CONCENTRATIONS OF COBALT AND OTHER METALS IN THE WESTERN CRAZY MOUNTAINS, INTERIOR ALASKA

by James C. Barker

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William P. Clark, Secretary

OF MINES

C. Horton, Director

PREFACE

The Bureau of Mines mission is to help insure that the supply of minerals is adequate to meet the Nation's needs at acceptable costs. The Bureau's Alaska Field Operations Center is currently reviewing and investigating numerous reported occurrences of critical and strategic minerals in Alaska. Many minerals that are obtained from foreign sources, and for which no satisfactory domestic substitutes are known, are essential to industry and defense. Minerals of this type are termed critical and strategic. This report discusses studies of cobalt in the western Crazy Mountains and is one of several on Alaska's critical and strategic mineral resources by the Bureau's Alaska Field Operations Center.

TABLE OF CONTENTS

	Page
Abstract	1
Introduction	2
Acknowledgments	2
Location and access	4
History and land status	4
Physiography and climate	5
Geology	6
Bureau of Mines reconnaissance	6
Outcrop mapping and description	8
Sampling procedures	11
Description of occurrences	12
Location A	12
Location B	14
Location C	20
Location D	22
Location E	26
Location F	30
Location G	30
Other locations	41
Summary and recommendations	41
References	43
Appendix.--Sample key	44

ILLUSTRATIONS

1. Location map 3

ILLUSTRATIONS--Continued

		Page
2.	Conformable contact of black shale and white quartzite along north shore of Preacher Creek........................	7
3.	Outcrop map of study area....................................	9
4.	Geology and sample locations at location A................	13
5.	Geology and sample locations at location B................	16
6.	Thrust faulted conglomerate overlying shale/graywacke unit..	17
7.	Altered fault zone at location C...........................	21
8.	Geology and sample locations at location D................	24
9.	Geology and mineral investigation of location E...........	27
10.	Ground water seep at location F............................	31
11.	Location of additional stream sediment and soil samples in the western Crazy Mountains............................	33
12.	Location of additional rock samples in the western Crazy Mountains..	40

TABLES

1.	Analytical results of soil, stream sediment, and rock samples from location A.....................................	15
2.	Analytical results of soil, steam sediment, and rock samples from location B.....................................	18
3.	Multi-element analyses of spring sediment and precipitates from location B...............................	19
4.	Analyses of spring water from location B..................	19

TABLES--Continued

Page

5. Analytical results of rock and soil samples from location C.. 23

6. Analytical results of soil, stream sediment, and rock samples from location D.................................... 25

7. Analytical results of soil and stream sediment samples from location E... 28

8. Analyses of spring sediment at location F.................... 32

9. Analytical results of additional soil and stream sediment samples from various locations in the western Crazy Mountains.. 34

10. Analytical results of additional rock samples from various locations in the western Crazy Mountains............ 39

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	ppb	parts per billion
in	inch	ppm	parts per million
oz/ton	ounces per ton	yr	year
pct	percent		

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By James C. Barker [1]

ABSTRACT

The U.S. Bureau of Mines made a reconnaissance in the western Crazy Mountains for cobalt and associated metals as part of the Alaska-wide critical and strategic metals program. The area, located about 75 miles north of Fairbanks in central Alaska, is underlain by complexly faulted, predominantly clastic sedimentary rocks bordering the Tintina Fault system. Above background metal concentrations were found to occur in altered fault zones, tectonic breccias, soils, and ground water seeps and precipitates that either cut or are derived from the faulted clastic sedimentary rocks. Up to 0.115 pct cobalt and more than 2.0 pct zinc were detected in soil samples. Spring precipitates contained up to 1.3 pct zinc, 0.037 pct tungsten, and other metals. Some localities lacked cobalt but contained anomalous amounts of copper, lead, zinc, silver, and other metals. No outcropping of primary metallic minerals was located because of colluvium and vegetation cover and extensive deep leaching. Therefore, whether the metal values encountered are due to primary deposits with economic development potential or are the results of concentration by ground water from low-grade sources is unknown. The presence of cobalt, nickel, and zinc, and the identification of minor tin and tungsten indicate that further investigation is warranted.

[1] Supervisory physical scientist, Alaska Field Operations Center, Bureau of Mines, Fairbanks, AK.

INTRODUCTION

In 1977 and 1978 a group of hills located west of the Crazy Mountains (fig. 1) was one of many areas investigated by the Bureau of Mines Alaska Field Operations Center (AFOC) as part of a general mineral assessment of lands selected for inclusion within proposed Alaska national interest land classifications (ANILCA, P.L. 96-487). These areas were selected for mineral examination on the basis of a variety of data ranging from verbal reports to published literature. The western Crazy Mountains were examined because of the presence of inactive lode mineral claims.

The 1977 and 1978 work indicated strongly anomalous concentrations of copper, cobalt, zinc, nickel, tin, tungsten, and other metals (1).[2]

[2]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

Since cobalt is one of the target elements of the Bureau's on-going critical and strategic minerals project and is one of the elements indicated to occur in the area, a more detailed surficial examination was made in 1981. Follow-up work was completed in 1982. This report summarizes the Bureau's findings to date.

ACKNOWLEDGMENTS

K. H. Clautice, geologist, formerly with the Bureau, assisted the author and conducted geologic field work in the area during 1977 and 1978. J. Y. Foley, geologist with the Bureau, performed the petrographic studies. Special appreciation is extended to F. R. Weber, of the U.S. Geological Survey (USGS), whose helpful advice and geologic knowledge of interior Alaska greatly assisted this project from the outset in 1977.

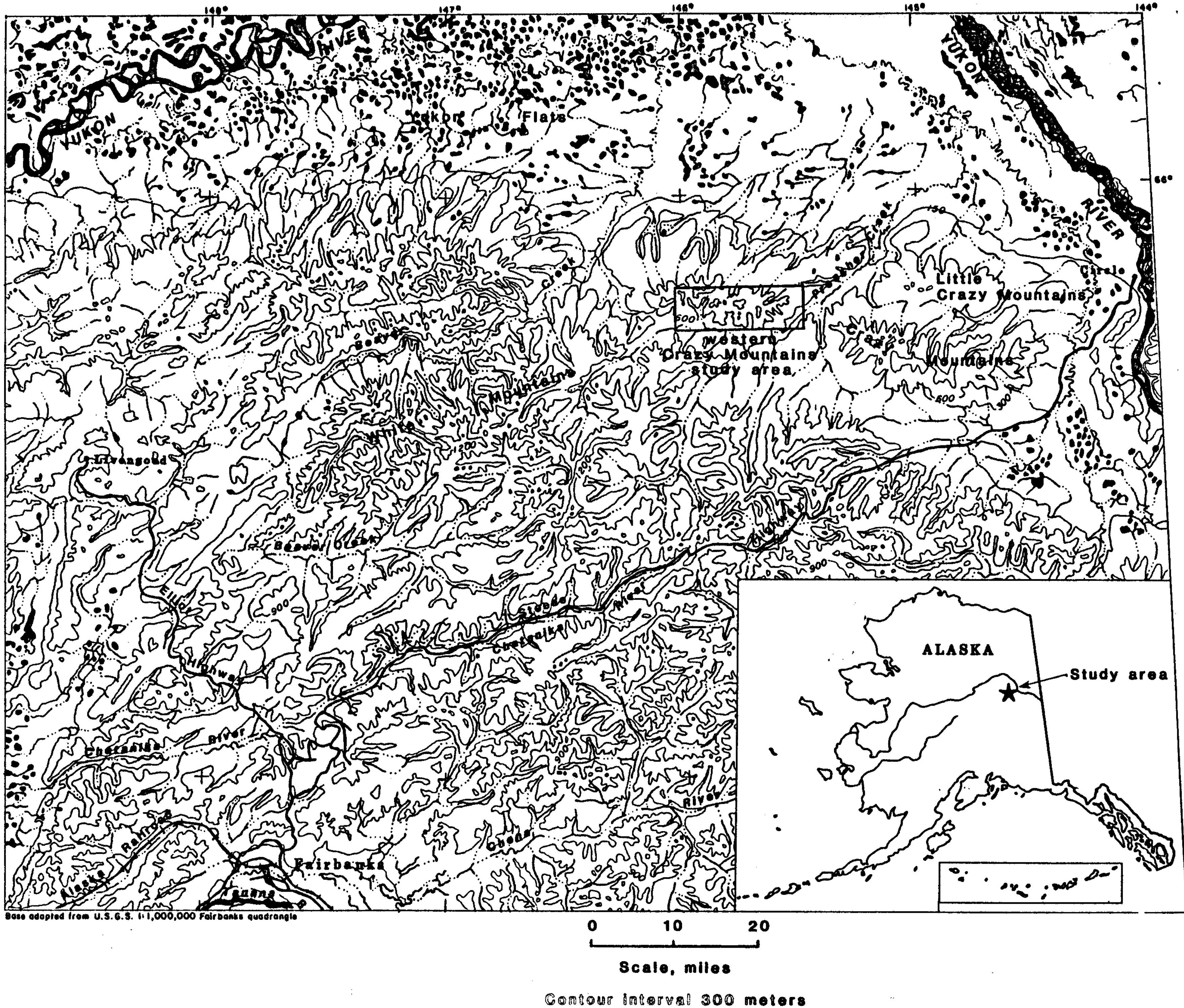


FIGURE 1. - Location map

LOCATION AND ACCESS

The report area consists of a group of unnamed hills located west of the Crazy Mountains, approximately 75 miles north of Fairbanks, in interior Alaska. For the purposes of this report these unnamed hills will be referred to as the western Crazy Mountains. Topographic maps covering the area are the D-4 and D-5, 1:63,360 sheets of the USGS Circle Quadrangle.

The area is relatively inaccessible. There are no overland routes into the region. Summer access is limited to float plane landing sites approximately 5 miles northwest of the hills or to helicopter. Due to the dense forest and brush growth, the availability of natural helicopter landing sites is limited to only the higher hilltops and to gravel bars along Preacher Creek. Because of the dense brush and extreme insect populations, it is recommended that future work be scheduled either before the foliage blooms in the spring or during late summer. The most practical supply and logistical center which can serve the area is Fairbanks. Charter helicopter service, communications, and lodging are also available at the village of Circle, located 50 miles to the east of the study area.

HISTORY AND LAND STATUS

The occurrence or potential for mineral resources in the western Crazy Mountains and vicinity was unknown prior to this study. The only documented report of exploration activity was the location of mining claims by Earth Resources Inc. in 1970.[3] The claims were subsequently allowed to lapse and no information is available as to the nature of the discovery.

[3]Claim records on file with the Alaska Department of Natural Resources, Division of Mining, 794 University Avenue, Fairbanks, AK.

There is no published geologic map, although reconnaissance-level 1:250,000 scale mapping is in preparation by the USGS.[4]

[4]USGS Alaska Mineral Resource Assessment Program (AMRAP), Circle Quadrangle in progress. Direct inquiries to H. Foster, principal investigator, 345 Middlefield Rd, Menlo Park, CA.

The entire area is presently withdrawn from mineral entry and included within the White Mountains National Recreation Area. The Bureau of Land Management (BLM) under Alaska National Interest Lands Conservation Act (ANILCA, P.L. 96-487) is responsible for land-use policy and disposition of natural resources in the area.

PHYSIOGRAPHY AND CLIMATE

The western Crazy Mountains are a deeply incised, low range of rounded hills with elevations ranging from 1,000 ft at the base to 3,536 ft at their highest point. The hills form a drainage divide between the Yukon Flats to the north and Preacher Creek to the south. Valleys are V-shaped and there is no evidence of glaciation. The area is well drained by clear-water, gravel-bottomed streams. Bedrock in the area is intensely faulted. There are numerous side-hill seeps and springs, some of which are red-stained due to the iron content of the ground water.

Weathering of bedrock and resultant accumulations of colluvium are extensive, particularly on the lower slopes. Rock outcrops are rare and the few that occur are very weathered. Permafrost was encountered at all sampling sites and appears to be continuous except for a few of the higher, southern exposures.

Vegetation, composed of spruce, alder, and birch forest, is very dense with thick undergrowths of brush. Only the higher ridges rise above the tree line and are typified by tundra and soil with frost-heaved rock.

The climate is continental, typical of interior Alaska with extreme variations in temperatures. The region was found to be free of snow from early May until late September. There are no weather records for the area, but precipitation is relatively light, approximately 10 in/yr.

GEOLOGY

The western Crazy Mountains are composed of a complexly faulted succession of predominantly clastic, weakly metamorphosed sedimentary rocks. They have either been intruded by or are in fault contact with mafic sills, dikes, and at least several small intrusive, stock-like bodies. At the present there is no stratigraphic correlation of the rock units, no formational names are assigned, and no age control is available.

The western Crazy Mountains are one of several fault-bounded blocks that possibly have shifted from the east by movement on the Tintina Fault System (2). Thus, no geologic continuity is expected either to the north or south; however repeated sequences of at least some of these rock units may be found to the east and west (for example, in the Crazy Mountains or Little Crazy Mountains). The western Crazy Mountains are bounded along the south by the prominent Preacher Creek Fault (3), a splay of the Tintina Fault. Displacement along the Tintina Fault appears responsible for the intense and complex faulting and repeated thrust sequences of the local sedimentary units (fig. 2).

BUREAU OF MINES RECONNAISSANCE

Field investigations by the Bureau included outcrop and rubble mapping and sampling of rocks, soils, and stream sediments. Brief field descriptions of the interpreted rock units are presented in conjunction with

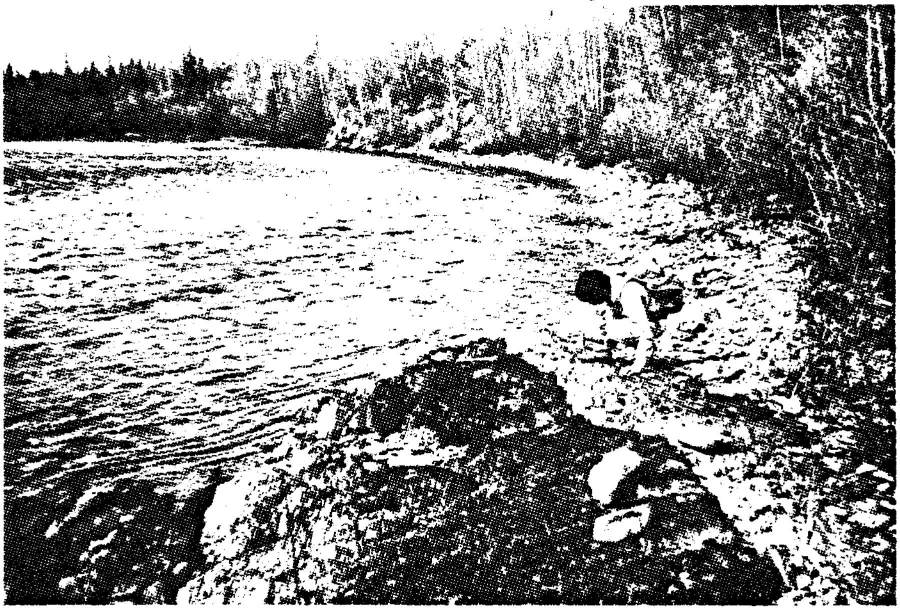


FIGURE 2. - Conformable contact of black shale and white quartzite along north shore of Preacher Creek. Note extensive shearing due to the immediate proximity to the Tintina Fault. In this area the north side of the fault is apparently undergoing minor uplift and exposing outcrops in this manner.

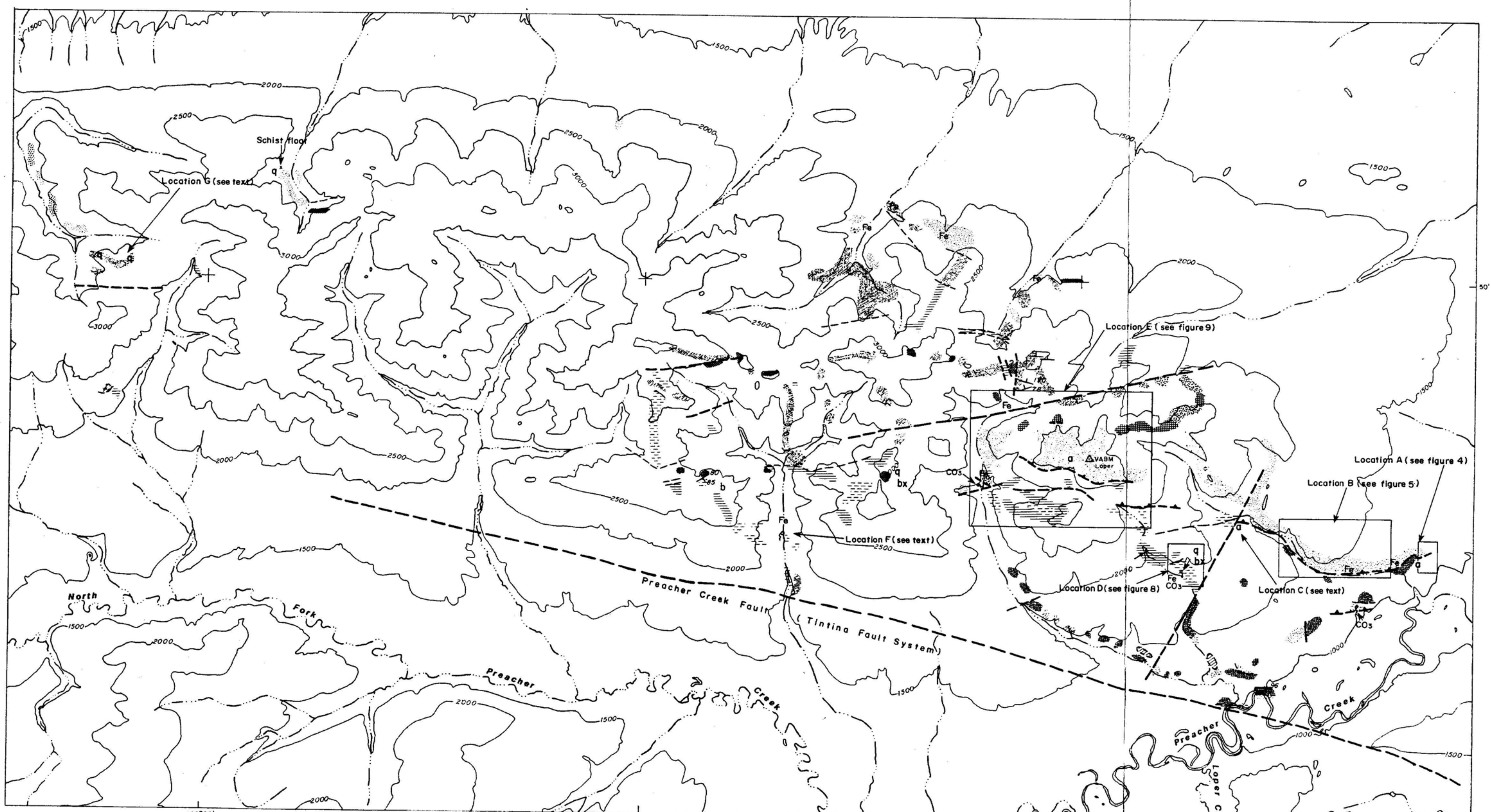
outcrop and sample locations, and locations of alteration features such as iron-staining and brecciation (fig. 3). No attempt was made to provide a continuous bedrock map of the study area or to delineate stratigraphic succession. This work is currently in progress as part of the USGS Alaska Mineral Resources Assessment Program (AMRAP). A total of 47 rock samples, 68 soil samples, and 119 stream and spring sediment samples were collected during the 1977 and 1978 and the 1981 and 1982 field studies. Analytical data from the combined sample sets are presented in tables 1-10. Specific areas (A through G) where mineralization was suggested by field observations and sampling are discussed in the following sections of the report.

OUTCROP MAPPING AND DESCRIPTION

A sedimentary sequence comprised of at least four mappable units of unknown structural and age relations and isolated igneous rocks were recognized. The structural relationship of poorly exposed isolated outcrops of andesitic volcanic rocks, stock-like bodies of porphyritic andesite, and greenstone sills to the sedimentary sequence is unknown. There is a spatial association of the mafic sills to the chert, argillite, and shale unit (unit 4), but evidence of intrusive contacts with these rocks is unclear.

Unit 1

The first unit is a polymictic clastic sequence composed primarily of conglomerate containing pebbles of quartz, green, gray, and lesser black chert, minor quartzite and green argillite, and rare mafics. Pebbles rarely exceed 1 in and are generally rounded although local strata of angular to sub-angular clasts were observed. The conglomerate typically has a sandy to siliceous matrix and is more resistant to weathering than



Base adapted from U.S.G.S. 1:63,360 Circle (D-4, D-5) quadrangle

N

0 0.5 1

Scale, mile

Contour interval 500 feet

FIGURE 3. - Outcrop map of study area

LEGEND

High level TQg gravels

Unit 1

Conglomerate - Typically comprising a poorly sorted chert-to polymictic-pebble composition. Clasts include vein quartz, quartzite, green argillite, and mafic rock. Dominant pebble size does not exceed 1 in. Rhythmically bedded sandstone and siltstone occur. Matrix of the conglomerate is sand, locally calcareous north of VABM Loper. Unaltered conglomerate will break across clasts. Some areas of stretch pebble texture were noted.

Sandstone

Siltstone

Calcareous sandstone, sandy limestone, and conglomerate with a carbonate matrix.

Unit 2

Gray to white, resistant and massive quartzite which generally lacks bedding and locally contains mica and black chert grains.

Gray to black shale interbedded with quartzite described above.

Unit 3

Limestone which forms massive white-weathering outcrops. The unit appears to be in fault contact with other units within the map area. The limestone is very similar to the Tolovana Limestone of the Livengood area as mapped by Chapman and others (3).

Unit 4

Tan and gray to green chert and olive-colored argillite, black shale grading to phyllite.

Gray to black shale often found adjoining outcrops of chert and argillite. Shale is very recessive and locally is also ferruginous and/or carbonaceous. Isolated outcrops may more closely correlate to the shale unit described above.

Shale of uncertain association. Primarily gray to black in color and includes argillite, graywacke, and claystone. May represent several diverse units. It is locally silicified and grades to phyllite.

Igneous Rocks

Mafic intrusive and extrusive rocks, includes amygdaloidal basalt, andesite to andesite porphyry, and greenstone. Diagonal pattern indicates intrusive mafic rocks.

a	Hydrothermal alteration
bx	Boxwork gossan
Fe	Iron staining in creek beds
q	Quartz veining
b	Brecciation

Inferred contact, projected where possible on basis of aerial photography

Fault, dashed where inferred

Trace of inferred thrust fault

Strike and dip of bedding

Spring (CO_3 indicates carbonate)

the associated interbedded sandstone and siltstone strata, thereby resulting in prominent escarpments. Locally this unit is calcareous and limonite-stained, particularly north of VABM Loper. Echinoderm and shell fossils were found on the ridge 3,000 ft northeast of VABM Loper during the 1982 investigations. A probable age interpretation of Upper Devonian-Carboniferous(?) was made.[5]

[5] Identification made by J. T. Dutro, USGS, U.S. National Museum, Washington, DC. Report available from J.C. Barker, Bureau of Mines, Fairbanks, AK.

Unit 2

This second unit is composed of massive, bluff-forming, white quartzite with minor proportions of white mica and black chert grains. It is found primarily along the southern front of the hills (figs. 2-3). The quartzite is interbedded with gray to black shale horizons and includes greenstone sills near Preacher Creek.

Unit 3

The third unit comprises white-weathering, massive gray limestone that mantles some of the higher ridges and appears to be only in fault contact with the other units. This limestone is tentatively correlated with the similar-appearing Silurian to Devonian Tolovana Limestone to the west. The Tolovana Limestone has been most recently described by Chapman and others (4).

Unit 4

The fourth unit is made up of a variable sequence of gray to green cherts, olive-colored argillites, black to gray laminated shales, phyllites, and minor graywacke. Much of the shale of unknown association shown on figure 3 may belong to this unit.

SAMPLING PROCEDURES

Stream sediment samples were obtained with a steel shovel from silty gravels taken from the center of active creek channels. Organic material was avoided. Approximately 0.5 lb of finer grain sediment was placed directly into water-resistant paper bags, air-dried, and screened at minus 80 mesh. The minus 80-mesh fraction was then pulverized prior to analytical procedures described below. Soil samples were collected from mixed mineral soil and rock chips and processed similarly to stream sediment samples. Rock samples consist of random chips generally collected within a few feet of the sample station. Rocks were pulverized and analyzed by procedures described in tables 1, 2, 5, 6, 10. Descriptions of samples listed in each table are taken from field notes, supplemented as required by thin section examination.

Sample data presented in this report include analytical results from earlier sampling (1977-1978) as well as 1981-1982. Various laboratories performing analyses are indicated on tables 1-10. Neutron activation (cobalt, zinc, manganese, iron) and X-ray fluorescence (silver, cadmium, copper, nickel, lead, tin, tungsten) analyses of some 1978 Bureau sample splits were provided and published by the Department of Energy (5-6).

Since a variety of laboratories and analytical procedures were used, it was not possible to utilize standard statistical methods to determine background and anomalous elemental values. Levinson states that the average cobalt content is 20 ppm for shales abd 4ppm for limestone while the earth's crust averages 25 ppm (7, p. 43). A range from 1 to 40 ppm is normally encountered in soil samples. For the purposes of this report 60 ppm was arbitrarily chosen as representing an anomalous cobalt concentration. Values for other elements are cited in the text where the values are clearly well above normal background levels as cited by Levinson.

DESCRIPTION OF OCCURRENCES

Weathering and leaching have been extensive in the western Crazy Mountains and these processes have been uninterrupted by glaciation. Sulfide minerals, if present in the area, would have been long since removed from surface rocks. The presence of sulfides, however, is indicated by fault-controlled seeps of metal-precipitating ground water, by gossans and boxworks with anomalous metal values, and by quartz veining and extensive hydrothermal and argillic alteration.

Areas containing metal concentrations in soil, water, or rock were found frequently underlain by unit 1 which is composed of chert to polymictic pebble conglomerates, sandstones, and siltstone. Geochemical data indicated that hydrothermally altered fault zones in the conglomerate are suspected hosts of some mineralized material. Specifically of interest was a northwest-trending fault contact (interpreted as a thrust) between the conglomerate and the underlying shale of unknown unit association (see locations A, B, C, and E, fig. 3). Other fault or shear zones are indicated to warrant further investigation. At location D, and possibly at F and G (fig. 3), cobalt, zinc, nickel, and to a lesser extent, copper enrichment appeared associated with tectonic breccias in unit 4.

Location A

Silicified chert-pebble conglomerate (unit 1) exposed on a hillside overlies an altered zone inferred as a thrust fault (fig. 4). Disseminated grains in the silica matrix were tentatively identified as chromite

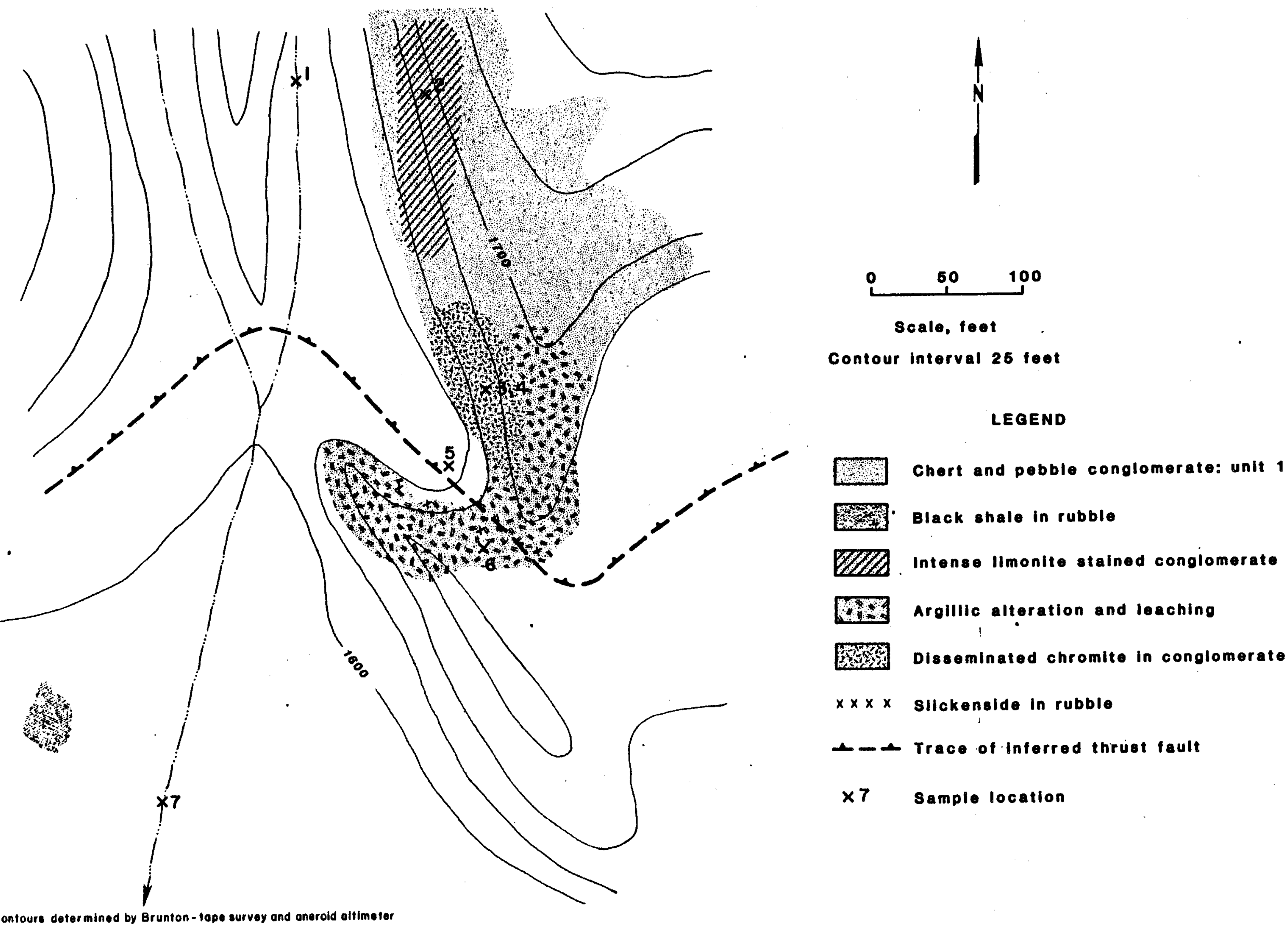


FIGURE 4. - Geology and sample locations at location A

(sample 3). Petrographic examination indicated that sericite in the matrix and halos of fuchsite (chrome mica) around the chromite grains have developed as alteration products.

The conglomerate exposure is bounded on the south by a zone of pervasive argillic alteration, sericite, hematite, and minor boxworks. In thin section the argillic rock (sample 6) appears originally to have been fine-grained graywacke. Breccia and slickenside rubble indicated a probable fault contact in the area. It could not be determined if the fine-grained rock was interlayered with the conglomerate or a separate unit.

North of the chromite(?)-bearing conglomerate is a pervasively iron-stained zone of conglomerate with interstitial cavities possibly formed by the leaching of pyrite.

Although no concentrations of economic metals were found in samples collected from location A (see table 1), the exposures provide an example of the type and degree of alteration that has occurred along the inferred thrust fault zone (see fig. 3).

Location B

Seeps occurring along the buried thrust (?) fault contact of the conglomerate (unit 1) and underlying black shale (possibly of unit 4) (figs. 5-6) contain concentrations of cobalt, copper, tungsten, and zinc in sediments and ferricrete precipitates (samples 15-19, tables 2-4). Sample 24A also contains a concentration of lead and nickel and tin was detected in sample 16. Ground water, colored red due to iron content and deposits layers of iron precipitate where it emanates onto the surface at the base of the slope. Scattered rubble of conglomerate found at the toe of the slope (fig. 5) were typically iron-stained and exhibited local

TABLE 1. - Analytical results[1] of soil, stream sediment, and rock samples from location A

mple	Ag, ppm	As, ppm	Co, ppm	Cu, ppm	Cr, ppm	Mo, ppm	Ni, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
....	2.6	NA	13	33	NA	ND	NA	26	NA	NA	79	Sed	Conglomerate and shale.
....	0.2	ND	11	17	NA	ND	18	17	ND	15	46	Soil	
....	NA	NA	NA	NA	2,000	20	NA	NA	NA	NA	NA	Rock	Silicified conglomerate with ≤ 1 pct opaque grains tentatively identified as chromite which are surrounded by green mica.
....	.1	NA	ND	2	NA	ND	NA	3	6	ND	ND	Rock	Silicified conglomerate with minor green staining and a brecciated texture with interstitial clay; borders a zone of intense argillic and hematitic alteration.
....	NA	ND	NA	NA	NA	NA	NA	NA	ND	NA	NA	Soil	
....	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Rock	Granulated and recrystallized graywacke with interstitial clay.
....	1.2	NA	12	21	NA	ND	NA	19	NA	NA	54	Sed	Organic-rich silty sand.

NA Not analyzed.
ND Not detected.
Sed Stream sediment sample.
[1]Analyzed by Technical Services Laboratory (TSL), Spokane, WA, for Sn and W by colori-
etric procedures, for Cr by X-ray fluorescence, and for all other elements by atomic absorp-
on.

TE.--See figure 4 for sample locations.

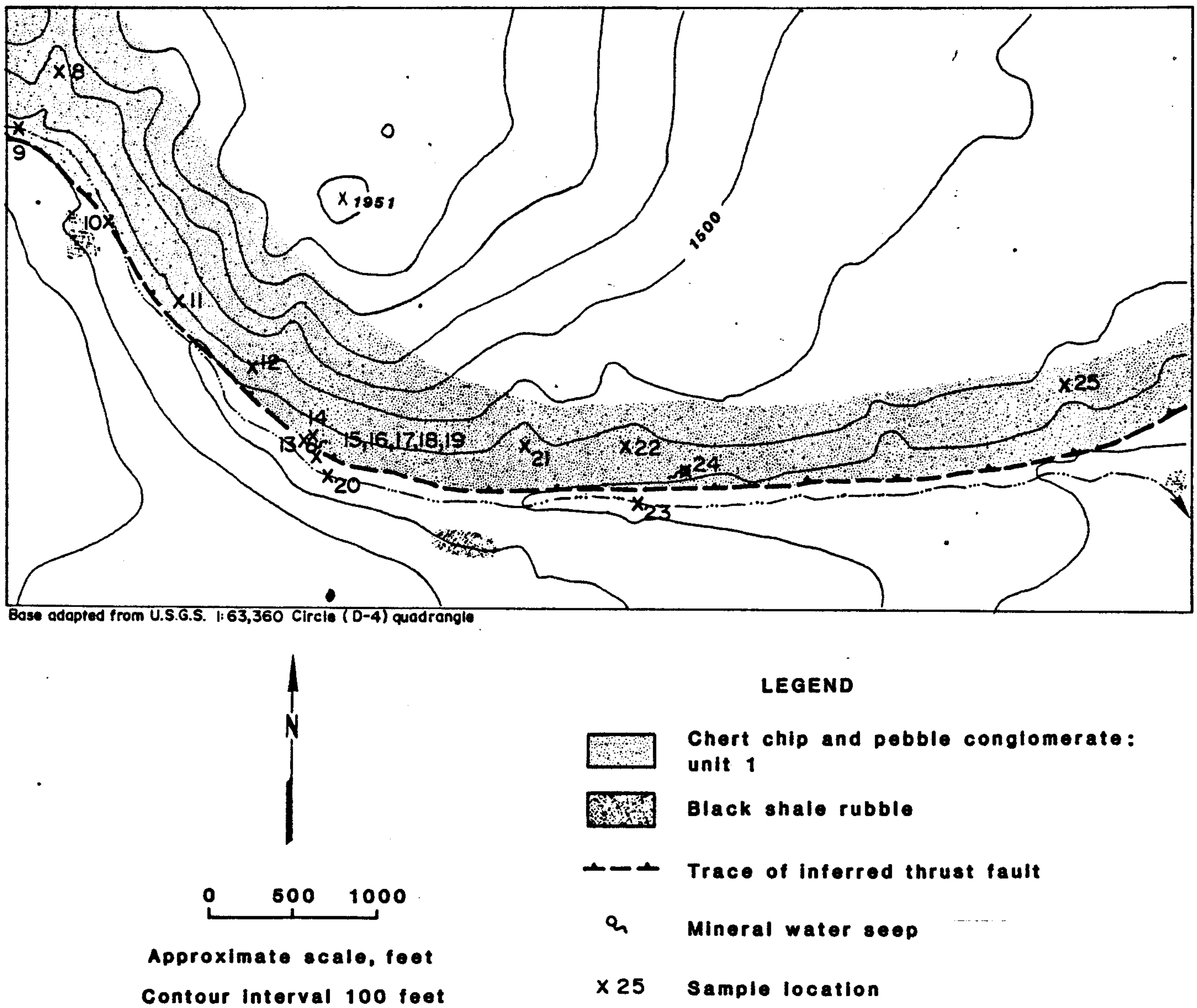


FIGURE 5. - Geology and sample locations at location B

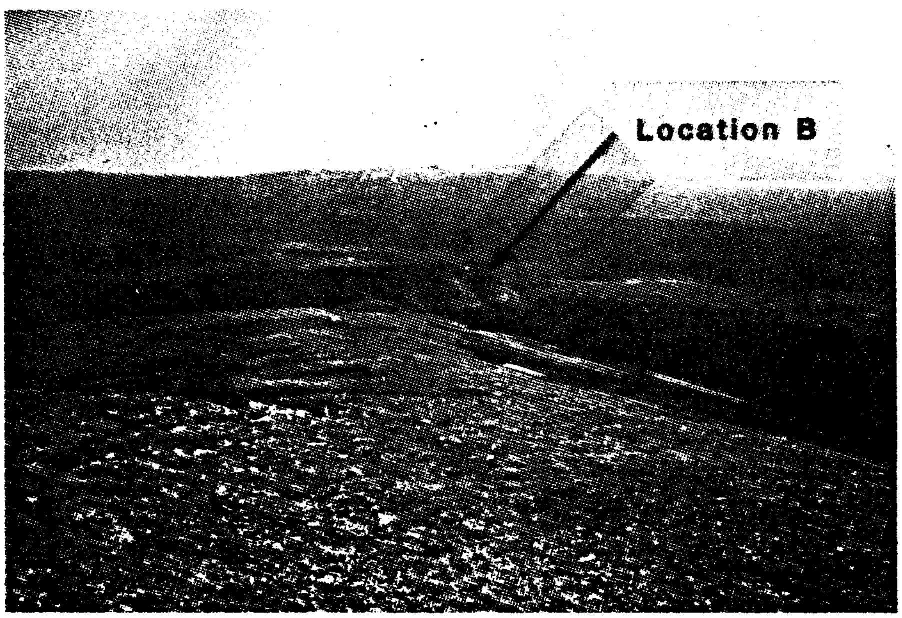

Location B

TABLE 2. - Analytical results[1] of soil, stream sediment, and rock samples from location B

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Zn, ppm	Sample type	Description
8....	ND	10	39	ND	375	586	Sed	Conglomerate.
9....	0.2	12	22	ND	25	320	Sed	Conglomerate and shale.
10....	7.8	10	18	ND	5	48	Sed	Shale and black clay.
11....	ND	NA	22	ND	25	94	Soil	Soil at toe of hillside slope, no limonite present.
12....	ND	NA	20	ND	ND	210	Soil	Soil at toe of hillside slope, no limonite present.
13....	ND	4.7	18	ND	ND	70	Rock	Sub-angular clasts in chert-pebble conglomerate.
14....	ND	NA	3	ND	ND	12,000	Soil	Soil taken from gossan and limonite rubble upslope of iron seeps.
15....	ND	74	20	ND	20	630	Soil	Soil from iron precipitate area near seeps.
17....	.1	[2]200	3	[2]100	ND	11,000	Sed	Taken from iron seep, sample also contains 700 ppm Te.[2]
19....	ND	100	5	ND	ND	13,300	Soil	Soil from iron precipitate area near seeps. Sample contained trace (0.029 ppm) Au.
20....	5	[2]50	100	ND	70	1,500	Sed	Shale and conglomerate in creek bed, taken below confluence of iron-rich spring water.
21....	ND	10	30	ND	155	240	Soil	Soil from rubble area of calcareous chert pebble conglomerate.
22....	ND	10.6	30	ND	650	710	Soil	Soil from small gulch cutting the conglomerate unit.
23....	ND	10	22	ND	46	476	Sed	Shale and conglomerate in creek bed, taken below confluence of iron-rich spring water.
24....	ND	368	48	ND	725	12,000	Soil	Red limonite soil from a marshy area of seeps below a slightly iron-stained conglomerate.
25....	1.7	4	31	ND	33	425	Rock	Extensively leached sub-angular chert pebble conglomerate with iron and manganese staining.

NA Not analyzed.
ND Not detected.
Sed Stream sediment sample.
[1]Samples 17 and 20 analyzed by Mineral Industry Research Laboratory (MIRL), University of Alaska, Fairbanks, AK, by atomic absorption. Samples 9, 10, and 25 analyzed by Technical Services Laboratories (TSL) Spokane, WA, by atomic absorption. All other samples analyzed by the Bureau's Reno (NV) Research Center by atomic absorption.
[2]Analyzed by semi-quantitative emission spectrographic methods by Mineral Industry Research Laboratory (MIRL), University of Alaska, Fairbanks, AK.

NOTE.--See figure 5 for sample locations.

TABLE 3. - Multi-element analyses[1] of spring sediment and precipitates from location B

Elements, units	Sample analyses	
	24A	16
Ag..ppm..........	ND	22
Cd..ppm..........	64	ND
Co..ppm..........	368.1	35.3
Cu..ppm..........	227	52
Fe..pct..........	8.94	29.4
Mn..pct..........	2.68	0.09
Ni..ppm..........	1,595	ND
Pb..ppm..........	1,063	ND
Sn..ppm..........	ND	72
W...ppm..........	3,282	329
Zn..ppm..........	8,400	7,548

ND Not detected.
[1]Analyses for Ag, Cd, Cu, Pb, Sn, and W by X-ray emission spectrography, all others by neutron activation, by Los Alamos (NM) Scientific Laboratory.

NOTE.--See figure 5 for sample locations.

TABLE 4. - Analyses[1] of spring water from location B

Elements, units	Sample analyses
	18
Ca..ppb..................	416,054
Co..ppb..................	217
Cr..ppb..................	70
Cu..ppb..................	31
Fe..ppb..................	159
Mg..ppb..................	214,180
Mn..ppb..................	2,461
Mo..ppb..................	ND
Ni..ppb..................	249
Pb..ppb..................	6,710
Ti..ppb..................	43
Zn..ppb..................	801
U...ppb..................	0.14

ND Not detected.
[1]Analyses by Los Alamos (NM) Scientific Laboratory.
Scattered rubble of conglomerate found at the toe of the slope (fig. 5)

NOTE.--See figure 5 for sample location.

boxwork or a leached matrix and, frequently, a brecciated texture. Little gossan or other alteration was observed although quartz veining is common.

Precipitate samples (samples 19 and 24) listed in table 2 contained up to 13,300 ppm Zn and 368 ppm Co, respectively. Multi-element analysis of spring sediment (sample 24A) and of ferricrete precipitate (sample 16) indicated metal concentrations shown in table 3. A sample of spring water (sample 18) gave the results shown in table 4.

Location C

A creek bank outcrop (fig. 7) exposes a contact of gray to black shale and graywacke with the conglomerate of unit 1. The contact consists of numerous closely spaced fractures and faults. Rocks on both sides of the contact are pervasively altered and weathered in a central zone approximately 50 ft wide that strikes N 60° E. The outcrop is near an inferred intersection with the previously described northwesterly thrust (?) fault (see fig. 3). The alteration grades into unaltered shale to the northwest and unaltered conglomerate to the southeast over a distance of approximately 100 ft along the creek bank.

Slickensides, boxworks, and a coarse breccia texture were observed in hand samples from the central altered zone. Stockworks of clay, chalcedony, and iron-oxide veinlets are common throughout the outcrop which is deeply weathered to a gritty gray and yellow color. No sulfides were observed. In thin section the rock in the central zone is comprised of a highly fragmented mass of quartz and mafic volcanic clasts of a basaltic composition within a clay matrix cut by quartz veins.

Samples 232, 233, and 234 were collected at location C. Conglomerate (sample 234) on the southeast margin of the altered zone contained minor

FIGURE 7. - Altered fault zone at location C. The zone is exposed in a low creek bank outcrop.

concentrations of zinc and copper (see table 5). No significant levels of cobalt were detected.

Location D

Several small seeps emanate from the base of a steep vegetated slope at location D (fig. 8). Extensive aufeis in the creek bed occurs below this locality during early summer, and minor limonitic staining is common on some of the gravel. Minor coatings of a hard carbonate "sponge" have formed on vegetation and soil at the base of the slope. There was also evidence of recent mass slumpage of the colluvium on the slope above the ground water seeps. Local bedrock is shale, chert, and argillite of unit 4.

Four shallow soil sample holes were dug into the slope approximately 150 to 250 ft north and upslope of the springs. These encountered black, carbonaceous, mixed soil and clay and chips of black shale, all of which are overlying ferricrete-cemented shale fragments. Samples contained anomalous levels of cobalt up to 1,150 ppm, as well as concentrations of zinc (see samples 26, 35-40, in table 6). Sample 36 also contained 515 ppm Ni and a trace of silver. Chips of black shale contained small crystals of gypsum and limonite-filled vugs. Soil from a dry gulch (sample 40) contained anomalous cobalt and greater than 20,000 ppm Zn. No sulfides were observed and the hillside appears to be deeply leached.

An area of rubble consisting of sheared silicified shale, limonite, and gossan is poorly exposed on a wooded hillside to the northeast (samples 27-30). Values of copper, lead, and zinc were slightly above normal and sample 30 contained anomalous cobalt.

TABLE 5. - Analytical results[1] of rock and soil samples from location C

Sample	Ag, ppm	As, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
232...	0.4	NA	2	6	ND	27	ND	ND	8	Rock..	Highly altered and faulted clastic rock including mafic volcanic fragments observable in thin section. There is a cataclastic texture and fine stockworks of clay and iron oxide. Rock weathers gray to yellow in outcrop with spotty chalcedony and quartz banding and appears to grade into unaltered conglomerate.
233...	6.8	12	4	35	4	42	NA	ND	84	Soil..	Altered zone along shale and conglomerate fault contact with high clay content.
234...	.4	NA	8	390	ND	14	NA	NA	615	Rock..	Leached conglomerate with milky chalcedony coating and quartz bands. Located about 50 ft from contact.

NA Not analyzed.
ND Not detected.
[1]Analyses by Technical Services Laboratories (TSL), Spokane, WA. Sn and W were analyzed using colorimetric procedures. Other elements were analyzed by atomic absorption.

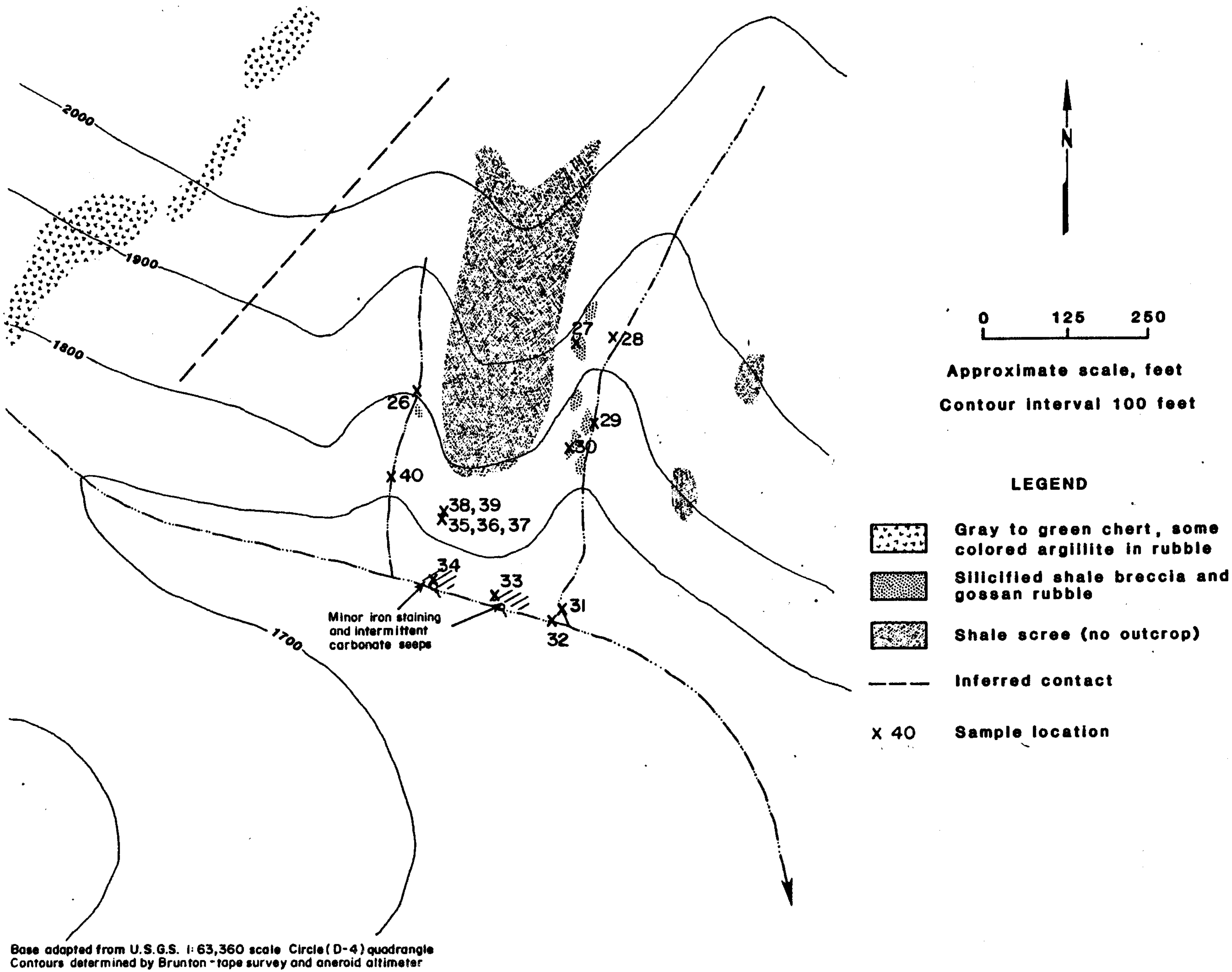


FIGURE 8. - Geology and sample locations at location D

TABLE 6. - Analytical results[1] of soil, stream sediment, and rock samples from location D

Sample	Ag, ppm	As, ppm	Co, ppm	Cu, ppm	Ni, ppm	Pb, ppm	W, ppm	Zn, ppm	Sample type	Description
26....	0.84	NA	16	100	89	45	NA	1,770	Soil	Moist dark gray silty soil and shale chips. Sample did not contain detectable Au.
27....	NA	NA	1	92	NA	44	ND	320	Rock	Limonitic silicified shale breccia and gossan. Occurs as hillside boulders.
28....	ND	NA	24	236	38	118	NA	590	Soil	From 2 ft depth in limonitic soils. Sample contained trace (0.013 ppm) Au.
29....	NA	NA	25	190	NA	91	NA	NA	Soil	Soil from gulch with abundant gossaniferrous rubble.
30....	NA	NA	65	108	NA	65	NA	620	Soil	Limonitic soil.
31....	NA	NA	31	128	NA	56	NA	360	Sed	Creek float consists of abundant shale, very little iron staining.
32....	NA	NA	11	51	NA	29	NA	200	Sed	Sediment from active creek bed.
33....	NA	NA	17	82	NA	44	NA	280	Soil	Moist soil from 1 ft depth in area of carbonate encrustation.
34....	6.4	ND	35	50	190	35	10	560	Soil	Iron-stained soil down slope of sample site 36.
35....	.75	NA	780	70	NA	34	8	490	Soil	Carbonaceous (sooty) soil and clay. Sample did not contain detectable Au.
36....	1.4	10	800	78	515	20	13	1,140	Soil	Same site as sample 35, sample taken at 1 ft depth.
37....	.2	NA	7	33	NA	17	NA	145	Rock	Chips of black shale with minor gypsum coatings.
38....	.2	NA	1,150	45	NA	24	NA	720	Soil	Ferricrete-cemented shale fragments in limonitic soil at 3 ft depth.
39....	NA	NA	13	37	NA	NA	NA	220	Rock	Black shale with secondary gypsum coatings, minor limonite staining, sample taken from 1.5 ft depth.
40....	NA	NA	345	79	80	34	NA	>20,000	Soil	Moist dark gray silty soil and shale chips.

NA Not analyzed.
ND Not detected.
Sed Stream sediment sample.
[1]Analyzed by Technical Services Laboratories, Spokane, WA for W by colorimetric procedures, and for all other elements by atomic absorption.

NOTE.--See figure 8 for sample locations.

Location E

The relatively flat hilltop upon which VABM Loper is located contains numerous rubble occurrences of altered limonite-stained, chert- and quartz-pebble conglomerate and boxworks of unit 1. The rubble occurs sporadically throughout the hilltop exposure and is particularly abundant along the southern edge (fig. 9). Samples of altered conglomerate rubble (samples 52, 65, 68, 70) contained local concentrations of lead, zinc, silver, tungsten, and copper (table 7). No cobalt was detected above normal background levels. To the northeast of samples 52 through 68, the conglomerate unit appears to grade into a calcareous sandstone and conglomerate. Marine fossils occur at sample 50. In the vicinity of sample 49, calcite vein stockworks with thin (>1 in) white barite veins occur with goethite and boxwork.

The conglomerate capping the top of the hill appears to be in thrust fault contact with the underlying unit 4 of chert-argillite-shale. The erratic distribution of slickensides in the conglomerate indicates faulting occurs as a zone of minor faults rather than along a single fault surface. Highly polished slickenside surfaces were frequently observed on the more highly altered conglomerate rubble. Argillite and limonite alteration of conglomerate and sandstone rubble locally contain bands of silica and clay parallel to the slickenside surfaces. Local developments of boxwork and sericite were seen in the rocks.

An attempt was made to determine if soil sampling would reflect zones of metal enrichment (samples 57, 60-64, 66-67). Pits, dug to depths of 3 ft, however, only encountered angular leached conglomerate and dry, well-drained, loose silt lacking even limonite. There was no clay or

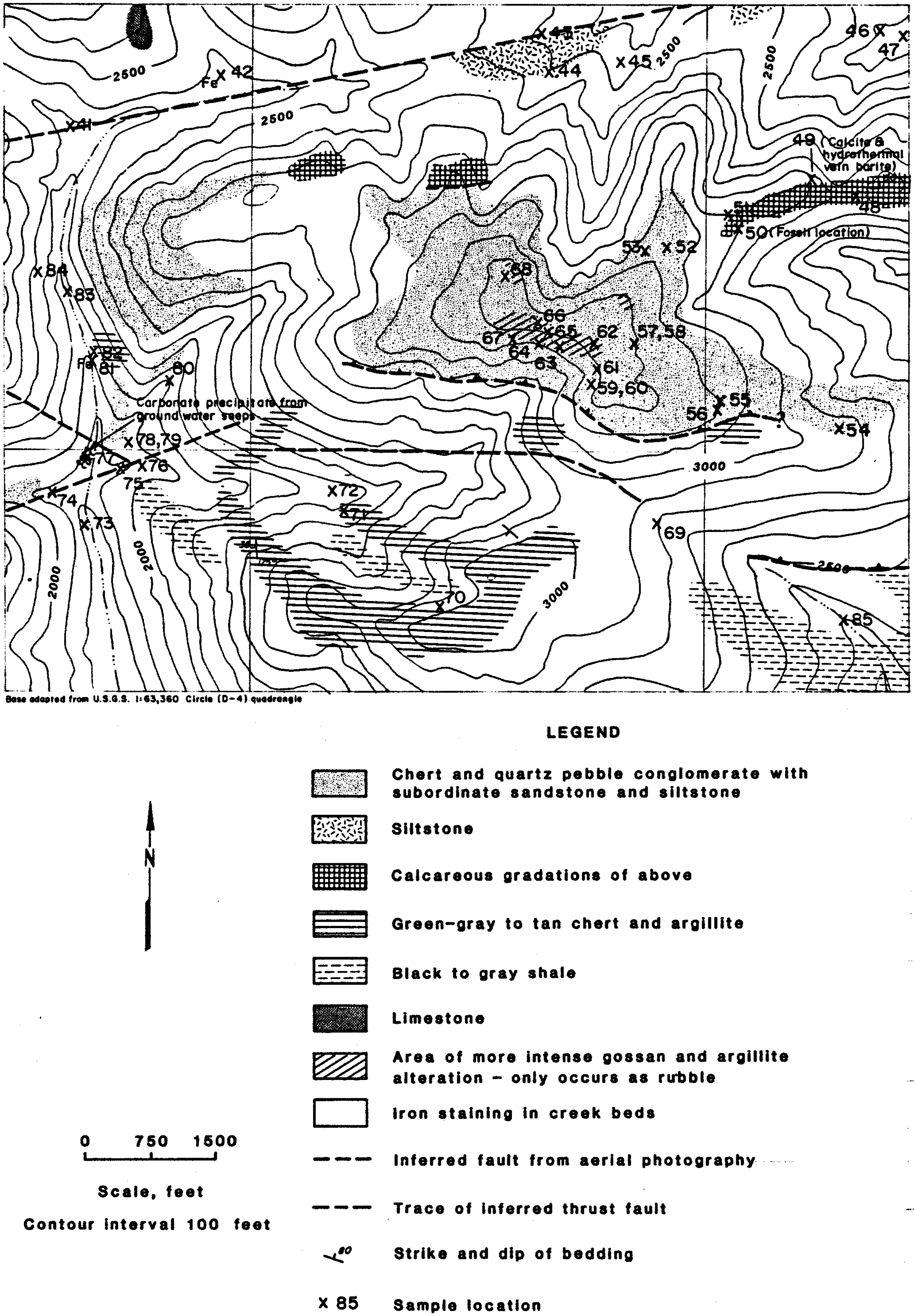


FIGURE 9. - Geology and mineral investigations at location E

TABLE 7. - Analytical results[1] of soil and stream sediment samples from location E

Sample	Ag, ppm	Co, ppm	Cu, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
41....	ND	NA	18	15	NA	NA	122	Sed	Organic-rich sediment.
42....	ND	NA	15	20	NA	NA	111	Sed	Gravel in iron-stained creek bed.
43....	ND	NA	10	20	NA	NA	90	Sed	All shale.
44....	ND	NA	36	55	NA	NA	357	Sed	Organic-rich sediment.
45....	ND	NA	33	35	NA	NA	197	Sed	Chert-pebble conglomerate, shale, and sandstone.
46....	ND	NA	25	25	NA	NA	159	Sed	Shale and conglomerate.
47[2]...	NA	5	29	25	NA	ND	196	Sed	Organic sediment with spotty limonite.
48....	ND	NA	20	75	NA	NA	241	Soil	Soil from zone of moderately red-stained calcareous chert-pebble conglomerate.
49[3]...	.99	ND	20	420	NA	24	120	Rock	White barite veins approximately 1 in thick, cutting calcareous sandstone with slickensides, goethite, limonite, and boxwork. Sample did not contain detectable Au.
50[3]...	NA	NA	NA	NA	NA	NA	NA	Rock	Fossil locality, specimens submitted to USGS.
51....	ND	NA	29	75	NA	NA	467	Sed	Mixed rounded gravel.
52[2]...	0.2	3	56	143	ND	3	NA	Rock	Chips of argillically altered conglomerate with minor limonite and goethite.
53[2]...	3.8	10	20	90	NA	<5	275	Soil	
54....	ND	3.6	40	15	ND	ND	18	Rock	Cross-bedded sandstone and conglomerate.
55....	ND	NA	16	25	NA	NA	49	Soil	
56....	ND	2.2	34	80	ND	ND	17	Rock	Red-stained chert.
57[2]...	NA	19	75	31	ND	2	NA	Soil	Dry, dark brown loose silt from 3 ft depth.
58[2]...	NA	4	112	24	ND	3	NA	Rock	Limonite- and manganese-coated siltstone strata in conglomerate unit.
59[2]...	NA	4	27	6	NA	NA	NA	Rock	Quartz- and chert-pebble conglomerate with leached matrix and limonite filling. Sample contained 0.008 tr oz/ton Au.
60[2]...	NA	15	63	71	NA	NA	NA	Soil	Soil from 3 ft depth.
61[2]...	NA	8	37	15	NA	NA	NA	Soil	Soil from near limonite-stained, unaltered conglomerate rubble from 2.5 ft depth.
62[2]...	5.0	13	34	17	NA	ND	185	Soil	Dark brown soil with fragments of iron-stained conglomerate.
63[2]...	1.6	11	130	59	NA	ND	270	Soil	Brown clayey soil down slope of conglomerate rubble.
64[2]...	6.6	4	45	65	NA	ND	115	Soil	Loose loamy light tan soil with conglomerate rubble.
65[2]...	1.3	16	220	2,530	ND	22	1,190	Rock	Leached, iron-stained, polymictic conglomerate with occasional boxworks, goethite banding, some secondary sericite, and quartz veining. Alteration follows fault zone.

See explanatory notes at end of table.

Analytical results[1] of soil and stream sediment samples from location E--Continued

Sample	Ag, ppm	Co, ppm	Cu, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
66[2]...	NA	3	47	33	ND	ND	NA	Soil	Dry, medium brown silt underlying altered conglomerate from 2.5 ft depth.
67[2]...	7.2	11	46	32	NA	ND	96	Soil	Dark brown soil down slope of conglomerate rubble.
68....	3	9.3	200	40	20	34	1,400	Rock	Red-stained sandstone and conglomerate grading to gossan.
69[2]...	1.4	15	19	21	NA	NA	100	Sed	Organic-rich silty sand.
70[2]...	NA	9	103	11	NA	NA	197	Rock	Limonite and boxwork zones with goethite and manganese stain. Zones are 2 to 6 in. thick, cutting tan chert.
71[2]...	NA	8	39	26	NA	NA	69	Sed	Float rock in creek is primarily carbonaceous black shale.
72[2]...	NA	19	24	44	NA	NA	267	Sed	Creek bed cuts through iron-rich gravels and muck.
73....	ND	NA	58	45	NA	NA	415	Sed	Shale and conglomerate float.
74....	ND	NA	33	30	NA	NA	210	Sed	Do.
75....	ND	NA	110	65	NA	NA	310	Sed	Do.
76[2]...	NA	39	257	79	NA	NA	530	Sed	Float rock in creek is black shale and conglomerate with a thin milky coating and discoloration in water.
77[2]...	NA	10	57	47	NA	NA	440	Soil	Sandy gray soil underlying slump area with carbonate encrustations.
78[2]...	NA	13	43	104	NA	NA	393	Sed	Float rock in creek is black shale and conglomerate.
79....	ND	NA	51	90	NA	NA	510	Sed	Shale and conglomerate float.
80[2]...	NA	14	46	134	NA	NA	420	Sed	Float rock in creek is entirely conglomerate.
81[2]...	NA	14	31	46	NA	NA	580	Sed	Float rock in creek is iron-stained conglomerate and sandstone.
82....	ND	7.1	63	30	ND	ND	100	Sed	Shale and conglomerate float rock in creek.
83....	ND	NA	26	75	NA	NA	1,500	Sed	Iron-staining in creek appears due to shale horizon below conglomerate.
84....	ND	NA	19	155	NA	NA	462	Soil	Conglomerate rubble nearby.

NA Not analyzed.
ND Not detected.
Sed Stream sediment sample.
[1]Unless noted otherwise, Ag, Cu, Pb, and Zn were analyzed by atomic absorption by the Bureau's Reno (NV) Research Center. Sn and W were analyzed by X-ray fluorescence, and Co by neutron activation by Los Alamos (NM) Scientific Laboratory.
[2]Analyzed for Ag, Co, Cu, Pb, and Zn using atomic absorption and for Sn and W using colorimetric procedures by Technical Services Laboratory (TSL), Spokane, WA.

NOTE.--See figure 9 for sample locations.

noticeable ground moisture. No anomalous metal concentrations, except silver, were encountered in the soil samples collected. Consequently further soil sampling on the hilltop near VABM Loper appears to be of little value.

The association of detectable tungsten and tin with the altered conglomerate (samples 52, 65, 68) at location E and other locations in the western Crazy Mountains is of interest; however no explanation was evident in the field.

Location F

Location F, a ground water seep precipitating ferricrete in a manner similar to location B, is located along the east bank of a south-flowing creek (fig. 10). Sample 192 of shale and chert fragments cemented with iron precipitate contained 303 ppm Co (see table 8 and fig. 11). Iron-stained soil in the creek bank immediately above the seep precipitate contained 505 ppm Zn (sample 191, table 9).

No bedrock is exposed in the immediate vicinity of the seep although limited areas of black shale scree (possibly of unit 4) occur on both sides of the valley. Approximately 1/2 mile to the south a small stock (?) composed of altered, pyritic, mafic intrusive rock (sample 98, table (10 and fig. 12) occurs but was found to contain no significant metal concentrations.

Location G

Gray to black argillite, chert breccia, with gossan along fractures, occur as rubble on a ridge crest at location G (fig. 3). The rubble is heavily iron-stained and cut by quartz veinlets. A sample with gossan fracture fillings (sample 85, table 10) contained slightly elevated values of cobalt, copper, molybdenum, and tungsten.

FIGURE 10. - Ground water seep at location F.

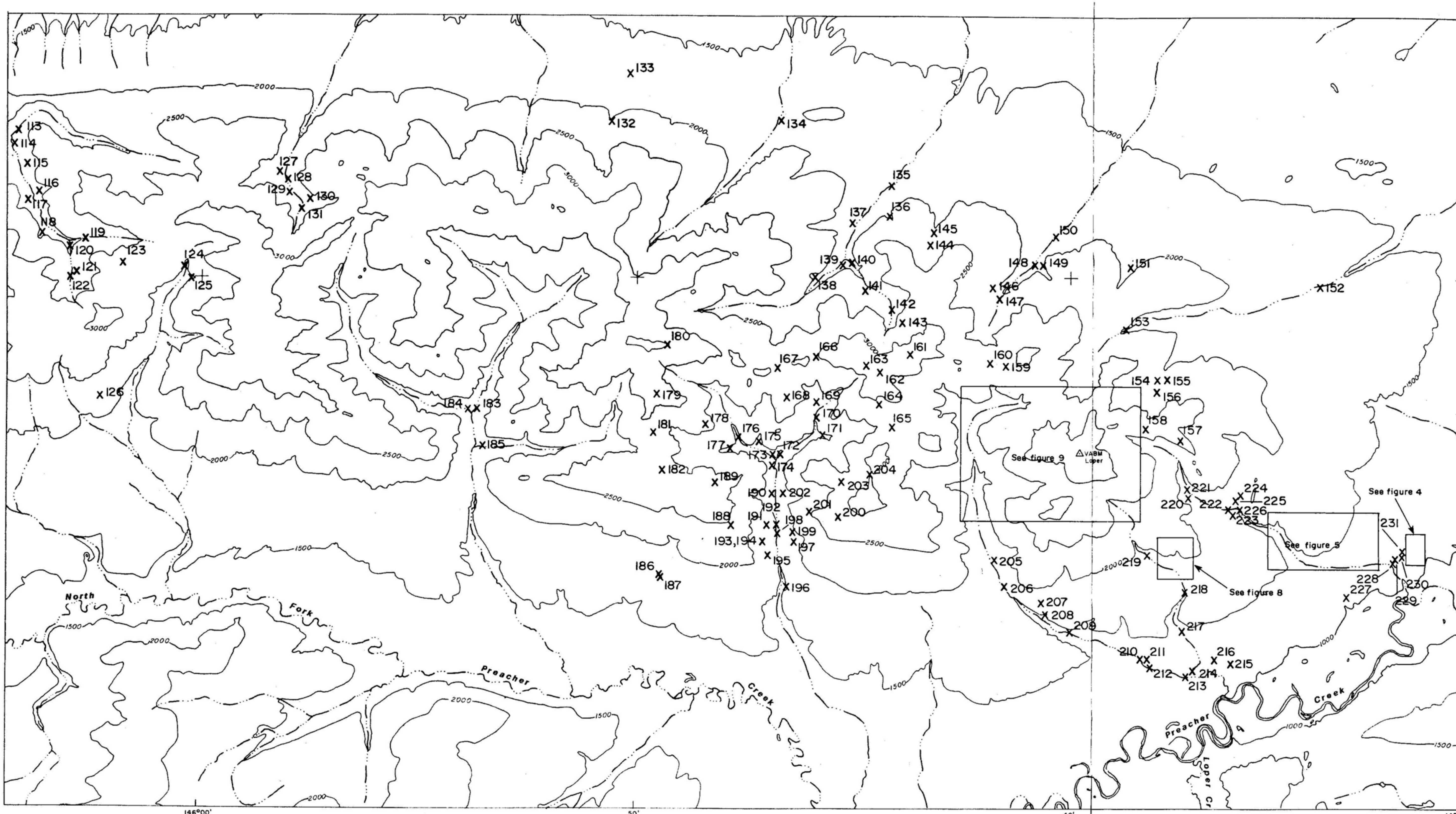
TABLE 8. - Analysis[1] of spring sediment at location F

Sample	192
Ag..ppm	ND
Cd..ppm	18
Co..ppm	303
Cu..ppm	ND
Fe..pct	23.72
Mn..pct	0.99
Ni..ppm	232
Pb..ppm	ND
Sn..ppm	12
W...ppm	42
Zn..ppm	237

ND Not detected.

[1]Analysis by Los Alamos (NM) Scientific Laboratory using neutron activation for Co, Fe, Mn, Ni, and Zn, and X-ray fluorescence for Ag, Cd, Cu, Pb, Sn, and W.

NOTE.--See figure 11 for sample location.



Base adapted from U.S.G.S. 1:63,360 Circle (D-4, D-5) quadrangle

N

LEGEND

X 220 Sample location

0 0.5 1

Scale, mile

Contour interval 500 feet

FIGURE 11. - Location of additional stream sediment and soil samples in the western Crazy Mountains

TABLE 9. - Analytical results[1] of additional soil and stream sediment samples from various locations in the western Crazy Mountains

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
112...	ND	8.8	21	ND	ND	ND	ND	130	Sed	Sandstone and shale.
113...	ND	10.9	27	ND	ND	ND	ND	140	Sed	Argillite, sandstone, and conglomerate.
114...	ND	11.5	20	ND	20	ND	24	630	Sed	Snow cover.
115...	ND	11.2	23	ND	ND	ND	ND	120	Sed	Do.
116...	ND	12.5	27	ND	ND	ND	ND	68	Sed	None.
117...	ND	10.3	25	ND	ND	ND	ND	76	Sed	Snow cover.
118...	ND	8.3	20	ND	ND	ND	ND	75	Sed	Abundant shale grading to phyllite.
119...	ND	16.6	39	ND	ND	ND	ND	67	Sed	Shale and minor limestone.
120...	ND	11.3	40	ND	ND	ND	ND	67	Sed	Shale chips and abundant organics.
121...	ND	12.4	38	ND	ND	ND	ND	64	Sed	Shale, conglomerate, and greenstone.
122...	ND	NA	28	ND	ND	NA	NA	37	Soil	From gossan zone in brecciated silicified argillite with abundant quartz veining.
123...	ND	10.2	28	ND	ND	ND	ND	92	Sed	Argillite and shale, some dolomite and quartz.
124...	ND	11.1	36	ND	ND	ND	ND	68	Sed	Argillite and chert.
125...	ND	NA	42	ND	ND	NA	NA	52	Sed	Slide area of dark green porphyritic mafic rock and vuggy gray chert-phyllite.
126...	ND	10.3	26	ND	ND	ND	ND	160	Sed	Shale, quartzite, and sandstone, all with abundant quartz veining.
127...	ND	11.2	28	ND	ND	ND	ND	150	Sed	Phyllite and cobbles of siliceous conglomerate.
128...	ND	14.5	30	ND	ND	ND	ND	125	Sed	Shale and conglomerate.
129...	ND	10.3	28	ND	ND	ND	ND	390	Sed	Limestone, dolomite, argillite, sandstone, and conglomerate.
130...	ND	12.9	25	ND	ND	ND	ND	125	Sed	Shale, conglomerate, and minor black limestone.
131...	ND	24.2	30	ND	15	ND	ND	270	Sed	Conglomerate and shale.
132[2]..	NA	50	150	ND	100	ND	ND	1,000	Sed	Do.
133[2]..	ND	10.4	38	NA	60	ND	ND	594	Sed	Organic silty sand.
134...	NA	30	70	ND	ND	ND	ND	ND	Sed	Shale and sandstone.
135...	ND	NA	14	ND	ND	NA	NA	98	Sed	Shale and conglomerate float in a highly iron-stained creek bed.
136...	ND	NA	20	ND	ND	NA	NA	110	Sed	Shale and conglomerate float in a highly iron-stained creek bed.
137...	ND	10.7	20	ND	20	ND	ND	91	Sed	Organics in creek bed with shale chips.

See explanatory notes at end of table.

Analytical results[1] of additional soil and stream sediment samples from various locations in the western Crazy Mountains--Continued

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
138...	ND	NA	37	ND	15	NA	NA	135	Sed	Shale.
139...	ND	NA	30	ND	15	NA	NA	120	Sed	Shale and chert-pebble conglomerate.
140...	ND	NA	28	ND	25	NA	NA	150	Sed	Do.
141...	ND	11.5	54	ND	25	ND	ND	120	Sed	Do.
142...	ND	NA	52	ND	20	NA	NA	83	Soil	Soil from area of limonite-coated gray chert with quartz veining.
143...	ND	NA	21	ND	ND	NA	NA	160	Sed	Conglomerate in iron-stained creek bed.
144...	ND	NA	17	ND	ND	NA	NA	130	Sed	Do.
145...	ND	NA	29	ND	20	NA	NA	150	Sed	Shale with minor vein quartz and chert.
146...	ND	12.8	41	ND	25	ND	ND	150	Sed	Dark gray shale, taken below limonitic outcrop of conglomerate.
147...	ND	NA	23	ND	15	NA	NA	108	Sed	Iron-stained, organic-rich sediment.
148...	ND	NA	23	ND	25	NA	NA	141	Sed	Do.
149[2]..	ND	ND	70	ND	50	ND	ND	ND	Sed	Shale and sandstone.
150...	ND	NA	14	ND	25	NA	NA	104	Sed	None.
151[2]..	ND	20	150	ND	70	ND	ND	ND	Sed	Silty organics.
152...	ND	10.7	30	ND	30	ND	ND	202	Sed	Orange algae and organic-rich sediment, taken below outcrop of chert breccia.
153...	ND	NA	20	ND	25	NA	NA	150	Sed	Shale and limonitic conglomerate.
154...	ND	NA	22	ND	25	NA	NA	155	Sed	Creek bed with shale below outcrop of cherty shale with abundant quartz veining.
155...	ND	NA	30	ND	50	NA	NA	286	Sed	Shale and conglomerate.
156...	ND	NA	25	ND	67	NA	NA	879	Soil	Soil from area of faulted and sheared sandstone and conglomerate.
157...	ND	NA	32	ND	40	NA	NA	388	Soil	Nearby rubble of iron-stained, chert-pebble conglomerate and sandstone.
158...	ND	NA	17	ND	20	NA	NA	59	Soil	Taken from frost-boil with shale fragments.
159...	ND	NA	20	ND	25	NA	NA	207	Soil	Shale and conglomerate outcrops nearby.
160...	ND	NA	23	ND	25	ND	ND	122	Soil	Limonitic clay and gossan zone in or near limestone.
161...	ND	NA	26	ND	15	NA	NA	57	Soil	Limonitic soil zone above probable chert bedrock.

See explanatory notes at end of table.

Analytical results[1] of additional soil and stream sediment samples from various locations in the western Crazy Mountains--Continued

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
162...	ND	NA	27	ND	20	NA	NA	64	Soil	Nearby outcrops of gray chert with abundant quartz veining.
163...	ND	NA	29	ND	15	NA	NA	68	Soil	Shale chips in sample.
164...	ND	NA	17	ND	20	NA	NA	60	Soil	Taken from frost boil with shale fragments.
165...	ND	NA	12	ND	20	NA	NA	49	Soil	Chert rubble in area.
166...	ND	NA	29	ND	20	NA	NA	42	Soil	Soil with fragments of black cherty shale.
167...	ND	NA	14	ND	20	NA	NA	60	Soil	Do. cherty shale.
169...	ND	NA	40	ND	25	NA	NA	138	Sed	Shale and chert.
170...	ND	NA	28	ND	25	NA	NA	162	Sed	None.
171...	ND	NA	29	ND	15	NA	NA	142	Sed	Shale.
172...	ND	NA	32	ND	20	NA	NA	99	Sed	Do.
173...	ND	NA	37	ND	15	NA	NA	91	Soil	Unvegetated zone of marble and black chert rubble.
174...	ND	NA	33	ND	ND	NA	NA	118	Sed	None.
175...	ND	NA	31	ND	ND	NA	NA	122	Sed	Do.
176...	ND	NA	26	ND	ND	NA	NA	86	Sed	Do.
177...	ND	NA	36	ND	ND	NA	NA	86	Soil	Taken from frost boil, conglomerate and black shale float in area.
178...	ND	NA	60	ND	165	NA	NA	895	Soil	Green mafic intrusive rubble in area.
179...	ND	NA	30	ND	20	NA	NA	60	Soil	Nearby rubble of chert-pebble conglomerate.
180...	ND	NA	20	ND	20	NA	NA	86	Soil	Black shale rubble in area.
181...	ND	NA	13	ND	40	NA	NA	159	Soil	Taken from frost-boil containing chips of limonitic limestone.
182[2]..	ND	ND	5	ND	ND	ND	ND	ND	Sed	None.
183[2]..	NA	ND	10	ND	ND	NA	NA	NA	Sed	Do.
184[2]..	ND	30	150	ND	50	ND	ND	ND	Sed	Shale and chert.
185...	ND	NA	35	ND	ND	NA	NA	119	Soil	Reddish-brown soil in small gulch.
186...	ND	9.5	34	ND	15	ND	ND	111	Sed	Gray chert, shale, tan claystone, and green and brown sandstone.
187...	ND	NA	15	ND	20	NA	NA	54	Soil	Light orange soil with chips of sheared gray chert.
188...	16	NA	156	ND	55	NA	NA	81	Soil	Bedrock is gray fractured chert.
189...	ND	NA	32	ND	35	NA	NA	68	Sed	Chert and shale.
190...	ND	NA	21	ND	15	NA	NA	82	Sed	Do.
191...	ND	NA	5	ND	ND	NA	NA	505	Soil	Soil from near iron-rich seep.
193...	ND	NA	28	ND	ND	NA	NA	135	Sed	Shale.
194...	ND	NA	19	ND	ND	NA	NA	58	Soil	Organic-rich soil.

See explanatory notes at end of table.

Analytical results[1] of additional soil and stream sediment samples from various locations in the western Crazy Mountains--Continued

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
195...	ND	9.5	21	ND	20	ND	ND	68	Sed	Shale and chert.
196...	ND	NA	19	ND	15	NA	NA	92	Sed	Tan shale and vein quartz in creek bed incised in black shale bedrock.
197...	ND	20.0	42	NA	11	ND	22	155	Sed	Shale and chert with mafic volcanic rock rubble.
198...	ND	NA	35	ND	15	NA	NA	88	Soil	Soil with fragments of shale and limestone.
199...	ND	NA	10	ND	15	NA	NA	19	Soil	Orange soil below outcrops of limonite-stained gray chert.
200...	ND	NA	35	ND	ND	NA	NA	119	Soil	Bedrock is brecciated limonite-stained gray chert.
201...	ND	NA	39	ND	20	NA	NA	107	Soil	Shale and chert fragments in soil within small gulch.
202...	ND	NA	14	ND	30	NA	NA	68	Soil	Soil from contact area of shale and conglomerate.
203...	ND	NA	44	ND	35	NA	NA	336	Soil	Soil from saddle on limestone ridge.
204[3]..	2.0	12	20	ND	16	NA	NA	105	Sed	Shale and chert.
205[3]..	1.4	15	34	ND	32	NA	NA	270	Sed	Frozen gravel.
206[3]..	4.0	9	15	ND	17	NA	NA	59	Soil	Slump area on hillside along a possible fault zone.
207[3]..	0.4	71	38	ND	23	NA	NA	800	Sed	Black shale.
208[3]..	3.4	12	18	ND	20	NA	NA	150	Sed	Frozen gravel.
209[3]..	0.2	14	22	ND	20	NA	NA	815	Sed	None.
210[3]..	1.8	12	19	ND	16	NA	NA	58	Sed	Black shale.
211[3]..	0.2	12	24	ND	21	NA	NA	170	Sed	Black shale and conglomerate.
212[3]..	0.8	11	11	ND	20	NA	NA	145	Sed	None.
213[3]..	2.6	10	15	ND	13	NA	NA	62	Sed	Silt and organics.
214[3]..	4.8	11	16	ND	14	NA	NA	76	Sed	Gravel derived from TQg.
215[3]..	0.6	12	15	ND	15	NA	NA	76	Sed	Shale.
216[3]..	1.4	12	19	ND	14	NA	NA	72	Sed	None.
217[3]..	1.4	12	21	2	21	NA	NA	100	Sed	Do.
218[3]..	0.8	20	38	2	23	NA	NA	120	Sed	Chert, shale, and conglomerate.
219[3]..	3.6	10	21	2	21	NA	NA	80	Sed	Shale and conglomerate.
220[3]..	4.4	12	21	ND	16	NA	NA	100	Sed	Do.
221[3]..	4.9	41	16	ND	61	NA	NA	1,320	Sed	Do.
222...	ND	24.7	30	ND	70	ND	71	1,300	Sed	Conglomerate.
223...	ND	NA	27	ND	20	NA	NA	115	Sed	Shale and sandstone.
224[3]..	10.6	13	14	ND	34	NA	NA	430	Sed	Organics and silty sand.
225...	ND	NA	23	ND	55	NA	NA	616	Sed	Conglomerate.
226[3]..	3.6	13	20	ND	18	NA	NA	150	Sed	Shale and vein quartz.
227[3]..	0.2	7	33	ND	17	NA	NA	145	Soil	Taken at toe of slope below quartzite rubble, abundant carbonate precipitate on surface.

See explanatory notes at end of table.

Analytical results[1] of additional soil and stream sediment samples from various locations in the western Crazy Mountains--Continued

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Sample type	Description
228[3]..	1.4	12	17	ND	23	NA	NA	330	Sed	Conglomerate and shale.
229[3]..	6.6	8	37	3	53	NA	NA	215	Sed	Black-gray sand overlying contact of conglomerate and shale.
230[3]..	5.2	11	47	ND	35	NA	NA	165	Sed	Creek cuts shale bedrock below conglomerate contact.
231[3]..	1.2	8	24	ND	47	NA	NA	120	Soil	Red-colored soil with fragments of shale and conglomerate.

NA Not analyzed.
ND Not detected.
Sed Stream sediment sample.

[1]Unless noted otherwise, Ag, Cu, Mo, Pb, and Zn were analyzed by atomic absorption by the Bureau's Reno (NV) Research Center. Sn and W were analyzed by X-ray fluorescence, and Co by neutron activation by Los Alamos (NM) Scientific Laboratory.

[2]Analyzed by semi-quantitative emission spectrography.

[3]Analyzed for Ag, Co, Cu, Mo, Pb, and Zn by atomic absorption by Technical Services Laboratory (TSL), Spokane, WA.

NOTE.--See figure 11 for sample locations.

TABLE 10. - Analytical results[1] of additional rock samples from various locations in the western Crazy Mountains

Sample	Ag, ppm	Co, ppm	Cu, ppm	Mo, ppm	Pb, ppm	Sn, ppm	W, ppm	Zn, ppm	Description
85...	ND	41.5	430	40	ND	ND	49	92	Gossan in brecciated argillite and chert with a few random quartz veinlets.
86...	ND	24.1	52	15	110	ND	ND	340	Chloritically-altered intermediate to basic igneous intrúsive rock.
87...	ND	16.0	130	ND	ND	ND	65	570	Volcanic(?) breccia seams in green shale.
88...	ND	2.1	3	ND	ND	ND	ND	42	Gray limestone.
89...	ND	17.1	56	ND	ND	ND	ND	66	Intermediate volcanic.
90...	ND	2.4	25	ND	ND	ND	ND	39	Black siliceous shale and black quartzite.
91...	ND	3.8	67	ND	ND	ND	ND	92	Black siliceous shale.
92...	ND	7.8	50	15	65	ND	ND	13	Iron-stained white chert breccia in a limonite and goethite matrix.
93...	ND	18.8	25	ND	ND	16	ND	110	Light green argillite.
94...	ND	2.7	6	ND	ND	ND	ND	3	Light colored chert.
95...	ND	1.7	6	ND	ND	ND	ND	5	Gray chert.
96...	ND	2.3	11	ND	ND	ND	ND	17	Vein quartz.
97...	ND	20.0	50	ND	ND	17	27	35	Diabase.
98...	ND	2.9	4	ND	ND	ND	ND	4	Highly altered (intrusive?) rock with sulfides.
99...	ND	5.3	44	ND	ND	ND	ND	70	Chip sample across a 200-ft-wide outcrop of foliated black shale.
100...	ND	20.0	44	ND	ND	ND	ND	110	Light green shale.
101...	ND	2.6	21	ND	30	ND	ND	430	Pyritic chert breccia and limestone beds.
102...	ND	2.4	120	ND	30	ND	ND	27	Fine-grained gray sandstone.
103...	ND	10.7	25	ND	ND	ND	ND	640	Chip sample collected across a 50-ft-wide outcrop of iron-stained polymictic conglomerate.
104...	ND	NA	81	ND	30	NA	ND	55	Unidentified.
105...	ND	8.5	10	ND	25	ND	ND	57	Chips from conglomerate and quartzite strata.
106...	ND	4.6	16	ND	ND	ND	20	52	Iron-stained, coarse-grained sandstone and conglomerate.
107...	ND	3.0	11	ND	15	ND	ND	42	Shale breccia.
108...	ND	20.6	41	ND	25	ND	ND	2,500	Iron-stained conglomerate and gossan.
109...	ND	4.5	110	ND	ND	ND	ND	120	Siliceous black shale with quartz veining.
110[2]..	0.3	9	46	ND	21	NA	ND	67	Typical unaltered gritty black shale.
111[2]..	0.5	19	35	ND	22	NA	29	120	Chip sample across 10-ft-thick section of clean, unaltered black shale.

NA Not analyzed.
ND Not detected.
[1]Unless noted otherwise, Ag, Cu, Pb, and Zn were analyzed by atomic abosrption by the Bureau's Reno (NV) Research Center. Sn and W were analyzed by X-ray fluorescence, and Co by neutron activation by Los Alamos (NM) Scientific Laboratory.
[2]Analyzed for Sn and W by colorimetric procedures, and by atomic absorption for all other elements by Technical Services Laboratory (TSL), Spokane, WA.

NOTE.--See figure 122 for sample locations.

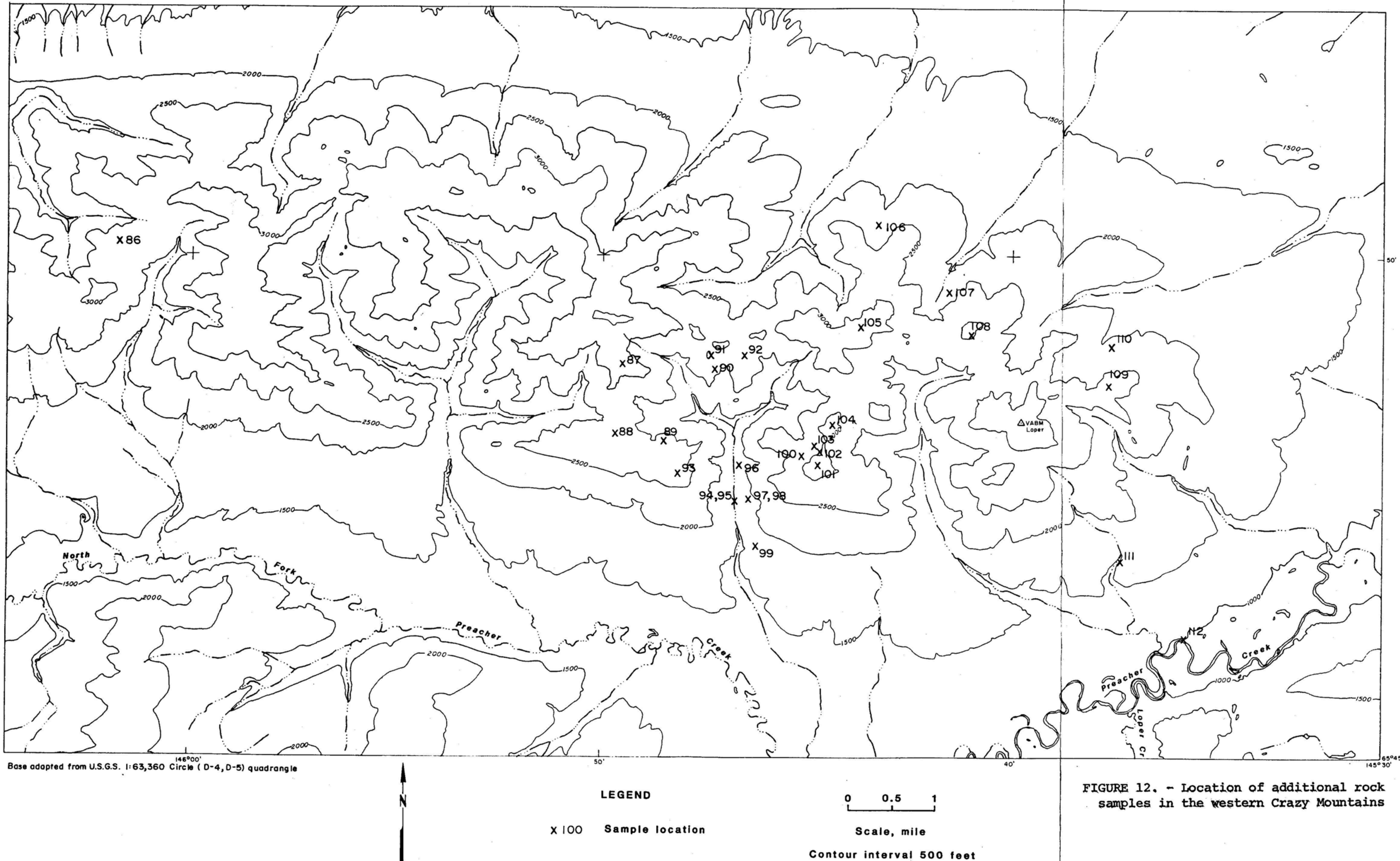


FIGURE 12. - Location of additional rock samples in the western Crazy Mountains

A porphyritic andesite stock (?) is poorly exposed in the creek valley approximately 3,000 ft to the east of location G.

Other Locations

Analytical results for miscellaneous rock samples are presented on table 10 and located on figure 12. Stream sediment and soil sample results are listed on table 9 and shown on figure 11. The data indicate additional geochemical anomalies, primarily for zinc, occur in the western Crazy Mountains. No further investigation of any of these other sites was attempted during this project.

SUMMARY AND RECOMMENDATIONS

The trace element data coupled with the limited geologic and structural observations suggest that the fault contact zones between unit 1 of the conglomerate-sandstone-siltstone and unit 4 of chert-argillite-shale are particularly favorable for polymetallic mineralization. Cobalt and other metal values detected in spring precipitates at locations B and F and in soil samples suggest these metals are associated with the shale of unit 4. Unit 4 is therefore recommended for additional study of cobalt reserve potential.

It cannot be determined, however, whether the metals found are derived from potentially economic concentrations as primary mineralization at depth; or rather, are due to naturally occurring concentration of metal ions from low-grade alteration zones, or other bedrock sources having an abnormally high background of trace metals. Metal values found occur as either oxides associated with clay and gossan, or are contained with iron- and manganese-rich precipitates. It is not likely that the question can be answered by surficial examinations.

Future investigations must be designed with the realization that exceedingly little bedrock is exposed. Consequently, the use of geophysical methods and eventually, drilling will be required. Soil grid surveys may be useful on sloped terrain, but not on leached ridge tops or valley floors. Further surface prospecting of the favorable fault and contact zones will likely produce additional geochemical targets similar to those described in this report.

Geologic mapping in conjunction with general prospecting should be pursued throughout the remaining areas of the western Crazy Mountains not examined during the investigation. The relationship of the various rock units to each other must be resolved. Particular emphasis should address the geologic relationships of the mafic intrusions. The possibility that these mafic rocks in some way correlate with mineralization should be investigated. The mafic intrusive area near rock sample 86 is suggested for further study.

The occurrence of low level tin and tungsten values in some altered rock and spring precipitate samples from the western Crazy Mountains is of interest and warrants further examination. Of six random samples analyzed for gold, (samples 19, 26, 28, 35, 49, and 59) three contained trace amounts. Further investigation of gold is recommended.

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APPENDIX.--SAMPLE KEY

Sample	Field no.	Sample	Field no.	Sample	Field no.	Sample	Field no.	Sample	Field no.
1.....	Li18867	47....	Li18952	94....	WC12411	141...	WC12441	188...	WC 9969
2.....	Li18882	48....	WC12269	95....	WC12409	142...	WC12440	189...	WC12407
3.....	Li18881	49....	Li18950	96....	WC 9994	143...	WC12452	190...	WC12434
4.....	Li18886	50....	Li18949	97....	WC 9996	144...	WC12451	191...	WC12410
5.....	Li18868	51....	WC12273	98....	WC12414	145...	WC 8068	192...	BE8134
6.....	Li18885	52....	Li16783	99....	WC12417	146...	WC 8066	193...	WC12433
7.....	Li18866	53....	Li18851	100...	WC10000	147...	WC 8069	194...	WC12432
8.....	WC12275	54....	WC12258	101...	WC 8058	148...	WC 8070	195...	WC12413
9.....	Li18873	55....	WC12256	102...	WC12419	149...	BE 8399	196...	WC12436
10....	Li18836	56....	WC12257	103...	WC 8059	150...	WC 8072	197...	BE 8132
11....	WC12505	57....	Li16784	104...	WC 8061	151...	BE 8131	198...	WC12435
12....	WC12504	58....	Li16785	105...	WC12453	152...	WC 8073	199...	WC12415
13....	WC12431	59....	Li16789	106...	WC 8067	153...	WC 8082	200...	WC 9997
14....	WC12524	60....	Li16790	107...	WC12439	154...	WC 8083	201...	WC12408
15....	WC12429	61....	Li16782	108...	WC 8087	155...	WC 8081	202...	WC12418
16....	WC12525	62....	Li18829	109...	WC 8085	156...	WC12274	203...	WC12420
17....	BE 8130	63....	Li18826	110...	Li18833	157...	WC 8088	204...	Li18896
18....	SC12526	64....	Li18827	111...	Li18834	158...	WC 8064	205...	Li18895
19....	WC12430	65....	Li18825	112...	BE 8174	159...	WC 8063	206...	Li18880
20....	BE 8128	66....	Li16786	113...	BE 8173	160...	WC 8062	207...	Li18893
21....	WC11375	67....	Li18828	114...	WC11429	161...	WC12438	208...	Li18892
22....	WC 8326	68....	WC12272	115...	WC11428	162...	WC12424	209...	Li18890
23....	WC12276	69....	Li18852	116...	BE 8172	163...	WC 8060	210...	Li18889
24....	WC 8327	70....	Li16031	117...	BE 8340	164...	WC12423	211...	Li18888
24A...	WC 8327A	71....	Li18941	118...	WC11427	165...	WC12425	212...	Li18879
25....	Li18871	72....	Li18942	119...	BE 8339	166...	WC 9984	213...	Li18857
26....	Li16248	73....	WC12457	120...	BE 8337	167...	WC 9981	214...	Li18859
27....	Li16249	74....	WC12459	121...	BE 8336	168...	WC12426	215...	Li18860
28....	Li16250	75....	WC12455	122...	WC11426	169...	WC12427	216...	Li18856
29....	Li16775	76....	Li18945	123...	BE 8547	170...	WC12428	217...	Li18855
30....	Li16776	77....	Li16032	124...	BE 8546	171...	WC12405	218...	Li18854
31....	Li16787	78....	Li18944	125...	BE 8548	172...	WC12403	219...	Li18853
32....	Li16788	79....	WC12454	126...	BE 8331	173...	WC12401	220...	Li18877
33....	Li16778	80....	Li18948	127...	BE 8332	174...	WC 9980	221...	Li18878
34....	Li18831	81....	Li18946	128...	BE 8333	175...	WC 9978	222...	WC12260
35....	Li16779	82....	WC12251	129...	BE 8335	176...	WC 9979	223...	WC12261
36....	Li18830	83....	WC12460	130...	BE 8334	177...	WC 9977	224...	Li18875
37....	Li18832	84....	WC12252	131...	BE 8550	178...	WC 9976	225...	WC12259
38....	Li16781	85....	WC11425	132...	BE 8409	179...	WC 9989	226...	Li18874
39....	Li16780	86....	WC 9975	133...	BE 8402	180...	WC 9973	227...	Li18835
40....	Li16247	87....	WC 9972	134...	BE 8400	181...	WC 9971	228...	Li18863
41....	WC12253	88....	WC 9970	135...	WC12450	182...	BE 8137	229...	Li18841
42....	WC12254	89....	WC 9990	136...	WC12449	183...	BE 8138	230...	Li18842
43....	WC 8077	90....	WC 9985	137...	WC12444	184...	BE 8136	231...	Li18843
44....	WC 8076	91....	WC 9983	138...	WC12445	185...	WC 9992	232...	Li18837
45....	WC 8075	92....	WC 9968	139...	WC12447	186...	WC 9991	233...	Li18838
46....	WC 8079	93....	WC 9993	140...	WC12443	187...	WC 9966	234...	Li18839