and zircon, moderate amounts of pyrite, monazite, and columbium-bearing rutile. The regolith also contains trace amounts of xenotime and the columbium minerals aeschynite, columbite, and ilmenorutile. Trace to major concentrations of barium, strontium, lanthanum, cerium, yttrium, silver, and titanium have also been identified. Each lens has a strike length of approximately 1,200 ft and persists for 200 to 250 ft downdip where unweathered magnetite-pyrite-apatite-zircon-bearing dolomitic marble has been encountered in drill core.

High columbium and generally higher zirconium and P_2O_5 concentrations are restricted to a central, hematite-rich, red-brown portion of the regolith lenses. These mineralized zones have an average thickness of approximately 22 ft, probably decrease in thickness by 50 pct 150 ft downdip, and have average columbium grades between 0.04 pct and 0.07 pct. Given these dimensions and at a grade of 0.07 pct Cb, the regolith lenses on upper Idaho Gulch contain approximately 340,000 lb of columbium resources. Approximately 30,000 lb of this resource is indicated whereas 310,000 lb is inferred. Large additional columbium resources are probably present in the dolomitic marble. The regolith also contains inferred resources of approximately 340,000 lb of zirconium and 12,250 st of P_2O_5.

Calculated composite concentrates from two large samples of regolith contained 53 and 57 pct of the columbium at grades of 0.97 and 0.86 pct Cb, respectively. In each case the grade could be improved to 1.1 pct Cb with a sacrifice of 9 pct recovery.

The unweathered source of the regolith, a dolomitic marble, could be of either igneous or sedimentary origin. Its mineralogy and trace-element geochemistry and the similarity of the regolith to descriptions of other columbium-enriched regoliths suggest the marble is a carbonatite. However, the lack of associated alkalic igneous rocks or alkali-rich alteration halo and the stratiform nature of the regolith can be interpreted as evidence for sedimentary origin of the marble.

The marble and regolith are a lode source for some of the minerals of the Tofty placer deposits. Similar bedrock geology or placer mineralogy suggests that additional lode sources may exist in the headwaters of Miller Gulch, Deep Creek, and Harter Gulch.

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APPENDIX A.—MODIFIED 1956 DRILL CORE LOGS AND GEOLOGIC CROSS SECTIONS CONSTRUCTED FROM DRILL CORE DATA

Tables A-1 through A-9 are logs of diamond drill holes D-1 through D-9. Geologic cross sections through drill holes D-1 through D-9 and trench T-8 are presented in figures A-1 through A-6.

Table A-1.—Log of diamond drill hole D-1, Idaho Gulch

Bearing	S 14° E	Depth ... ft	194.0
Inclination	45°	Size: NX, 0 to 15.5 ft; BX, 15.5 to 119.5 ft; AX, 119.5 to 194.0 ft.	
Collar elevation ... ft	852		

Interval, ft	Recovery, ft	Description
0.0 to 9.8	0.70	Muscovite-quartz schist, weathered with limonite on fractures.
9.8 to 39.7	5.15	Dark quartz-muscovite schist with up to 1-in-wide quartz veins and limonite on fractures.
39.7 to 56.6	.30	White quartzose phyllite with partings of muscovite phyllite and quartz veins.
56.6 to 126.5	2.45	Black graphite-muscovite schist, minor pyrite and quartz veins.
126.5 to 132.2	.0	Black phyllite with limonite on fractures.
132.2 to 143.3	.35	Limonite (regolith).
143.3 to 162.8	10.70	Gray to light-green calcareous quartz-chlorite-sericite phyllite.
162.8 to 194.0	6.85	Dark-gray argillite and chloritic schist, limonite after pyrite and on fractures.

Table A-2.—Log of diamond drill hole D-2, Idaho Gulch

Bearing	S 15° E	Depth ... ft	179.4
Inclination	−68°30′	Size: NX, 0 to 14.5 ft; BX, 14.5 to 59.3 ft; AX, 59.3 to 179.4 ft.	
Collar elevation ... ft	52		

Interval, ft	Recovery, ft	Description
0.0 to 3.0	0.00	Silt with fragments of phyllite.
3.0 to 14.5	1.5	Muscovite-quartz schist, weathered with limonite on fractures.
14.5 to 38	(1)	Dark quartz-muscovite schist with local quartz veinlets.
38 to 105	16.88	White to gray quartzose muscovite phyllite grading downward to thinly laminated quartz and muscovite schist with minor pyrite and muscovite-graphite phyllite.
105 to 179.4	21.34	Muscovite-graphite pyllite grades downward into graphite-muscovite schist, and then, to graphitic argillite. Pyrite disseminated throughout.

[1]Included with recovery from 38- to 105-ft interval.

Table A-3.—Log of diamond drill hole D-3, Idaho Gulch

Inclination	−90°	Depth	278.0
Collar elevation ... ft	835.2	Size: BX, 0 to 18.9 ft; AX, 18.9 to 206.2 ft; EX, 206.2 to 278.0 ft.	

Interval, ft	Recovery, ft	Description
0.0 to 9.0	0.0	Frozen silt.
9.0 to 58.0	.99	Gray phyllite with limonite on fractures.
58.0 to 60.0	.98	Quartz with limonite after pyrite.
60.0 to 190.7	8.80	Interlaminated dark-gray to black quartz and muscovite-graphite schists, thin bands of quartz, some with pyrite.
190.7 to 192.0	.45	Calcareous chlorite-sericite schist with limonite after pyrite and calcite veinlets.
192.0 to 193.3	[1].0	Granular limonite (regolith).
193.3 to 264.7	(2)	Dolomitic marble, weathered, yellow color with abundant quartz and magnetite grains, limonite after pyrite, and veinlets of limonite, calcite-dolomite, and apatite.
264.7 to 278.0	38.97	Quartz-chlorite-sericite schist with disseminated magnetite and pyrite.

[1]Rock type identified from coarse cuttings in sludge.
[2]Included with 264.7- to 278.0-ft interval.

Table A-4.—Log of diamond drill hole D-4, Idaho Gulch

Inclination	−90°	Size: NX, 0 to 20.0 ft; BX, 20.0 to 50.4 ft; AX, 50.4 to 184.7 ft; EX, 184.7 to 259.8 ft.
Collar elevation ... ft	811	
Depth ... ft	259.8	

Interval, ft	Recovery, ft	Description
0.0 to 5.0	[1]0.0	Frozen silt.
5.0 to 40.0	[1].0	Black phyllite.
40.0 to 50.4	.25	Kaolinized phyllite.
50.4 to 65.4	.43	Siliceous light gray phyllite with pyrite.
65.4 to 75.4	.48	Decomposed Phyllite.
75.4 to 135.4	10.71	Gray to black phyllite with thin quartz seams.
135.4 to 174.1	15.86	Slightly calcareous quartz-chlorite-muscovite ± (talc-serpentine) phyllite with quartz along foliation.
174.1 to 191.0	(1,2)	Unweathered moderately coarsely crystalline dolomitic marble with disseminated magnetite, pyrite and pyrrhotite, and rare quartz veins.
191.0 to 259.8	16.36	Limonite-stained calcareous dolomite marble with disseminated magnetite. More altered intervals include 225 to 228 ft and 232 to 245 ft.

[1]Rock type identified from coarse cuttings in sludge.
[2]Included with 191.0- to 259.8-ft intervals.

Table A-5.—Log of diamond drill hole D-5, Idaho Gulch

Inclination	–90°	Size: NX, 0 to 45.7 ft; BX, 45.7 to 75.4 ft; AX, 75.4 to 95.4 ft; EX, 95.4 to 155.1 ft.
Collar elevation ft	801	
Depth ft	155.1	

Interval, ft	Recovery, ft	Description
0.0 to 5.0	[1]0.0	Frozen silt, granular dolomite, and limonite.
5.0 to 10.0	.15	Phyllite, quartz, and granular limonite.
10.0 to 27.9	8.84	Weathered, granular rock with coarse dolomite grains in a fine limonitic matrix. Contains fragments of chloritic material, magnetite, limonite after pyrite, pyrite, limonite on fractures, and quartz veins.
27.9 to 65.4	20.39	Coarse dolomitic marble with disseminated magnetite, pyrite, and trace pyrrhotite. Minor hematite after magnetite and local limonite on fractures. Chloritic at base.
65.4 to 80.4	3.85	Gray calcareous phyllite.
80.4 to 155.1	1.01	Black phyllite with quartz veinlets.

[1]Rock type identified from coarse cuttings in sludge.

Table A-6.—Log of diamond drill hole D-6, Idaho Gulch

Inclination	–90°	Depth ft	134.6
Collar elevation ft	827	Size: NX, 0 to 5.0 ft; BX, 5.0 to 45.0 ft; AX, 45.0 to 134.6 ft.	

Interval, ft	Recovery, ft	Description
0.0 to 5.0	0.0	Frozen silt and schist fragments.
5.0 to 18.0	.17	Frozen, fractured and altered muscovite-graphite phyllite.
18.0 to 25.0	.78	Fractured and weathered muscovite phyllite, minor quartz veins and limonite.
25.0 to 61.0	.30	Frozen granular limonite, some magnetite (regolith).
61.0 to 70.0	([1])	Weathered and fractured limonitic marble, locally chlorite- and sericite-rich with disseminated magnetite, hematite, and limonite after pyrite and veinlets of limonite and calcite.
70.0 to 74.4	([1])	Porous limonite with calcite veinlets.
74.4 to 75.0	([1])	Kaolinitic schist.
75.0 to 95.4	24.9	Interfoliated muscovite ± chlorite ± sericite schists with minor limonite after pyrite and on fractures.
95.4 to 110.4	5.68	Chlorite-quartz-calcite schist.
110.4 to 134.6	6.00	Interfoliated dolomitic limestone and pyritic graphite schist.

[1]Included with 75.0- to 95.4-ft interval.

Table A-7.—Log of diamond drill hole D-7, Idaho Gulch

Inclination	–90°	Depth ft	44.3
Collar elevation ft	832	Size: BX, 0 to 44.3 ft.	

Interval, ft	Recovery, ft	Description
0.0 to 14.3	([1])	Dark, goethite-limonite hematite-bearing regolith, nonmagnetic.
14.3 to 19.3	3.71	Orange earthy limonitic regolith with fragments of chloritic phyllite.
19.3 to 19.8	.5	Kaolinitic clay with a few fragments of metallic goethite.
19.8 to 43.3	16.55	Nonfoliated, chlorite-sericite-quartz phyllite with segregations of chlorite-serpentine.

[1]Included with 14.3- to 19.3-ft interval.

Table A-8.—Log of diamond drill hole D-8, Idaho Gulch

Inclination	–90°	Depth ft	50.3
Collar elevation ft	836	Size: NX, 0 to 5.0 ft; BX, 5.0 to 50.3 ft.	

Interval, ft	Recovery, ft	Description
0.0 to 5.0	([1])	Earthy, limonitic magnetic regolith.
5.0 to 13.8	2.64	Nonmagnetic limonitic regolith.
13.8 to 50.3	4.95	Chlorite-talc-sericite-(serpentine) schist, locally calcareous and altered to kaolinite and limonite.

[1]Included with 5.0- to 13.8-ft interval.

Table A-9.—Log of diamond drill hole D-9, Idaho Gulch

Inclination	–90°	Depth ft	143.9
Collar elevation ft	851	Size: BX, 0 to 30.3 ft; AX, 30.3 to 143.9 ft.	

Interval, ft	Recovery, ft	Description
0.0 to 45.3	3.08	Dark-gray to blue-colored weathered and fractured phyllite; locally limonitic.
45.3 to 50.3	1.85	Chloritic schist.
50.3 to 74.3	2.60	Dark-gray to blue-colored decomposed phyllite with iron-stained quartz.
74.3 to 89.4	1.63	Frozen granular limonite (regolith).
89.4 to 93.7	1.85	Dark-gray calcareous schist.
93.7 to 109.6	.70	Chlorite schist, slightly calcareous, with thin quartz seams that contain pyrite.
109.6 to 110.4	[1].0	Talc schist.
110.4 to 112.8	[1].0	Granular limonite.
112.8 to 143.9	5.30	Gray, slightly calcareous schist.

[1]Rock type identified from coarse cuttings in sludge.

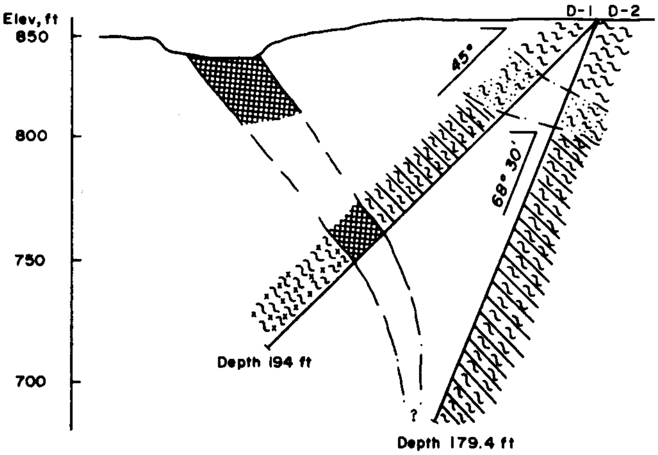


Figure A-1.—Geologic section through drill holes D-1 and D-2 and trench T-8.

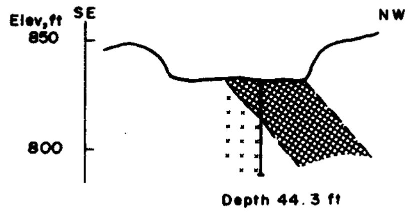


Figure A-3.—Geologic section through drill hole D-7 and trench T-8.

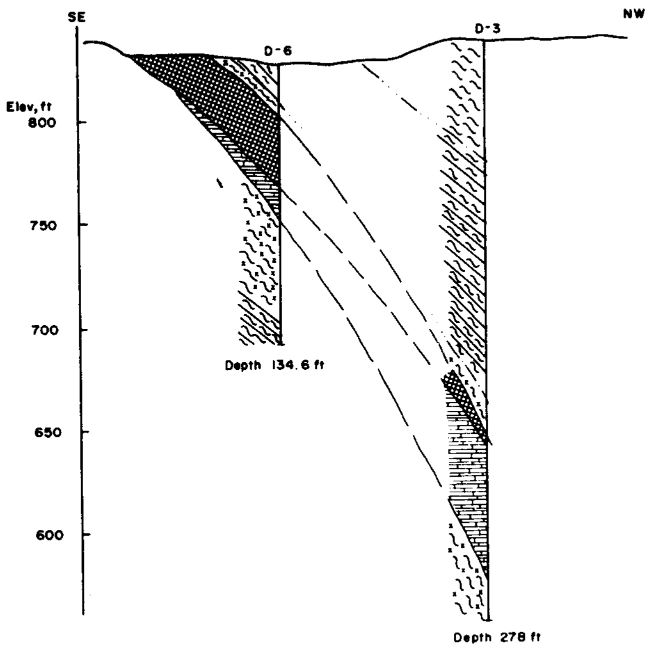
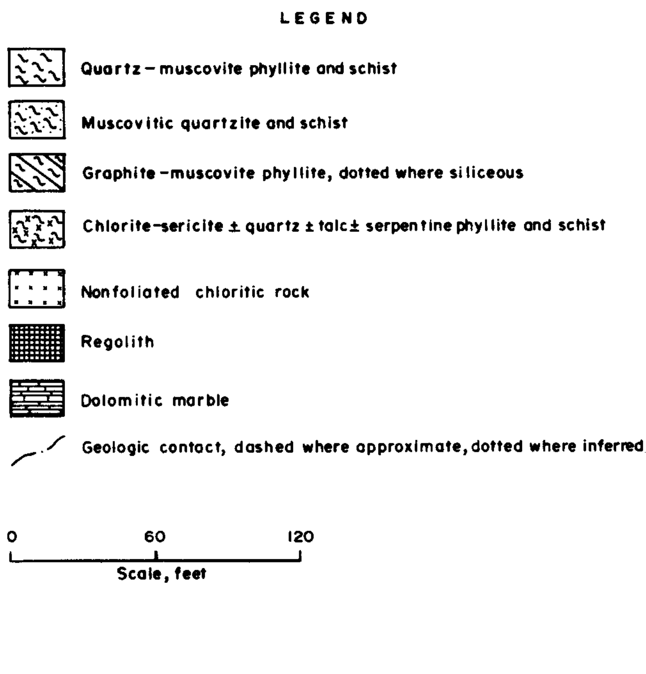


Figure A-2.—Geologic section through drill holes D-3 and D-6 and trench T-8.



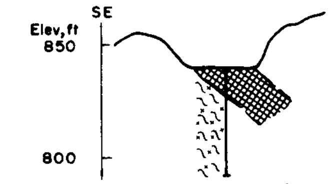


Figure A-4.—Geologic section through drill hole D-8 and trench T-8.

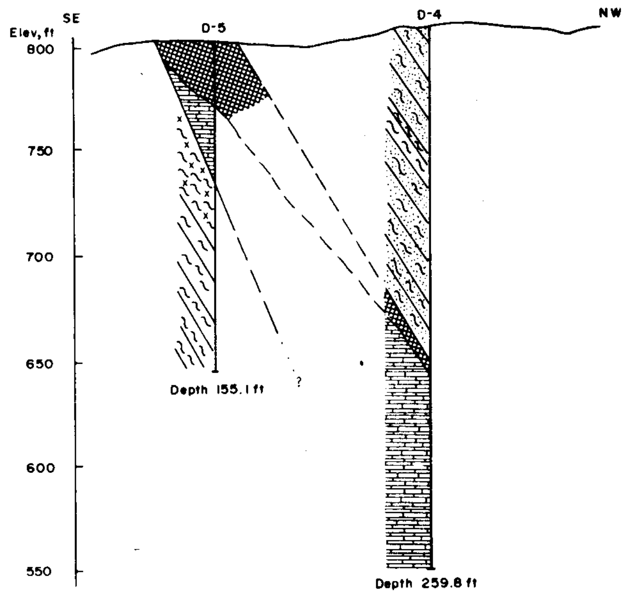


Figure A-6.—Geologic section through drill holes D-4 and D-5 and trench T-6.

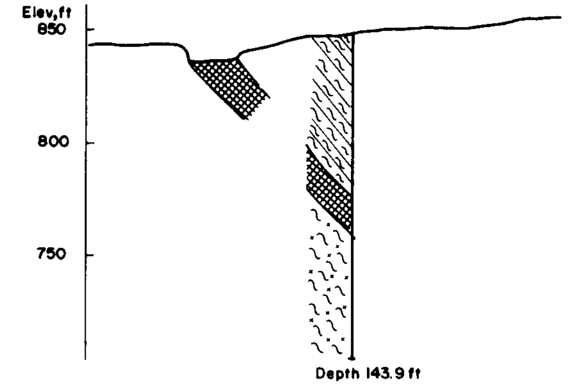
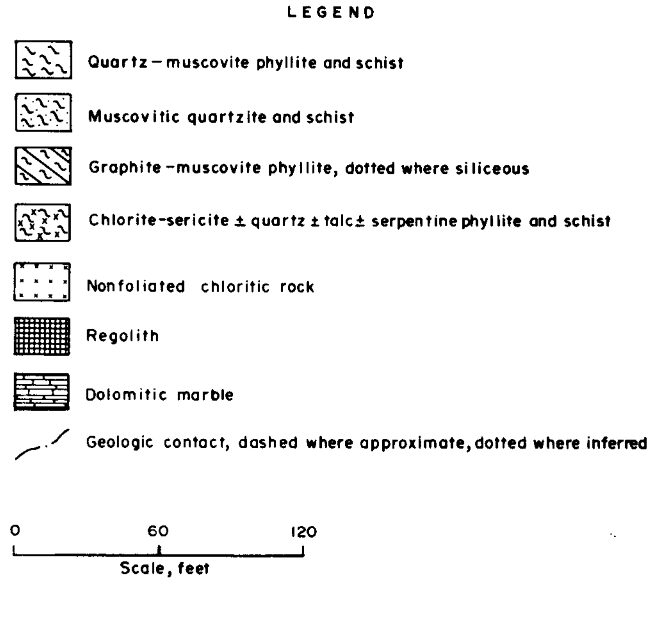


Figure A-5.—Geologic section through drill hole D-9 and trench T-8.



APPENDIX B.—TEST PROCEDURE FOR CHARACTERIZATION OF TOFTY REGOLITH CONCENTRATES 5, 9, 15, AND 30

Planned concentrate samples were acid leached in a 1:1 HCl solution to remove excess iron oxide. The material was then screened at 20 mesh. The plus 20-mesh fraction was optically, radiometrically, and spectroscopically examined and was found to contain no properties characteristic of the suspected columbium-bearing minerals. The remaining minus 20-mesh fraction of each sample was run through a laboratory-model isodynamic magnetic separator at 0-, 0.1-, 0.2-, 0.3-, 0.4-, 0.5-, 0.6-, 1.0-, and 1.7-A settings to isolate minerals of similar magnetic susceptibilities. These fractions were examined optically, radiometrically, and spectroscopically to determine possible concentrations of columbium-bearing minerals. The fractions determined to contain the highest concentration of columbium were prepared in polished grain mounts for scanning electron microscope (SEM) and microprobe studies. Aeschynite was positively identified by SEM methods and found to be well concentrated in the 0.7-A magnetic fraction. Columbite was also identified and found concentrated in the 0.5-A magnetic fraction. Columbium-bearing rutile (possibly altered in part to ilmenorutile) was also concentrated in the 0.5-A fraction.

Table B-1 summarizes the results of the analyses.

Table B-1.—Mineralogical analyses of magnetic[1] fractions of samples representative of the regolith concentrates selected for SEM studies, weight percent

Magnetic fraction .... A ..	0.3	0.4	0.5	0.7	1.0
Magnetite	35	ND	ND	ND	ND
Goethite	35	60	ND	ND	ND
Miscellaneous silicates	20	25	15	10	25
Columbite	6	6	20	ND	ND
Monazite	4	4	ND	ND	ND
Aeschynite	ND	2	5	70	45
Rutile	ND	ND	ND	10	10
Zircon	ND	ND	60	10	15
Other	ND	ND	ND	ND	5

ND Not detected.
[1]Separated on a laboratory-model isodynamic magnetic separator.

APPENDIX C.—RESULTS OF EMISSION SPECTROGRAPHIC ANALYSES[1] OF REGOLITH SAMPLES

Sample	11	12	13	16	17	18	19	20	22	23	24	25	26
						CONCENTRATION, ppm							
Ag	<70	<10	<100	60	100	<80	<40	<60	<400	<400	<100	< 300	<300
As	<200	1,000	900	<200	<200	<500	<400	<100	<1,000	<800	<90	<700	<800
Au	<20	<40	<40	<20	<20	<50	<30	<20	<400	<400	<20	<30	<50
B	<60	<100	<100	<40	<40	<100	<80	<30	<100	<100	<200	<100	<100
Be	6	7	4	4	5	<3	<2	4	4	<3	4	5	5
Bi	<100	<100	<500	<2,000	<1,000	<100	<400	<200	<500	<100	<100	<6,000	<2,000
Cb	<400	600	200	<200	<300	<100	400	<100	300	400	600	<100	700
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	50	100	50	60	80	200	100	<30	200	200	200	100	100
Cr	100	700	200	1,000	400	800	500	70	300	400	1,000	2,000	600
Cu	30	10	6	10	30	20	20	30	10	<6	9	<6	40
Ga	20	30	20	<9	30	60	30	20	20	20	40	<2	20
La	<300	1,000	<300	<100	<100	1,000	1,000	<100	<100	<200	<200	<100	800
Li	<30	<20	<20	<20	<30	<30	<20	<20	<20	<20	<20	<20	<20
Mo	<10	<10	<10	<10	<10	<10	<10	<1	<1	<1	<1	<1	<1
Ni	200	700	600	1,000	400	900	800	100	<400	500	2,000	3,000	800
Pb	<50	100	<40	<60	<50	90	<20	<40	<20	<20	<50	<20	<20
Pd	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pt	<40	<100	<80	<70	<50	<100	<100	<40	<100	<100	<200	<200	<100
Sb	<2,000	<2,000	<2,000	<1,000	<2,000	<1,000	<1,000	<2,000	<3,000	<3,000	<2,000	<3,000	<3,000
Sc	<4	10	<4	<4	<5	10	<8	<4	<8	<8	<4	<4	<7
Sn	<200	<200	400	<200	<200	<200	<80	<200	<800	<70	<300	<200	<100
Sr	100	4,000	1,000	3	10	1,000	700	300	300	200	40	30	1,000
Ta	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<300
Te	<500	<400	<500	<400	<400	<400	<400	<400	<400	<400	<700	<400	<600
Ti	5,000	10,000	5,000	3,000	7,000	7,000	5,000	4,000	9,000	10,000	4,000	2,000	6,000
V	300	500	500	200	400	800	500	400	500	600	600	200	500
Y	<9	<10	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9
Zn	100	90	40	100	100	<10	<4	<20	<10	<10	<50	<40	60
Zr	100	1,000	300	<30	60	400	200	100	2,000	1,000	100	<30	500
						CONCENTRATION, pct							
Al	>5	>3	0.6	>5	>6	>3	1	>6	0.6	1	0.5	0.9	>2
Ba	.6	>6	.8	.07	.2	.7	.5	1	.1	.08	.2	.1	.5
Ca	<.5	3	1	.4	.7	3	<.6	<.4	<.6	<.7	<.3	<.4	4
Fe	10	10	10	8	9	10	10	10	>10	>10	>10	10	10
K	10	5	7	9	10	7	4	7	6	9	7	10	7
Mg	.4	.3	.3	1	1	.9	.4	.4	<.05	<.01	.2	.2	.2
Mn	>4	>5	>4	>2	>2	>6	>5	>4	>10	>10	>3	>9	>10
Na	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3
P	<1	3	<2	<.7	<.7	<.7	<1	<.8	<.7	<.7	<.9	<1	2
Si	>10	5	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10

[1]Analyses by Bureau's Reno Research Center, Reno, NV.

RESULTS OF EMISSION SPECTROGRAPHIC ANALYSES[1] OF REGOLITH SAMPLES—Continued

Sample	27	28	32	33	34	35	36	37	38	39	40	41
						CONCENTRATION, ppm						
Ag	<300	<30	<80	<300	<70	<5	<40	<70	<40	<50	200	100
As	<800	<100	<200	<800	<800	<90	<90	<90	<100	<100	<1,000	<90
Au	<40	<20	<20	<40	<50	<100	<50	<20	<20	<20	<20	<20
B	<90	<50	<50	<100	<100	<300	<100	<200	100	<70	100	100
Be	1	4	8	<3	<3	5	4	8	7	6	4	9
Bi	<200	<600	<100	<2,000	<200	<200	<100	<700	<100	<100	<100	<100
Cb	300	<200	<300	<200	800	1,000	200	<70	<100	<100	<100	<200
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	100	<20	200	90	100	400	60	80	<10	<10	100	70
Cr	400	100	6,000	600	200	300	200	500	50	200	200	100
Cu	6	100	30	20	40	100	20	50	40	50	100	100
Ga	30	<10	20	<9	20	70	<10	<10	<8	<2	60	40
La	300	<100	<100	<100	300	300	<100	<100	<100	<100	300	<300
Li	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	80	70
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ni	400	100	3,000	1,000	800	2,000	400	600	200	400	200	400
Pb	<20	<20	<60	<20	<20	<60	<30	<70	<30	<20	100	<80
Pd	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pt	<100	<6	<300	<100	<100	<300	<70	<90	<20	<30	<20	<6
Sb	<2,000	<600	<3,000	<3,000	<3,000	<3,000	<3,000	<4,000	<600	<600	<700	<2,000
Sc	<4	<4	<9	<4	<4	20	<4	<4	<4	<4	<5	<5
Sn	<20	<80	<300	<200	<200	<800	<200	600	<100	<100	<300	<300
Sr	400	20	100	80	50	70	1,000	2,000	8	60	100	100
Ta	<200	<200	<300	<200	<200	<200	<300	<100	<200	<200	<200	<200
Te	<400	<400	1,000	<400	<400	<900	<600	<900	<400	<400	<400	<900
Ti	7,000	10,000	3,000	10,000	10,000	20,000	10,000	10,000	6,000	6,000	7,000	6,000
V	500	400	400	500	600	1,000	600	800	200	100	700	400
Y	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<10	<9
Zn	<1	<30	200	40	<60	<20	<40	<20	80	80	<2	200
Zr	2,000	40	90	200	400	4,000	90	100	<30	30	200	100
						CONCENTRATION, pct						
Al	1	>6	>3	>3	0.8	>2	0.7	1	>5	<5	>7	>6
Ba	.3	.1	.3	.4	.1	.3	.2	.3	.2	.1	1	.6
Ca	<.6	1	<.4	<.8	<.2	<.1	>10	>10	.9	2	<.1	.7
Fe	10	7	10	10	>10	>10	>10	>10	8	9	9	>10
K	6	10	8	9	9	4	7	<1	>10	>10	>10	10
Mg	.2	1	.4	.3	.2	.2	.5	.4	1	1	.4	.4
Mn	>10	.3	>4	>8	>5	>7	>5	>5	.7	>2	>3	>2
Na	<.3	2	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3	<.3
P	<2	<.7	<2	<1	<1	<2	6	8	<.7	<.7	<.7	<.7
Si	>10	>10	>10	>10	>10	>10	3	4	>10	>10	>10	>10

[1]Analyses by Bureau's Reno Research Center, Reno, NV.

APPENDIX D.—RESULTS OF MAGNETIC,[1] RADIOMETRIC,[2] AND SOIL SAMPLE[3] SURVEYS

Station	Magnetic intensity, gammas	Radioactivity, cps	Cb, ppm	P_2O_5, pct	Zn, ppm
LINE 9,600 NE					
9,500 SE	572	73	NS	NS	NS
9,525 SE	524	72	NS	NS	NS
9,550 SE	507	73	NS	NS	NS
9,575 SE	521	72	NS	NS	NS
9,600 SE	522	68	NS	NS	NS
9,625 SE	520	76	NS	NS	NS
9,650 SE	520	76	NS	NS	NS
9,675 SE	514	76	NS	NS	NS
9,700 SE	510	83	NS	NS	NS
9,725 SE	515	74	NS	NS	NS
9,750 SE	531	73	NS	NS	NS
9,775 SE	526	72	NS	NS	NS
9,800 SE	523	67	NS	NS	NS
9,825 SE	520	66	NS	NS	NS
9,850 SE	520	66	NS	NS	NS
9,875 SE	508	70	NS	NS	NS
9,900 SE	504	70	NS	NS	NS
9,925 SE	465	78	NS	NS	NS
9,950 SE	514	71	NS	NS	NS
9,975 SE	515	76	NS	NS	NS
10,000 SE	530	71	NS	NS	NS
LINE 9,800 NE					
9,500 SE	526	75	NS	NS	NS
9,525 SE	522	70	NS	NS	NS
9,550 SE	526	72	NS	NS	NS
9,575 SE	522	72	NS	NS	NS
9,600 SE	530	71	NS	NS	NS
9,625 SE	528	84	NS	NS	NS
9,650 SE	530	72	NS	NS	NS
9,675 SE	545	74	NS	NS	NS
9,700 SE	521	70	NS	NS	NS
9,725 SE	530	75	NS	NS	NS
9,750 SE	535	75	NS	NS	NS
9,775 SE	529	72	NS	NS	NS
9,800 SE	539	72	NS	NS	NS
9,825 SE	523	78	NS	NS	NS
9,850 SE	527	77	NS	NS	NS
9,875 SE	540	78	NS	NS	NS
9,900 SE	524	82	NS	NS	NS
9,925 SE	520	87	NS	NS	NS
9,950 SE	520	88	NS	NS	NS
9,975 SE	524	81	NS	NS	NS
10,000 SE	526	83	NS	NS	NS
LINE 10,000 NE					
9,500 SE	566	86	<50	0.35	270
9,525 SE	559	87	<50	.16	190
9,550 SE	536	84	<50	.18	230
9,575 SE	531	81	<50	.13	200
9,600 SE	562	88	<50	.23	180
9,625 SE	565	92	<50	.16	190
9,650 SE	447	107	<50	.23	190
9,675 SE	578	106	<50	.16	200
9,700 SE	685	100	<50	.12	170
9,725 SE	605	91	<50	.16	190
9,750 SE	648	89	<50	.17	190
9,775 SE	895	87	<50	.20	200
9,800 SE	645	89	<50	.11	190
9,825 SE	538	91	<50	.26	210
9,850 SE	512	89	<50	.12	170
9,875 SE	494	92	<50	.14	200
9,900 SE	519	97	<50	.12	190
9,925 SE	525	99	<50	.20	220
9,950 SE	546	102	<50	.16	200
9,975 SE	551	97	<50	.14	200
10,000 SE	540	86	<50	.15	220
LINE 10,000 NE					
9,500 SE	518	80	NS	NS	NS
9,525 SE	541	87	NS	NS	NS
9,550 SE	536	97	NS	NS	NS
9,575 SE	536	106	NS	NS	NS
9,600 SE	569	93	NS	NS	NS
9,625 SE	580	83	NS	NS	NS
9,650 SE	597	85	NS	NS	NS
9,675 SE	605	79	NS	NS	NS
9,700 SE	653	86	NS	NS	NS
9,725 SE	674	86	NS	NS	NS
9,750 SE	692	86	NS	NS	NS
9,775 SE	702	95	NS	NS	NS
9,800 SE	689	110	NS	NS	NS
9,825 SE	658	93	NS	NS	NS
9,850 SE	602	113	NS	NS	NS
9,875 SE	524	102	NS	NS	NS
9,900 SE	586	114	NS	NS	NS
9,925 SE	537	103	NS	NS	NS
9,950 SE	536	87	NS	NS	NS
9,975 SE	524	94	NS	NS	NS
10,000 SE	444	96	NS	NS	NS
LINE 10,200 NE					
9,500 SE	602	91	<50	0.14	170
9,525 SE	600	90	<50	.12	190
9,550 SE	595	89	<50	.18	210
9,575 SE	607	87	<50	.16	200
9,600 SE	620	88	<50	.15	180
9,625 SE	630	95	<50	.13	190
9,650 SE	641	96	<50	.12	190
9,675 SE	641	88	<50	.12	180
9,700 SE	661	95	<50	.10	200
9,725 SE	672	90	<50	.10	180
9,750 SE	661	89	NS	NS	NS
9,775 SE	643	85	<50	.10	180
9,800 SE	627	88	<50	.12	200
9,825 SE	616	93	<50	.11	190
9,850 SE	610	88	<50	.14	180
9,875 SE	583	94	<50	.36	210
9,900 SE	557	93	<50	.10	170
9,925 SE	537	111	<50	.29	220
9,950 SE	553	109	<50	.11	170
9,975 SE	523	102	<50	.13	180
10,000 SE	508	83	<50	.17	190
LINE 10,300 NE					
9,500 SE	632	96	NS	NS	NS
9,525 SE	611	101	NS	NS	NS
9,550 SE	622	102	NS	NS	NS
9,575 SE	630	108	NS	NS	NS
9,600 SE	685	116	NS	NS	NS
9,625 SE	694	124	NS	NS	NS
9,650 SE	868	115	NS	NS	NS
9,675 SE	636	117	NS	NS	NS
9,700 SE	576	86	NS	NS	NS
9,725 SE	586	99	NS	NS	NS
9,750 SE	569	96	NS	NS	NS
9,775 SE	545	114	NS	NS	NS
9,800 SE	544	190	NS	NS	NS
9,825 SE	626	204	NS	NS	NS
9,850 SE	816	214	NS	NS	NS
9,875 SE	527	220	NS	NS	NS
9,900 SE	518	147	NS	NS	NS
9,925 SE	519	134	NS	NS	NS
9,950 SE	511	110	NS	NS	NS
9,975 SE	489	93	NS	NS	NS
10,000 SE	501	92	NS	NS	NS

NS No sample, NR No reading.
[1]Total-field magnetic intensity, all readings have a base of 56,000 gammas.
[2]Total-count gamma-ray radiation.
[3]Soil sample analyses by XRF by Bureau's Reno Research Center, Reno, NV.

RESULTS OF MAGNETIC,[1] RADIOMETRIC,[2] AND SOIL SAMPLE[3] SURVEYS—Continued

Station	Magnetic intensity, gammas	Radioactivity, cps	Cb, ppm	P_2O_5, pct	Zn, ppm
LINE 10,400 NE					
9,500 SE ...	580	86	<50	0.19	180
9,525 SE ...	571	88	<50	.16	190
9,550 SE ...	581	92	<50	.13	180
9,575 SE ...	576	92	<50	.13	190
9,600 SE ...	645	96	<50	.13	190
9,625 SE ...	738	113	<50	.77	210
9,650 SE ...	1081	109	<50	.32	220
9,675 SE ...	887	174	NS	NS	NS
9,700 SE ...	576	149	250	5.40	460
9,725 SE ...	545	112	<50	.29	180
9,750 SE ...	397	105	<50	.28	230
9,775 SE ...	504	98	<50	.17	170
9,800 SE ...	548	98	<50	.20	200
9,825 SE ...	560	106	<50	.13	170
9,850 SE ...	582	133	<50	.26	210
9,875 SE ...	602	167	<50	.56	330
9,900 SE ...	560	250	180	2.60	1160
9,925 SE ...	507	179	<50	.52	280
9,950 SE ...	510	189	70	.89	320
9,975 SE ...	511	124	<50	.31	290
10,000 SE .	532	100	<50	.20	200
LINE 10,500 NE					
9,500 SE ...	582	94	NS	NS	NS
9,525 SE ...	551	91	NS	NS	NS
9,550 SE ...	539	86	NS	NS	NS
9,575 SE ...	636	81	NS	NS	NS
9,600 SE ...	624	87	NS	NS	NS
9,625 SE ...	659	103	NS	NS	NS
9,650 SE ...	677	108	NS	NS	NS
9,675 SE ...	608	159	NS	NS	NS
9,700 SE ...	587	112	NS	NS	NS
9,725 SE ...	586	107	NS	NS	NS
9,750 SE ...	595	90	NS	NS	NS
9,775 SE ...	594	87	NS	NS	NS
9,800 SE ...	585	90	NS	NS	NS
9,825 SE ...	593	98	NS	NS	NS
9,850 SE ...	591	174	NS	NS	NS
9,875 SE ...	631	208	NS	NS	NS
9,900 SE ...	591	196	NS	NS	NS
9,925 SE ...	601	188	NS	NS	NS
9,950 SE ...	545	165	NS	NS	NS
9,975 SE ...	527	139	NS	NS	NS
10,000 SE .	521	100	NS	NS	NS
LINE 10,600 NE					
9,500 SE ...	541	86	<50	0.18	200
9,525 SE ...	547	101	<50	.17	200
9,550 SE ...	553	102	<50	.22	200
9,575 SE ...	592	90	<50	.21	220
9,600 SE ...	715	92	<50	.16	190
9,625 SE ...	954	99	<50	.28	210
9,650 SE ...	1159	127	<50	5.10	480
9,675 SE ...	722	142	480	1.85	290
9,700 SE ...	593	98	270	.26	220
9,725 SE ...	540	97	<50	.17	200
9,750 SE ...	555	99	<50	.22	230
9,775 SE ...	568	98	<50	.20	170
9,800 SE ...	586	87	<50	.22	190
9,825 SE ...	612	83	<50	.16	160
9,850 SE ...	671	95	<50	.26	250
9,875 SE ...	558	86	<50	.25	250
9,900 SE ...	560	77	<50	.36	170
9,925 SE ...	556	81	<50	.21	180
9,950 SE ...	553	76	<50	.25	200
9,975 SE ...	543	83	<50	.24	230
10,000 SE .	563	83	<50	.18	190

Station	Magnetic intensity, gammas	Radioactivity, cps	Cb, ppm	P_2O_5, pct	Zn, ppm
LINE 10,700 NE					
9,500 SE ...	540	73	NS	NS	NS
9,525 SE ...	537	75	NS	NS	NS
9,550 SE ...	527	78	NS	NS	NS
9,575 SE ...	521	73	NS	NS	NS
9,600 SE ...	508	74	NS	NS	NS
9,625 SE ...	507	70	NS	NS	NS
9,650 SE ...	498	81	NS	NS	NS
9,675 SE ...	545	79	NS	NS	NS
9,700 SE ...	548	78	NS	NS	NS
9,725 SE ...	535	73	NS	NS	NS
9,750 SE ...	543	81	NS	NS	NS
9,775 SE ...	576	86	NS	NS	NS
9,800 SE ...	694	84	NS	NS	NS
9,825 SE ...	900	63	NS	NS	NS
9,850 SE ...	951	71	NS	NS	NS
9,875 SE ...	712	62	NS	NS	NS
9,900 SE ...	548	60	NS	NS	NS
9,925 SE ...	521	63	NS	NS	NS
9,950 SE ...	519	63	NS	NS	NS
9,975 SE ...	530	63	NS	NS	NS
10,000 SE .	507	61	NS	NS	NS
LINE 10,800 NE					
9,500 SE ...	567	78	NS	NS	NS
9,525 SE ...	568	81	NS	NS	NS
9,550 SE ...	592	79	NS	NS	NS
9,575 SE ...	633	75	NS	NS	NS
9,600 SE ...	662	73	NS	NS	NS
9,625 SE ...	600	82	NS	NS	NS
9,650 SE ...	557	104	NS	NS	NS
9,675 SE ...	545	101	NS	NS	NS
9,700 SE ...	544	88	NS	NS	NS
9,725 SE ...	532	65	NS	NS	NS
9,750 SE ...	564	62	NS	NS	NS
9,775 SE ...	594	87	NS	NS	NS
9,800 SE ...	643	71	NS	NS	NS
9,825 SE ...	764	60	NS	NS	NS
9,850 SE ...	701	57	NS	NS	NS
9,875 SE ...	655	NR	NS	NS	NS
9,900 SE ...	591	66	NS	NS	NS
9,925 SE ...	594	63	NS	NS	NS
9,950 SE ...	567	61	NS	NS	NS
9,975 SE ...	568	62	NS	NS	NS
10,000 SE .	544	62	NS	NS	NS
LINE 10,900 NE					
9,500 SE ...	555	83	<50	0.26	210
9,525 SE ...	559	90	<50	.13	190
9,550 SE ...	577	88	<50	.13	200
9,575 SE ...	651	84	<50	.14	200
9,600 SE ...	735	85	<50	.13	190
9,625 SE ...	909	79	<50	.25	200
9,650 SE ...	962	84	<50	.15	180
9,675 SE ...	589	84	<50	.17	180
9,700 SE ...	572	89	<50	.15	180
9,725 SE ...	581	87	<50	.10	180
9,750 SE ...	557	114	<50	.23	220
9,775 SE ...	574	117	<50	.39	390
9,800 SE ...	587	90	<50	.20	210
9,825 SE ...	608	81	<50	.14	160
9,850 SE ...	607	79	<50	.19	180
9,875 SE ...	588	72	<50	.13	180
9,900 SE ...	736	82	<50	.25	280
9,925 SE ...	724	86	340	2.43	390
9,950 SE ...	566	140	<50	1.05	220
9,975 SE ...	546	91	100	.21	260
10,000 SE .	549	85	<50	.38	230

NS No sample, NR No reading.
[1]Total-field magnetic intensity, all readings have a base of 56,000 gammas.
[2]Total-count gamma-ray radiation.
[3]Soil sample analyses by XRF by Bureau's Reno Research Center, Reno, NV.

RESULTS OF MAGNETIC,[1] RADIOMETRIC,[2] AND SOIL SAMPLE[3] SURVEYS—Continued

Station	Magnetic intensity, gammas	Radioactivity, cps	Cb, ppm	P_2O_5, pct	Zn, ppm
		LINE 11,000 NE			
9,500 SE	558	82	NS	NS	NS
9,525 SE	554	82	NS	NS	NS
9,550 SE	577	89	NS	NS	NS
9,575 SE	575	93	NS	NS	NS
9,600 SE	646	86	NS	NS	NS
9,625 SE	700	97	NS	NS	NS
9,650 SE	802	95	NS	NS	NS
9,675 SE	614	87	NS	NS	NS
9,700 SE	571	79	NS	NS	NS
9,725 SE	556	80	NS	NS	NS
9,750 SE	545	76	NS	NS	NS
9,775 SE	563	76	NS	NS	NS
9,800 SE	569	79	NS	NS	NS
9,825 SE	577	74	NS	NS	NS
9,850 SE	592	80	NS	NS	NS
9,875 SE	623	81	NS	NS	NS
9,900 SE	687	82	NS	NS	NS
9,925 SE	775	83	NS	NS	NS
9,950 SE	784	79	NS	NS	NS
9,975 SE	802	79	NS	NS	NS
10,000 SE	549	78	NS	NS	NS
10,025 SE	544	75	NS	NS	NS
		LINE 11,100 NE			
9,500 SE	523	83	<50	0.17	200
9,525 SE	507	93	<50	.20	200
9,550 SE	506	85	<50	.14	200
9,575 SE	520	90	<50	.15	180
9,600 SE	536	85	<50	.10	190
9,625 SE	562	87	<50	.19	240
9,650 SE	562	84	<50	.15	190
9,675 SE	624	85	<50	.12	180
9,700 SE	771	82	<50	.11	190
9,725 SE	946	86	<50	.15	190
9,750 SE	660	85	<50	.18	190
9,775 SE	585	78	<50	.15	200
9,800 SE	566	82	<50	.14	210
9,825 SE	580	86	<50	.10	200
9,850 SE	573	87	<50	.12	200
9,875 SE	580	82	<50	.17	210
9,900 SE	611	88	<50	.15	200
9,925 SE	594	86	<50	.20	200
9,950 SE	613	84	<50	.14	190
9,975 SE	599	82	<50	.17	190
10,000 SE	600	75	<50	.21	190
10,025 SE	595	NR	<50	.18	180
10,050 SE	551	NR	NS	NS	NS
10,075 SE	530	NR	NS	NS	NS
10,100 SE	539	NR	NS	NS	NS
		LINE 11,200 NE			
9,500 SE	547	84	NS	NS	NS
9,525 SE	550	81	NS	NS	NS
9,550 SE	536	90	NS	NS	NS
9,575 SE	530	88	NS	NS	NS
9,600 SE	543	92	NS	NS	NS
9,625 SE	557	85	NS	NS	NS
9,650 SE	600	82	NS	NS	NS
9,675 SE	650	80	NS	NS	NS
9,700 SE	808	82	NS	NS	NS
9,725 SE	625	87	NS	NS	NS
9,750 SE	498	92	NS	NS	NS
9,775 SE	506	77	NS	NS	NS
9,800 SE	508	78	NS	NS	NS
9,825 SE	515	70	NS	NS	NS
9,850 SE	529	79	NS	NS	NS
9,875 SE	528	82	NS	NS	NS
9,900 SE	543	82	NS	NS	NS
9,925 SE	540	88	NS	NS	NS
9,950 SE	544	87	NS	NS	NS
9,975 SE	522	82	NS	NS	NS
10,000 SE	518	76	NS	NS	NS
10,025 SE	527	78	NS	NS	NS
10,050 SE	527	77	NS	NS	NS
10,075 SE	527	78	NS	NS	NS
10,100 SE	526	75	NS	NS	NS
10,125 SE	519	77	NS	NS	NS
10,150 SE	522	80	NS	NS	NS
10,175 SE	522	75	NS	NS	NS
10,200 SE	521	81	NS	NS	NS
		LINE 11,300 NE			
9,500 SE	523	70	<50	0.17	200
9,525 SE	524	66	<50	.16	190
9,550 SE	516	75	<50	.15	190
9,575 SE	521	70	<50	.19	190
9,600 SE	525	69	<50	.16	200
9,625 SE	528	70	<50	.15	200
9,650 SE	540	68	<50	.21	220
9,675 SE	536	65	<50	.14	220
9,700 SE	540	71	<50	.13	180
9,725 SE	551	77	<50	.14	180
9,750 SE	519	65	<50	.15	210
9,775 SE	528	77	<50	.12	190
9,800 SE	530	76	<50	.13	200
9,825 SE	526	76	<50	.15	200
9,850 SE	535	83	<50	.11	190
9,875 SE	540	87	<50	.20	200
9,900 SE	535	81	<50	.14	200
9,925 SE	527	66	<50	.14	190
9,950 SE	525	75	<50	.16	180
9,975 SE	516	82	<50	.17	200
10,000 SE	549	81	<50	.16	200
10,025 SE	531	73	<50	.18	190
10,050 SE	532	74	<50	.16	190
10,075 SE	538	76	<50	.16	190
10,100 SE	528	88	<50	.17	190
10,125 SE	527	81	<50	.20	190
10,150 SE	556	85	<50	.13	190
10,175 SE	565	76	<50	.15	200
10,200 SE	545	76	<50	.14	180
		LINE 11,500 NE			
9,500 SE	540	69	NS	NS	NS
9,525 SE	528	69	NS	NS	NS
9,550 SE	533	69	NS	NS	NS
9,575 SE	528	77	NS	NS	NS
9,600 SE	519	77	NS	NS	NS
9,625 SE	520	82	NS	NS	NS
9,650 SE	519	84	NS	NS	NS
9,675 SE	522	81	NS	NS	NS
9,700 SE	530	82	NS	NS	NS
9,725 SE	541	74	NS	NS	NS
9,750 SE	533	79	NS	NS	NS
9,775 SE	537	85	NS	NS	NS
9,800 SE	532	85	NS	NS	NS
9,825 SE	530	84	NS	NS	NS
9,850 SE	514	85	NS	NS	NS
9,875 SE	511	80	NS	NS	NS
9,900 SE	512	82	NS	NS	NS
9,925 SE	502	77	NS	NS	NS
9,950 SE	506	77	NS	NS	NS
9,975 SE	510	76	NS	NS	NS
10,000 SE	511	75	NS	NS	NS
10,025 SE	533	81	NS	NS	NS
10,050 SE	527	81	NS	NS	NS
10,075 SE	521	79	NS	NS	NS
10,100 SE	521	81	NS	NS	NS
10,125 SE	514	87	NS	NS	NS
10,150 SE	531	88	NS	NS	NS
10,175 SE	535	80	NS	NS	NS
10,200 SE	532	81	NS	NS	NS
10,225 SE	532	85	NS	NS	NS
10,250 SE	539	81	NS	NS	NS
10,275 SE	531	79	NS	NS	NS
10,300 SE	535	78	NS	NS	NS
10,325 SE	531	82	NS	NS	NS
10,350 SE	530	64	NS	NS	NS
10,375 SE	531	69	NS	NS	NS
10,400 SE	535	72	NS	NS	NS

NS No sample, NR No reading.
[1]Total-field magnetic intensity, all readings have a base of 56,000 gammas.
[2]Total-count gamma-ray radiation.
[3]Soil sample analyses by XRF by Bureau's Reno Research Center, Reno, NV.

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