UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A COMPARISON OF ROCK AND SOIL SAMPLES FOR GEOCHEMICAL MAPPING OF TWO PORPHYRY-METAL SYSTEMS IN COLORADO

By

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Abstract

Paired rock and soil samples were collected at widely spaced locations in large segments of the porphyry-metal systems of the Montezuma district in central Colorado and of a northwestward extension of the Summitville district into Crater Creek in southern Colorado. The paired samples do not covary closely enough for one sample medium to proxy for the other. However, the areal distributions of elements in both rocks and soils in these two districts conform to alteration zoning as defined by mineralogy. Differing geochemical patterns of rocks and soils reflect species-dependent responses to weathering. Soils appear to be statistically enriched in ore elements and depleted in rock elements as compared to the matching rocks. These differences are largely artificial, owing to different methods of sample preparation and chemical analysis for rocks and for soils. The distributions of metals in soils delineate the occurrence of ore-metal minerals, mostly from vein deposits, whereas the distributions of metals in rocks conform to zones of pervasive hydrothermal alteration and to the distribution of varied mineral deposits among these zones. Rock and soil samples are equally useful, of comparable map resoluton, and complement one another as a basis for geochemically mapping these porphyry-metal systems.

Introduction

Areal patterns of element distributions in both rocks and soils are related to the petrographic and structural construction, or edifice (Neuerburg, 1978), of the porphyry-metal system and are maps of the probable locations of its latent* mineral deposits. Chemical compositions of fresh rock comprise hypogene distribution patterns, whereas soil compositions comprise patterns that reflect the chemical changes of weathering and the dispersions and sortings of soil formation. Comparisons of rock and soil compositions in geochemical mapping of porphyry-metal systems in the alpine climate is afforded by analysis of paired samples of rock and soil over parts of two porphyry-metal systems: (1) the Montezuma stock in central Colorado and (2) the Crater Creek segment of mineralized rocks centered on the Platoro caldera in southern Colorado. The comparisons are made in terms of a model (Whitten, 1964) of the porphyry-metal system (Neuerburg, 1978) and its weathering and erosion into soil.

A model of the porphyry-metal system.--Hydrothermal alteration and mineralization of the porphyry-metal system is centered on the volcanic venting structures of calc-alkalic batholiths. Alteration is reconstitution of rock minerals by substitution of hydrogen (Hemley and Jones, 1964) for the lithophile cations of aluminosilicates; a net loss of substance is characteristic. Mineralization is principally the addition of sulfur and chalcophile metals to the altered rocks. Some of the original rock cations dissolved by the altering fluids are later re-precipitated during mineralization (table 1). Mineralization is a dependent function of alteration: precipitation of ore elements results from super-saturation

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* Present or potential, but not manifest (Morris, 1976).

(Khamskii, 1969) of the hydrothermal fluids by the solvent losses and solute gains of alteration. The extent and nature of alteration and mineralization vary outward from a center in the vent column (fig. 1). The sequence of alteration changes, categorized as zones (table 2), provides the framework to which other characteristics of the porphyry-metal edifice are conveniently related.

Table 1.--Conspicuous changes in the chemical compositions of rocks subjected to porphyry-metal alteration-mineralization

CHANGE	ELEMENTS	REMARKS
Subtracted	Ca, Mg, K, Na, Sr	Removed almost entirely from the system
Added	Sb, As, Bi, B, Cd, C, Cu, F, H, Au, Hg, Pb, Mo, Ag, S, Te Sn, W, Zn	The principal ore-elements of the system
Redistributed	Ba, Fe, Mn, Si, Zn	Prominent in gangue minerals
Residually enriched	Si, Ti	Mainly evident in the phyllic zone

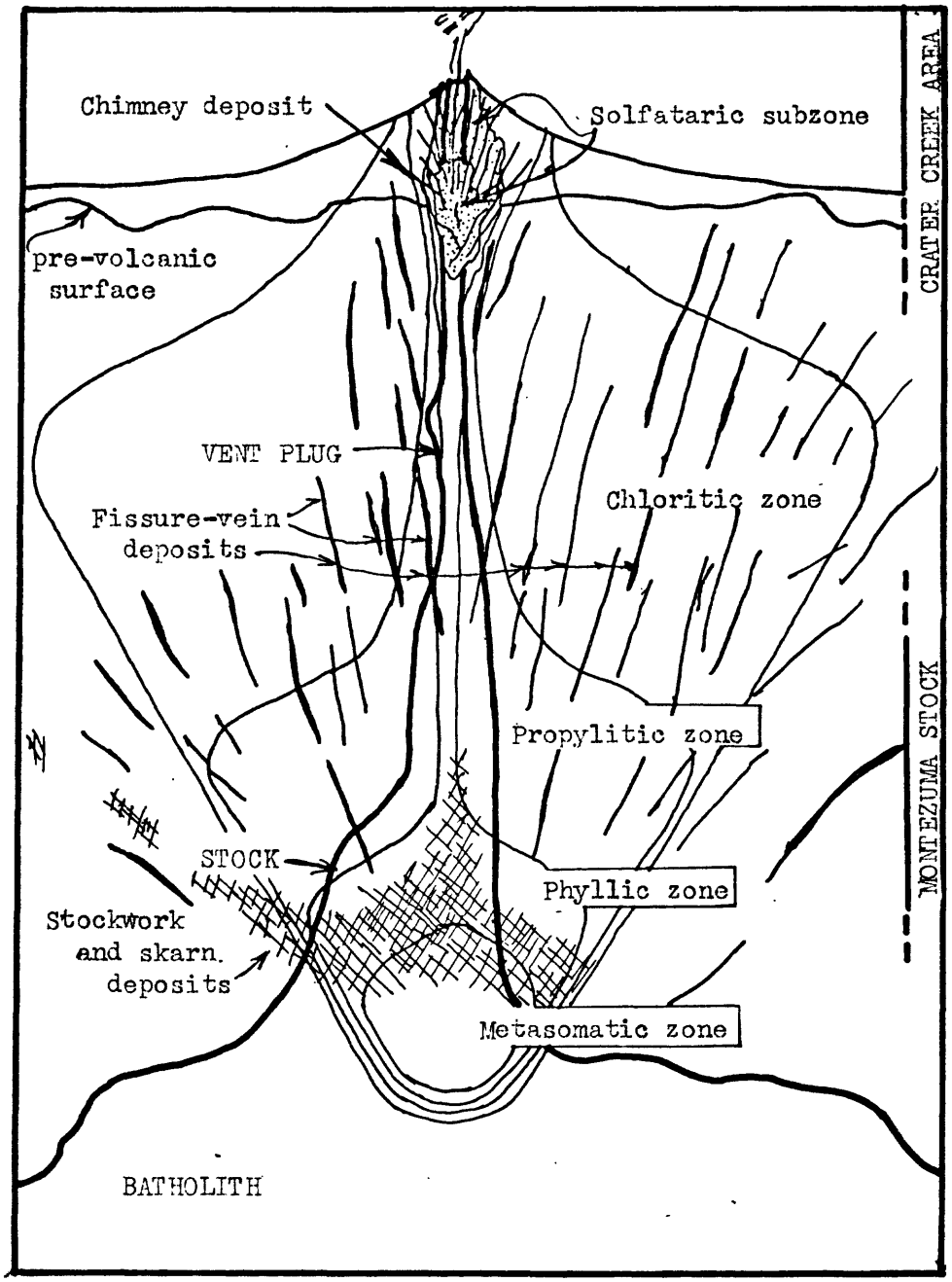


Figure 1.--Geometric patterns of alteration and mineralization on the batholith-vent-volcano framework of the porphyry-metal edifice. Approximate levels of the Montezuma stock and of the Crater Creek area are indicated along the right margin.

Table 2.--Alteration zones of the porphyry-metal system

Zone	Petrography	Changes
Chloritic	Mafic minerals partly chloritized, especially adjacent to fractures. Small amounts of carbonates, iron sulfides and silica minerals added. Textures unchanged.	Trivial addition, mainly of H_2O, S, and CO_2.
Propylitic	Mafic minerals extensively altered to chlorite, and plagioclase to albite, montmorillonite, epidote, and carbonate. Iron sulfides are prominent. Original textures are recognizable.	Addition, mainly of H_2O, S, CO_2, Fe, Mn, and ore metals, most notably Pb and Zn.
Phyllic (includes saussuritic, sericitic, and solfataric stages as subzones)	Mafic minerals and feldspars replaced (plagioclase only, in saussuritic stage) by phyllosilicates (clays and micas) in decussate textures. Grain size and porosity increase with alteration-intensity to form vuggy-sericitic rocks at depth, under reducing conditions, and aluminous-solfataric rocks near the surface, under oxidizing conditions.	Extensive subtraction of Na, Ca, Mg, and Fe; major addition of S and H_2O; and residual enrichment of SiO_2.
Metasomatic	Plagioclase replaced by K-feldspar, carbonates replaced by silicates, and magnetite added. Granoblastic textures.	Exchange: K for Ca, SiO_2 for CO_2. Cu, Fe, Mo, Sn, and(or) W may be added.

Patterns of element dispersion in the porphyry-metal system are distinctive and characteristic of hydrothermal processes in general; their association with batholith venting structures is unique. The effects of both alteration and mineralization are entirely focused on once-permeable structures and textures. Ore elements and minerals are virtually restricted to intergranular sites in the fabric of rock minerals. Extreme outcrop variance, that is, the spatially heterogeneous distribution of metal values at all sampling scales is the outstanding expression of these hydrothermal modes of dispersion.

Supergene alteration intensifies the dichotomous hypogene alteration-mineralization pattern resulting from different processing of lithophile and chalcophile elements. Weathering intensifies base leaching and the formation of aluminous phyllosilicates. The dispersion of ore elements by weathering is species-dependent, analogous to the hypogene metal zoning. Some elements are residually enriched owing to a refractory nature or to the insolubility of their oxidation compounds. Others are removed in solution or as gases. Supergene leaching is focused on the permeable fabrics of veins and their alteration envelopes (Lovering, 1934, p. 32).

Soils are natural samplings of weathered rock that are in turn further changed in many ways by the mechanical and chemical processes affecting soil formation (Hawkes and Webb, 1962). The detrital components of soils represent vanished bedrock whereas ore elements adsorbed and precipitated from ground waters and gases are derived mainly from existing bedrock. Mineralization components of soils are detrital particles of primary and secondary ore minerals and the ore elements adsorbed from solutions. Here also, the dichotomy of hypogene alteration and mineralization is preserved as syngenetic and epigenetic secondary dispersions (Hawkes and Webb, 1962, p. 144). Soil patterns of element distribution are perhaps more complex and just as heterogeneous as the rock patterns, but in very different geometrical arrangements.

Geology

Both the Montezuma stock and the Crater Creek area (fig. 2) are relatively small parts of complex, multi-episodic porphyry-metal systems. They correspond to different exposure levels of the system (fig. 1). The Montezuma stock includes pyrometasomatic and disseminated mineral deposits of the lower cupola region (Neuerburg and others, 1974) as well as the outlying vein zone. Crater Creek is dominated by chimney deposits and their overlapped, or telescoped vein zones, in solfataric-altered rocks characteristic of the volcanic hood (Neuerburg, 1978).

Montezuma stock.--The Montezuma district is one of the clusters of porphyry intrusives, ore deposits, and altered rocks that make up the Colorado mineral belt. The geology of the Montezuma district is dominated by the Oligocene Montezuma stock and the Precambrian Montezuma shear zone, the principal venting structure of the Montezuma assemblage of porphyry-metal edifices (Neuerburg and others, 1974). This texturally composite quartz monzonite stock intruded Precambrian gneisses and granites and Cretaceous black shales. The stock is roughly quartered by two faults of probable pre-intrusive ancestry: the east-west Ruby Gulch fault and the north-south

Thurman Gulch fault (fig. 3). The areal distribution of stock textures, mineral deposits, and alteration zones is related to these faults (Neuerburg, 1971a).

Crater Creek area.--Mineralized rocks of the Crater Creek area (fig. 4) are a continuation of altered and mineralized rocks extensively exposed in the Platoro caldera. The continuation is along the Pass Creek-Elwood Creek-Platoro fault zone (Lipman, 1975), a complex graben structure that connects the Platoro and Mount Hope calderas across the southeastern edge of the postulated San Juan Batholith (Plouff and Pakiser, 1972). Conspicuous features of this graben structure are monzonite stocks, various dikes, iron-stained rocks, and scattered mineral deposits. Country rocks are dominantly volcaniclastic rocks but include some lava flows, and shales and sandstones of the Upper Cretaceous and Paleocene Animas Formation. Three porphyry-metal edifices are present and overlapping one another in the Crater Creek area (Neuerburg, 1978).

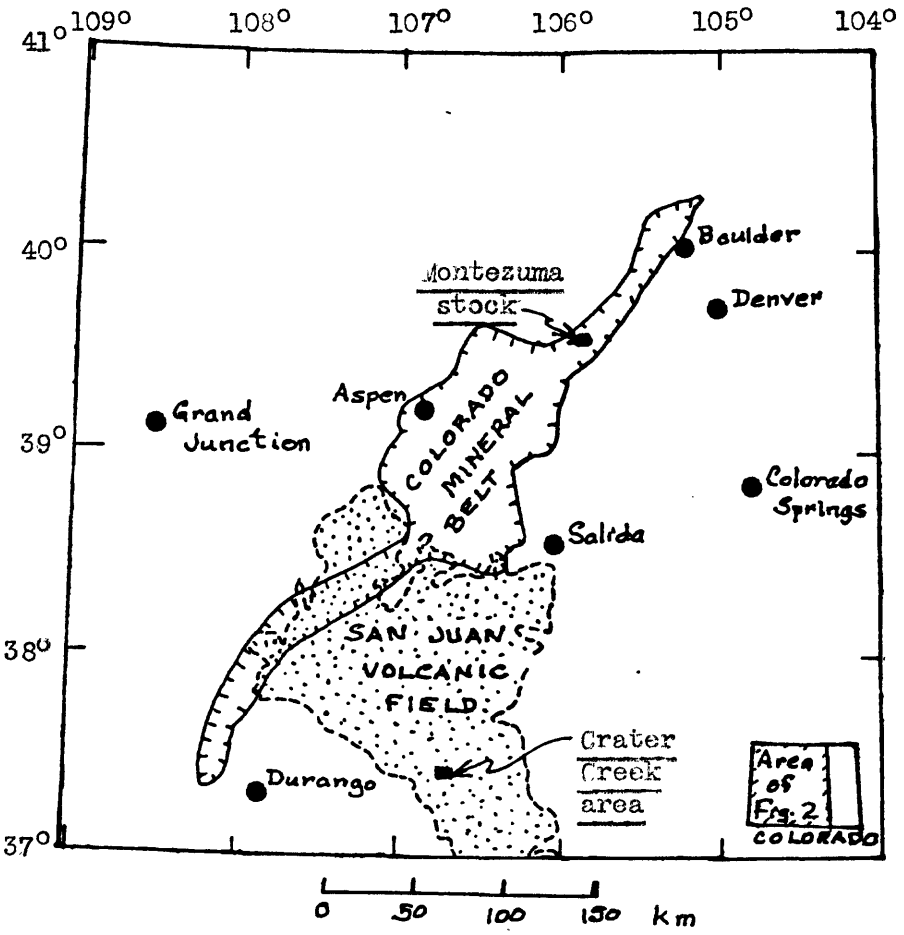
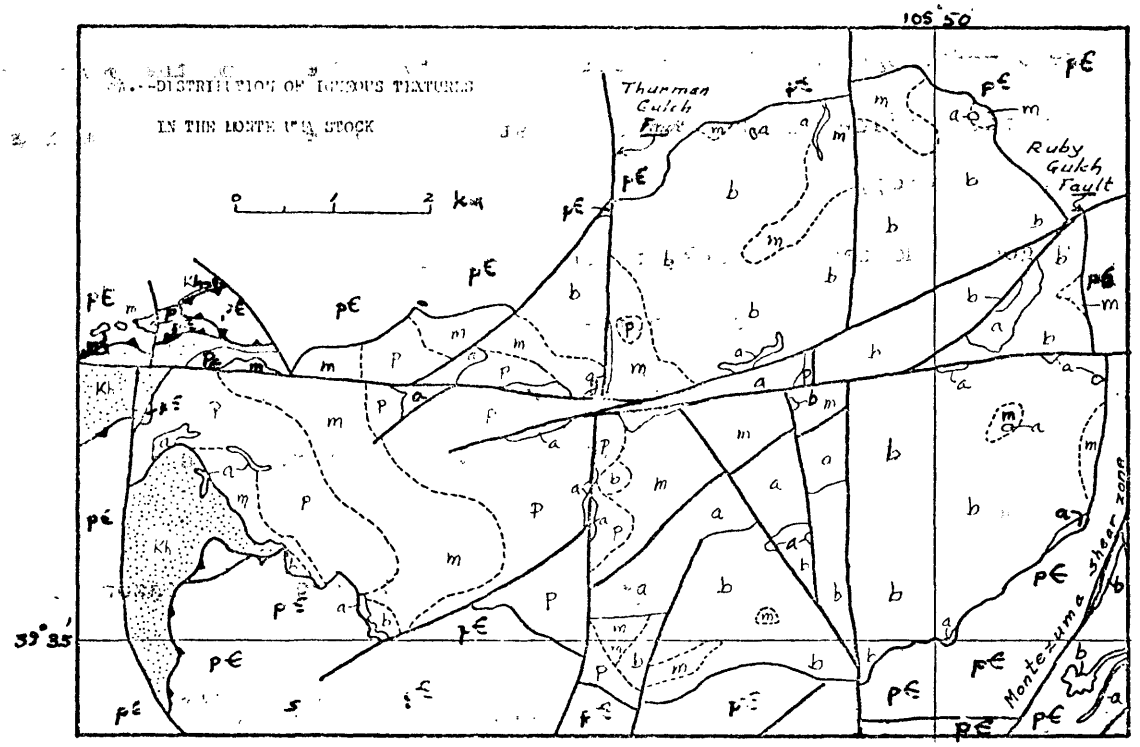


Figure 2.--Index map of central and western Colorado, showing the Montezuma stock and the Crater Creek area in relation to the San Juan volcanic field and to the Colorado mineral belt.


105°50'
3A.--DISTRIBUTION OF IGNEOUS TEXTURES
IN THE MONTEZUMA STOCK
0 1 2 km
Thurman Gulch Fault
Ruby Gulch Fault
Monte-uma shear zone
39°35'

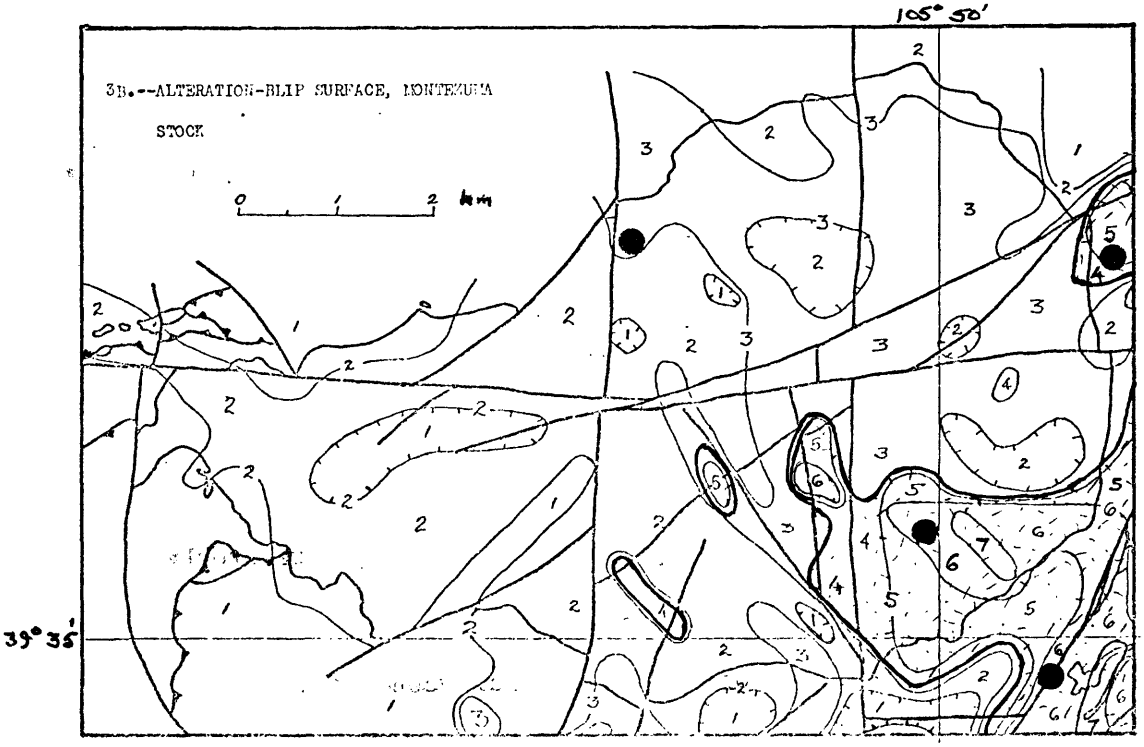

105°50'
3B.--ALTERATION-BLIP SURFACE, MONTEZUMA
STOCK
0 1 2 km
39°35'

FIGURE 3.

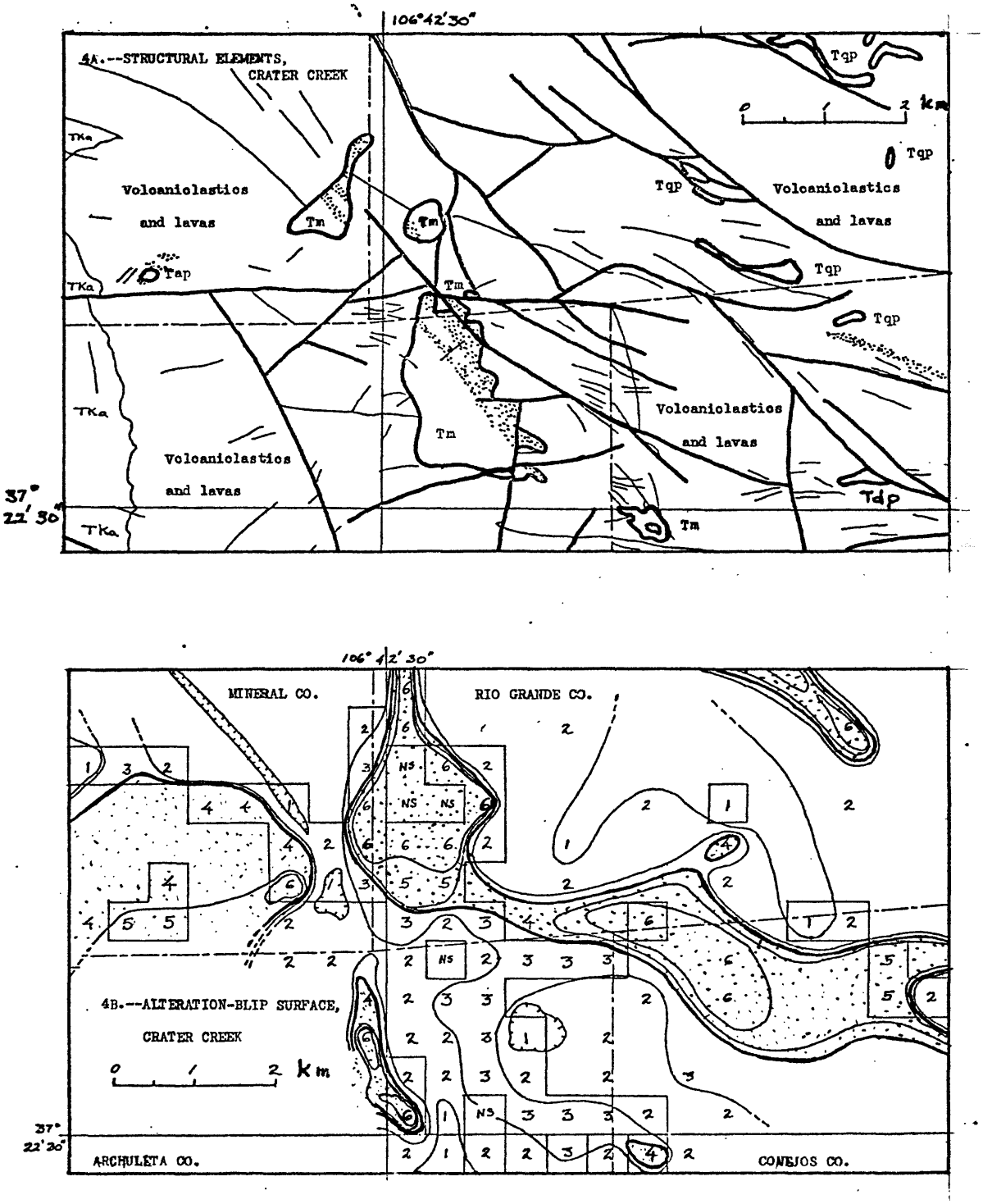

106°42'30"
4A.--STRUCTURAL ELEMENTS,
CRATER CREEK
Volcaniclastics
and lavas
Tm
Tap
TKa
Tqp
Tdp
0 1 2 km
37°
22'30"
MINERAL CO.
RIO GRANDE CO.
4B.--ALTERATION-BLIP SURFACE,
CRATER CREEK
0 1 2 km
NS
ARCHULETA CO.
CONEJOS CO.

FIGURE 4.

Figure 4.--Structural-petrographic (A) and alteration (B) patterns of the porphyry-metal edifices in the Crater Creek area. Prepared from data in Lipman (1974) and Whittington and others (1976).

A. Intrusive rocks:

Tqp - Quartz latite biporphyry (Miocene)

Tdp - Rhyodacite porphyry (Oligocene)

Tap - Andesite porphyry (Oligocene)

Tm - Monzonite and monzonite porphyry (Oligocene)

Sedimentary rocks:

TKa - Animas Formation (Upper Cretaceous and Paleocene)

Thin lines - dikes

Heavy lines - faults

Heavy outlines - stocks and plugs

Dotted trains - protoclastic and intrusive breccia zones

B.--Alteration zones: 1 - pyrogenic, i.e., not altered

2 - chloritic (not hydrothermal)

3 - propylitic

4 - saussuritic

5 - phyllic

6 - solfataric

Subtractive alteration zones (4, 5, and 6) are shaded.

Figure 3.--Petrographic (A) and alteration (B) patterns of the porphyry-metal edifice in the Montezuma stock. Adapted from Neuerburg and others (1977).

A.--Oligocene Montezuma stock, textural varieties:

a - granite aplite and rhyolite

b - biotite granodiorite-biotite quartz latite biporphyry

m - mortar-textured porphyritic biotite granodiorite-quartz monzonite

p - phaneritic-porphyritic biotite granodiorite-quartz monzonite

Intruded rocks:

Kh - Cretaceous hornfelsed black shales

pG - Precambrian gneisses and granites

B.--Alteration zones: 1 - pyrogenic or metamorphic, i.e., not altered

2 - chloritic

3 - propylitic

4 - saussuritic

5 - phyllic

6 - vuggy sericitic

7 - vuggy sericitic, with quartz stockworks

Subtractive alteration zones shaded:

Solid circles - areas of major ore-fluid conduits.

Sampling design.--Matching rock and soil samples were collected from 538 localities over the 40 km^2 area of the Montezuma stock (Neuerburg, 1971a, b). Rock samples were chosen for freshness and to test as nearly as possible only the effects of pervasive alteration; sheared, jointed, and rock-contact areas of outcrops were avoided. The soils are thin, postglacial and mostly of local origin. The upper 4-5 cm of the A_1 soil horizon, chosen for ease of sampling, were collected as close as possible to and generally above the rock sampling site. Rocks and soils were chemically analyzed for Sb, As, Bi, Cu, Au, Pb, Hg, Ag, Te, and Zn. Coarsely jaw-crushed 4-5 gram single-fragment sub-samples (Neuerburg and Granger, 1960) of rock were leached with 1:1 HNO_3 for 48 hours; the leachate alone was analyzed and referred to the whole rock. The minus-80-mesh fraction of soils was analyzed using conventional dissolution techniques (Ward and others, 1963); concentrations do not refer to the full (unsieved) soil sample weight.

Outcrops and adjacent soils in the Crater Creek area were sampled at 154 localities (USGS and USBM, 1977) over an area of 14 km^2. Rocks of maximum alteration-mineralization were sampled at each site; brecciated, sheared, and (or) fractured, but mostly fresh samples were selected. Other less altered rocks were also sampled at many localities to further explore correlations of ore elements with degree of alteration and with rock type. The soils are post-glacial residual accumulations. The upper 4-5 cm of the A_1 soil horizon were collected from the soil above and nearest to the rock sampling site. Rock samples of 100-150 grams were submitted for analysis, whereas only the minus-80-mesh fraction of air-dried soils was subsampled for analysis. All samples were analyzed spectrographically and results for both rocks and soils were obtained for Ag, B, Ba, Be, Bi, Ca, Cr, Co, Cu, Fe, La, Mg, Mn, Mo, Ni, Pb, Sb, Sc, Sn, Sr, Ti, V, Y, Zn, and Zr, and the samples were also analyzed chemically for Au, Hg, Te, and Zn (Whittington and others, 1976).

Geochemical comparisons of rocks and soils

Paired rocks and soils.--Metal contents of rocks and soils from contiguous sampling sites differ in absolute and relative magnitude from place to place within the porphyry-metal edifices of Montezuma and Crater Creek. The metal concentrations of each sampling medium are systematic in relation to nearness of mineral deposits and to position within the edifice, but they vary independently from one another. Soils were collected so as to preclude any soluble-metal contribution ("contamination") from the sampled rock to the sampled soil. Metals of the particulate components of the soil are from vanished bedrock, further precluding any dependent relation to the paired rock sample. Different analytical procedures were used for rocks and soils, thereby artificially exaggerating existing differences. Specifically, the whole rock sample was analyzed, whereas only the minus-80 mesh-soil fraction was analyzed, as if it were the whole sample. As a rule, the minus-80-mesh soil fraction contains most of the phyllosilicates and most of the ore minerals and adsorbed ore metals of the sample. Measurement of only the labile metals (Neuerburg and Granger, 1960) in the Montezuma rocks and the avoidance of fractured areas of outcrop further exaggerate the contrast between metal concentrations of rocks and soils for the Montezuma sample set.

Comparisons (fig. 5) of the metal contents of matched rock and soil samples in both areas show only a generally diffuse positive correlation of metal concentrations. The statistical modes of these comparisons indicate varying enrichment or depletion of elements in soils (table 3) relative to the paired outcrops. For the stated experimental conditions, ore metals are mostly enriched and rock elements are mostly depleted in soils in comparison with rocks presumably like the parent rocks of the soils. These patterns are predictable projections of the processes of rock weathering, and are thus real to some unknown degree. Although an experimental artifact, the reported soil enrichment is helpful in geochemical mapping (Chaffee, 1977; Cox and Learned, 1977; Learned and Boissen, 1973; Rostad, 1969) because it brings more samples into analytical range; i.e., above threshold.

Table 3.--Modes of dispersion of elements between rocks and the minus-80-mesh fraction of soils, Montezuma stock and Crater Creek area, Colorado

Area	Enriched in soil	Depleted in soil	No fractionation
Crater Creek	Sb, B, Au, Pb, Hg, Mo, Te, Zn	Ba, Ca, Cr, Co, Fe, La, Mg, Mn, Ni, Sc, Ag, Sr, Ti, V, Y	Be, Bi, Cu, Zr
Montezuma stock	Sb, Cu, Au, Pb, Hg, Ag, Te, Zn	*	Bi

* None among the elements analyzed for both rocks and soils from the Montezume stock.

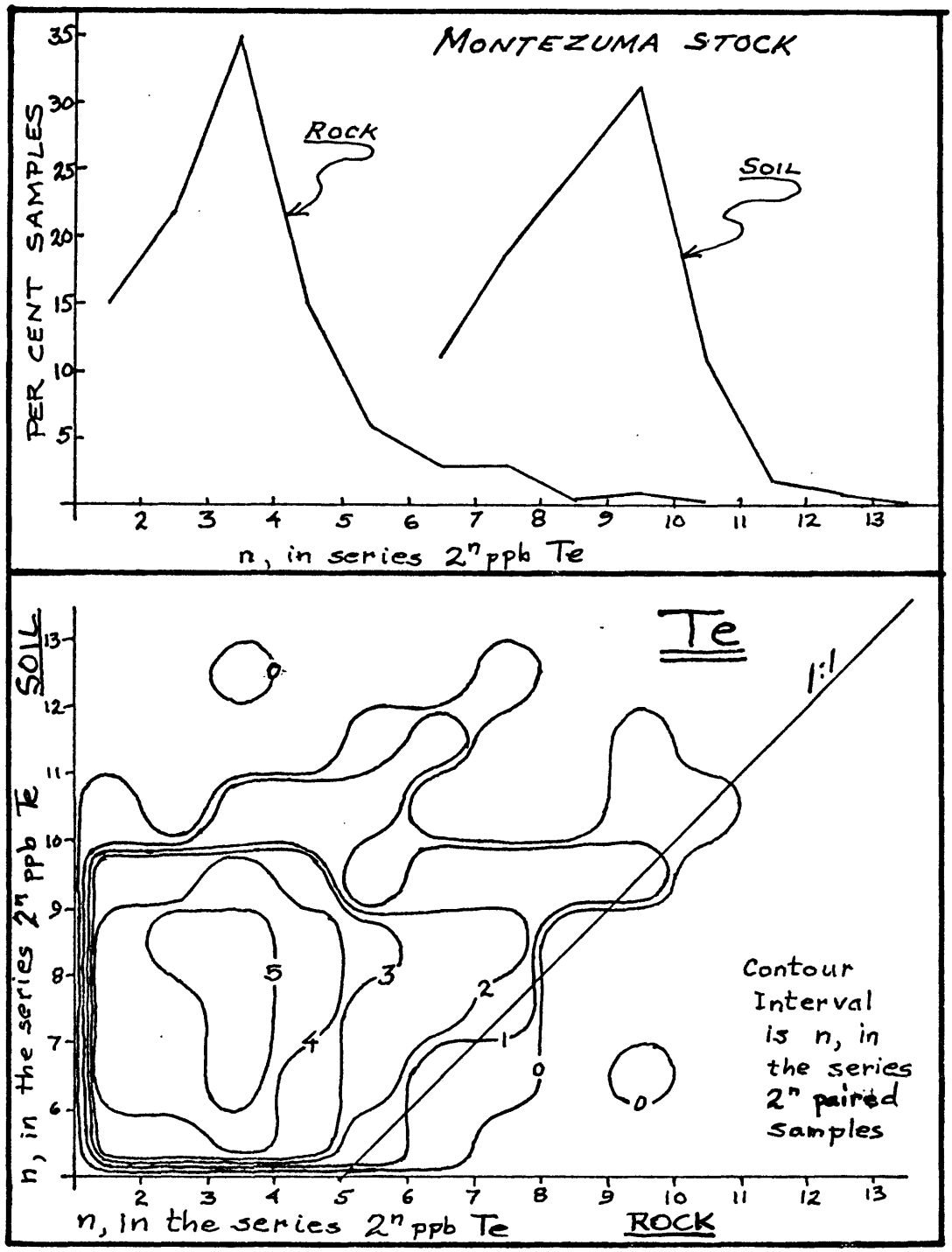


Figure 5.--Frequency curves and contoured scatter diagram of rock Te and soil Te for matched rock and soil samples from the Montezuma stock, as an example of the general nature of such covariation for all measured elements from both the Montezuma stock and the Crater Creek area. Ranges: rock, L(5) - 1,030 ppb; soil, L(100) - 3,000 ppb. (L - present, but less than the lower limit of measurement in parenthesis).

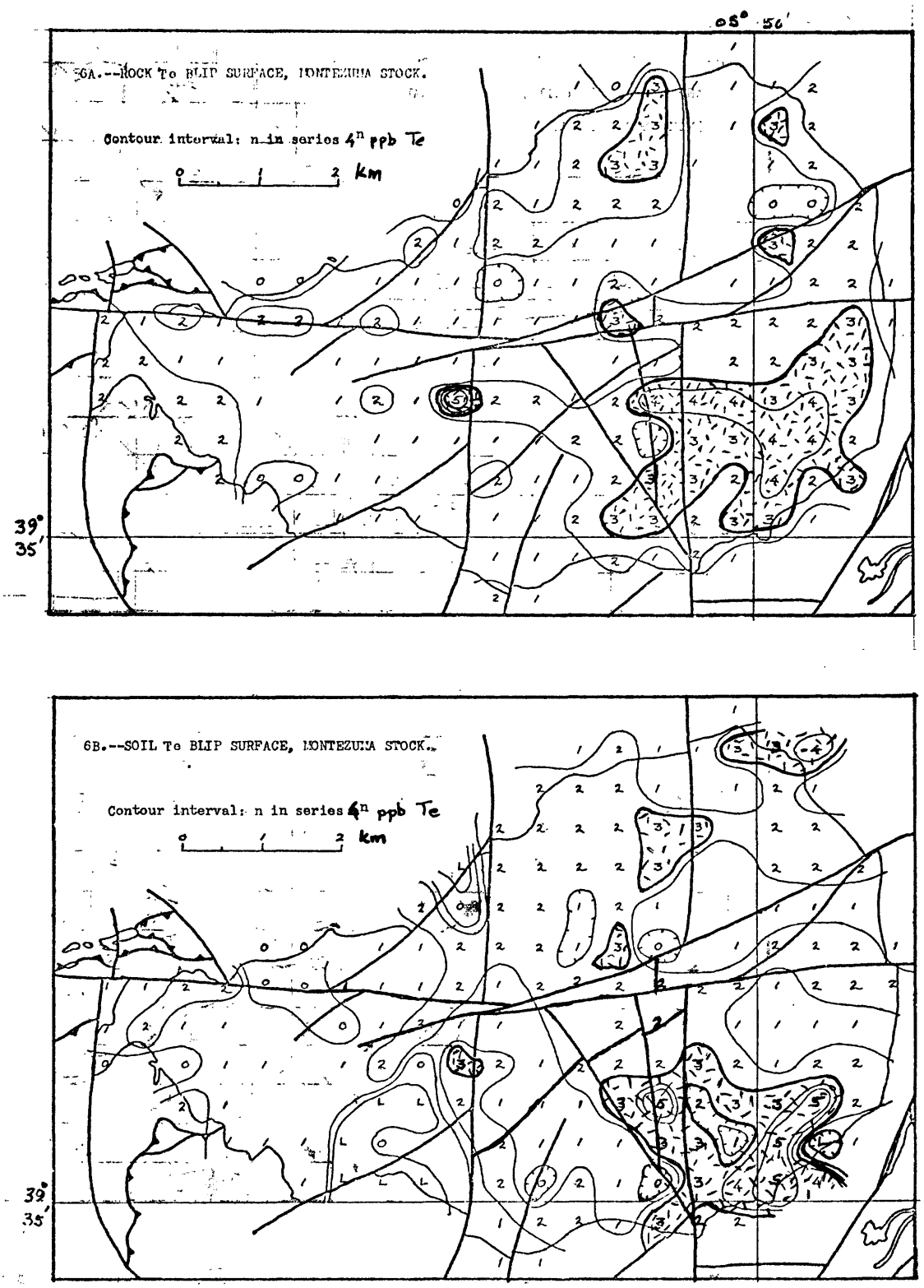


Figure 6.--Blip-surfaces of rock Te (A) and of soil Te (B) in the Montezuma stock. Ranges: rock Te, L(5) - 1,030 ppb; soil Te, L(100) - 4,400 ppb. Concentrations greater than 64 ppb Te are shaded.

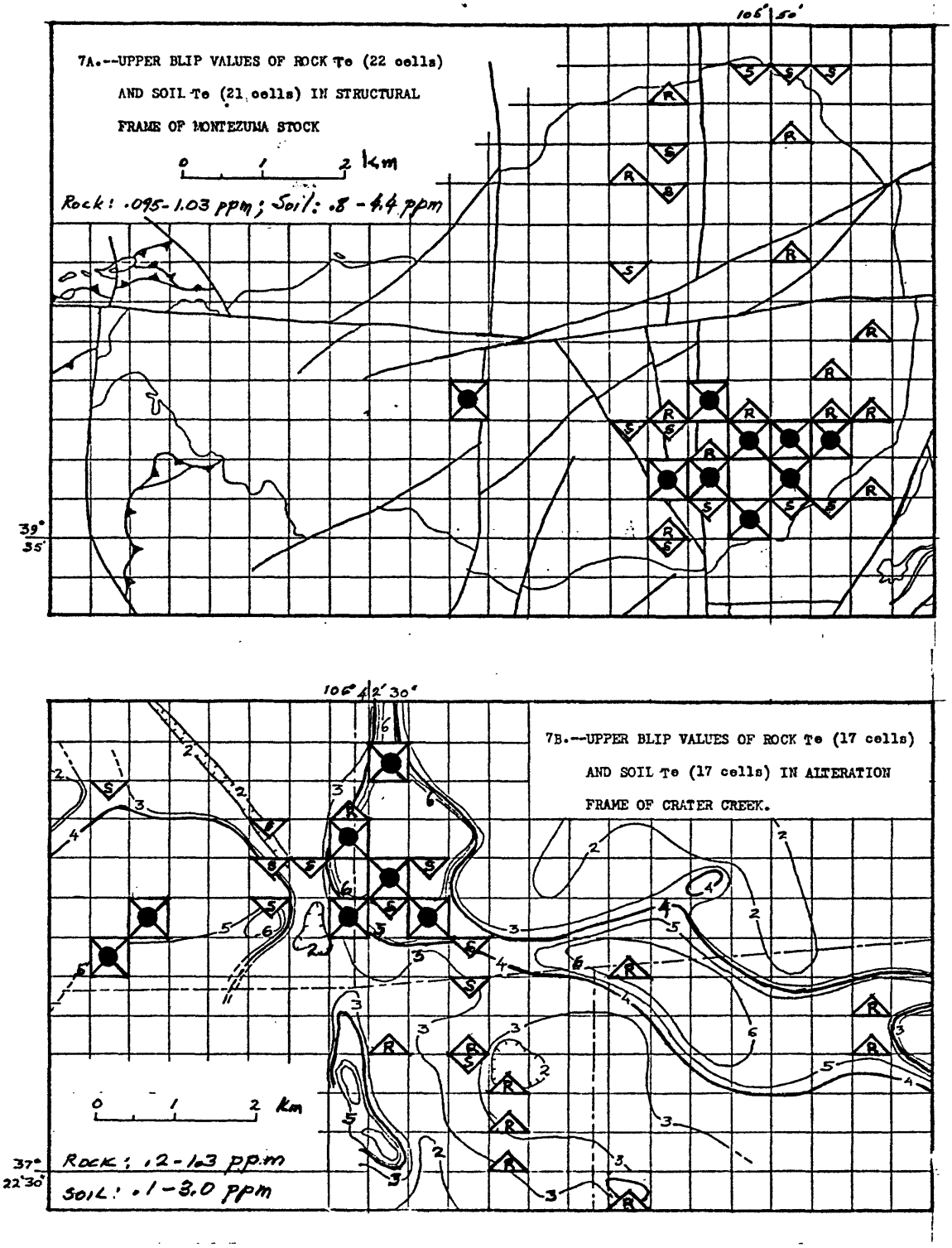
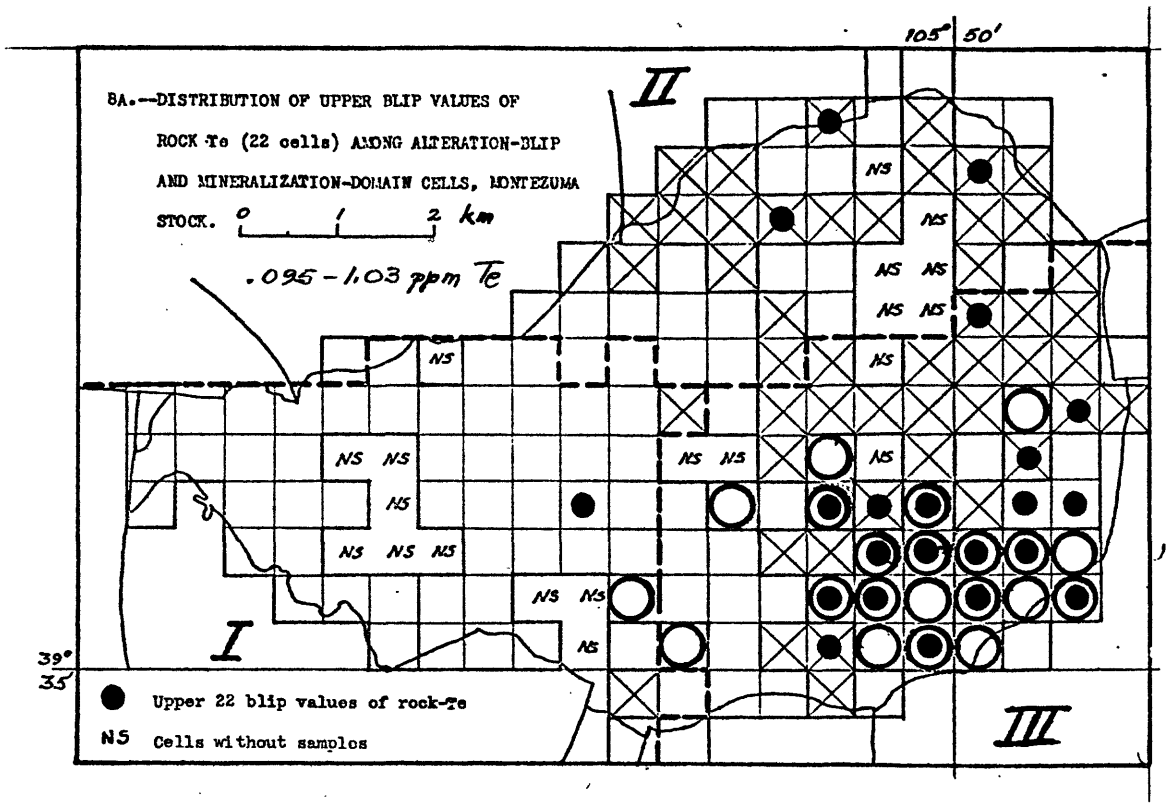


Figure 7.--Comparisons of the distributions of upper blip values of rock Te and soil Te in the structural frame of the Montezuma stock (A) and in the alteration frame of the Crater Creek area (B). R- rock, S- soil, and maltese cross- rock and soil upper blip value in indicated grid cell.


8A.--DISTRIBUTION OF UPPER BLIP VALUES OF ROCK Te (22 cells) AMONG ALTERATION-BLIP AND MINERALIZATION-DOMAIN CELLS, MONTEZUMA STOCK.
0 1 2 km
.095 - 1.03 ppm Te
105° 50'
39° 35'
I
II
III
NS
Upper 22 blip values of rock-Te
NS Cells without samples

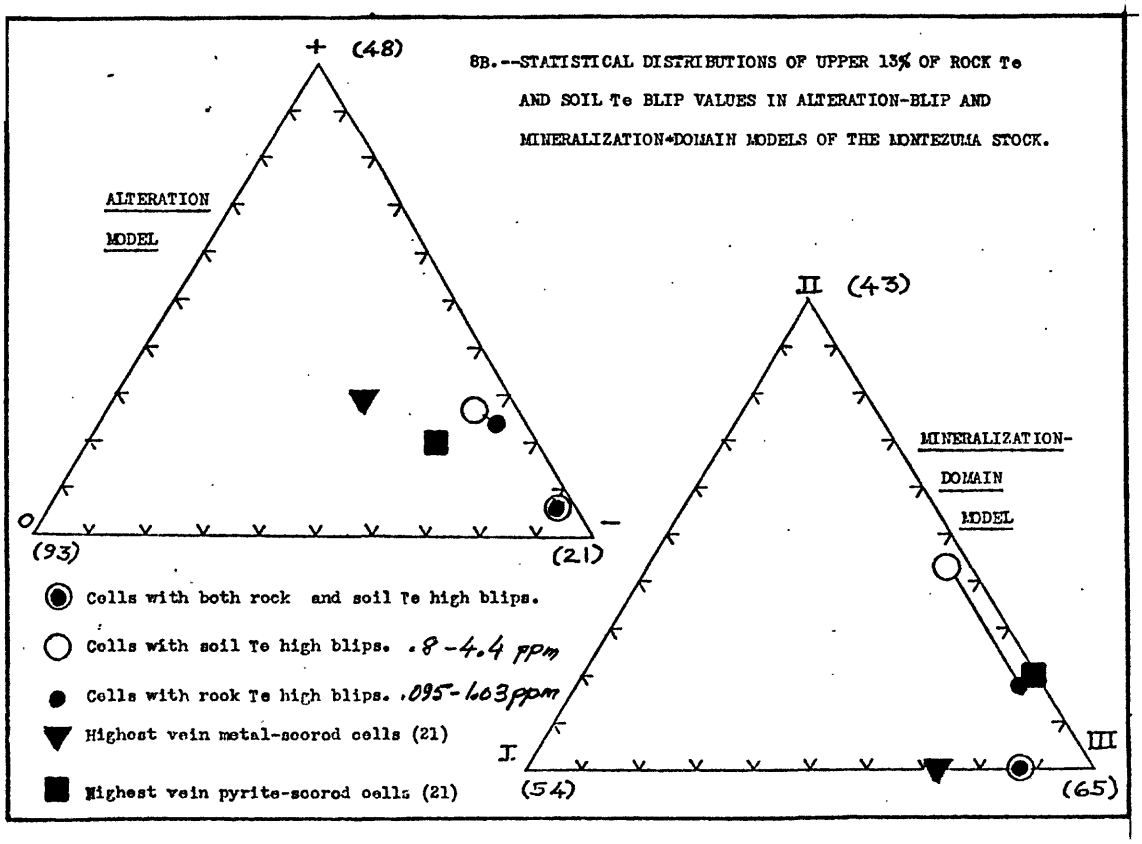

8B.--STATISTICAL DISTRIBUTIONS OF UPPER 13% OF ROCK Te AND SOIL Te BLIP VALUES IN ALTERATION-BLIP AND MINERALIZATION-DOMAIN MODELS OF THE MONTEZUMA STOCK.
ALTERATION MODEL
+ (48)
(93)
(21)
MINERALIZATION-DOMAIN MODEL
II (43)
I
III
(54)
(65)
Cells with both rock and soil Te high blips.
Cells with soil Te high blips. .8 - 4.4 ppm
Cells with rock Te high blips. .095 - 1.03 ppm
Highest vein metal-scored cells (21)
Highest vein pyrite-scored cells (21)

FIGURE 8.

Figure 8.--Distribution of upper Te blip values among cells of the alteration model and the mineralization-domain model of the Montezuma stock in map form (A) and graphically (B).

Mineralization domains (Neuerburg, 1971a) are areas of

I - Sparse greisen-flanked veins in sporadically chloritized, mostly phaneritic quartz monzonite.

II - Sparse phyllic-flanked veins in propylitized, mostly biporphyritic quartz monzonite.

III - Numerous phyllic-flanked veins in propylitized biporphyritic quartz monzonite around a core of pervasively phyllic-altered quartz monzonite.

Alteration-blip cell classification (table 2).

8A	8B	
Circles	- (n)*	Subtractive alteration: phyllic
Crosses	+ (n)	Additive alteration: propylitic
Blank	0 (n)	Little or no change: chloritic and pyrogenic rocks

* (n) number of cells in the category

Metal scores (fig. 8B) are arbitrarily calculated ratings of the base metal and pyrite vein mineralization of each cell (Neuerburg and others, 1977).

Lithophile elements of rocks and soils in characterizing the porphyry-metal system.--Soils are largely composed of rock minerals and thus should reflect the alteration zone-structure of the porphyry-metal edifice. Rock elements are leached in hydrothermal alteration; maximum measures of alteration are accordingly the smaller analytical values. Low cell values for these elements in Crater Creek rocks characterize the phyllic zone (fig. 9). This correlation persists in less pronounced degree with the matching soils, except for barium and iron, which are more or less evenly distributed among the alteration components. Barium is leached from rock during alteration but remains in the system as barite gangue in veins. Veins are virtually coextensive with phyllic-altered rocks (fig. 9) at Crater Creek. The resistate mineral, barite is thus a detrital component of soils in the phyllic zone and low-barium soils accordingly occur outside the phyllic zone cells. The ambiguous distribution of iron in soil in the alteration model is explained by its differing fabric modes of occurrence among the alteration zones. Soils with low iron are in areas of propylitic-altered rocks where iron occurs prominently as magnetite and pyrrhotite (fig. 9) in a dense, impermeable fabric, whereas rock with low iron is phyllic-altered, where iron occurs mainly as pyrite in a very permeable fabric. Evidently the higher iron content of the propylitic-altered rocks is not readily available to and not very reactive with weathering agents to yield much iron to the associated soils. With the exceptions of barium and iron, low soil-lithophile metal concentrations afford recognizable pattern identification of phyllic-altered bedrock terrane.

Relative association of ore elements in rocks and soils with alteration.--The distribution of selected high rock and high soil metals among the three principal alteration modes is compared in figure 10. Metals in rocks correlate with both alteration and vein deposits (fig. 10A). Metals in Crater Creek rocks are more closely associated with alteration than those in the Montezuma stock (fig. 10A), corresponding to a greater concentration of metalliferous veins in solfataric cells at Crater Creek or conversely to the greater dispersion of veins into lesser altered rocks of the Montezuma stock. Metals in soils over the Montezuma stock are relatively more dispersed than metals in rocks and are more associated with propylitic alteration. The metals of Crater Creek soils are more closely associated with phyllic-solfataric cells owing to the coincidence of vein cells with solfataric cells. The ore metals of Crater Creek soils are more diagnostic of the subtractive-alteration zones than are those of rocks. Whatever the explanation, the metal patterns of rocks and soils are evidently (1) parochial and (2) empirical. Altogether, the close association of high soil metal-blip cells with vein cells in these diagrams is indicative of major contributions of metals from ore minerals in veins and other structural concentrations.

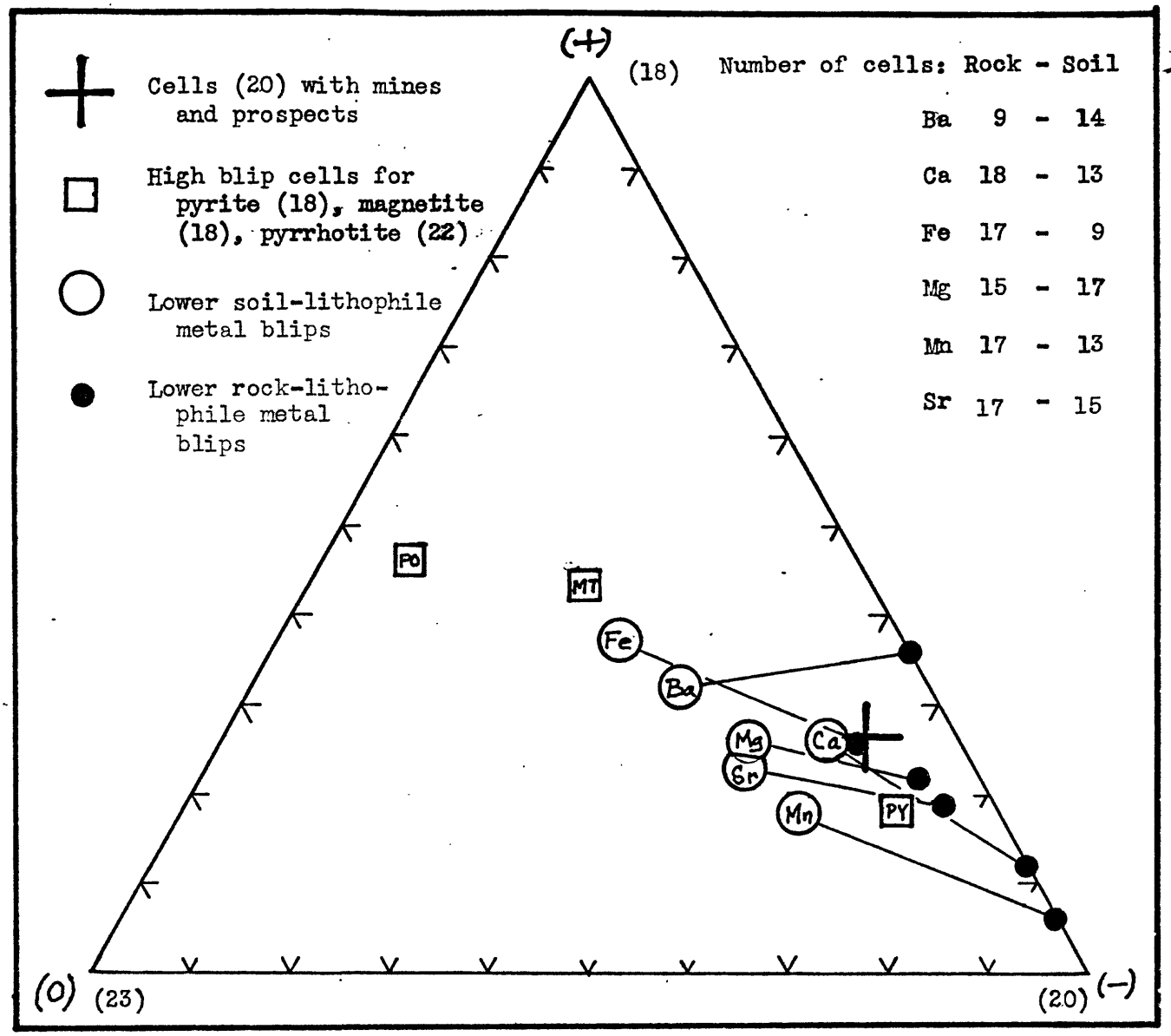


Figure 9.--Statistical distributions of lower values for lithophile elements of rocks and soils in the alteration-blip model of the Crater Creek area.

RANGES:	ROCK	SOIL	
Ba	100-1,000	100-700 ppm	by emission spectrography
Ca	.05-.3%	.1-.3%	
Fe	1-3%	.7-1.5%	
Mg	.03-1%	.1-.5%	
Mn	15-300	150-500 ppm	
Sr	20-700	100-700 ppm	

(-, +, o as in figure 8B.)

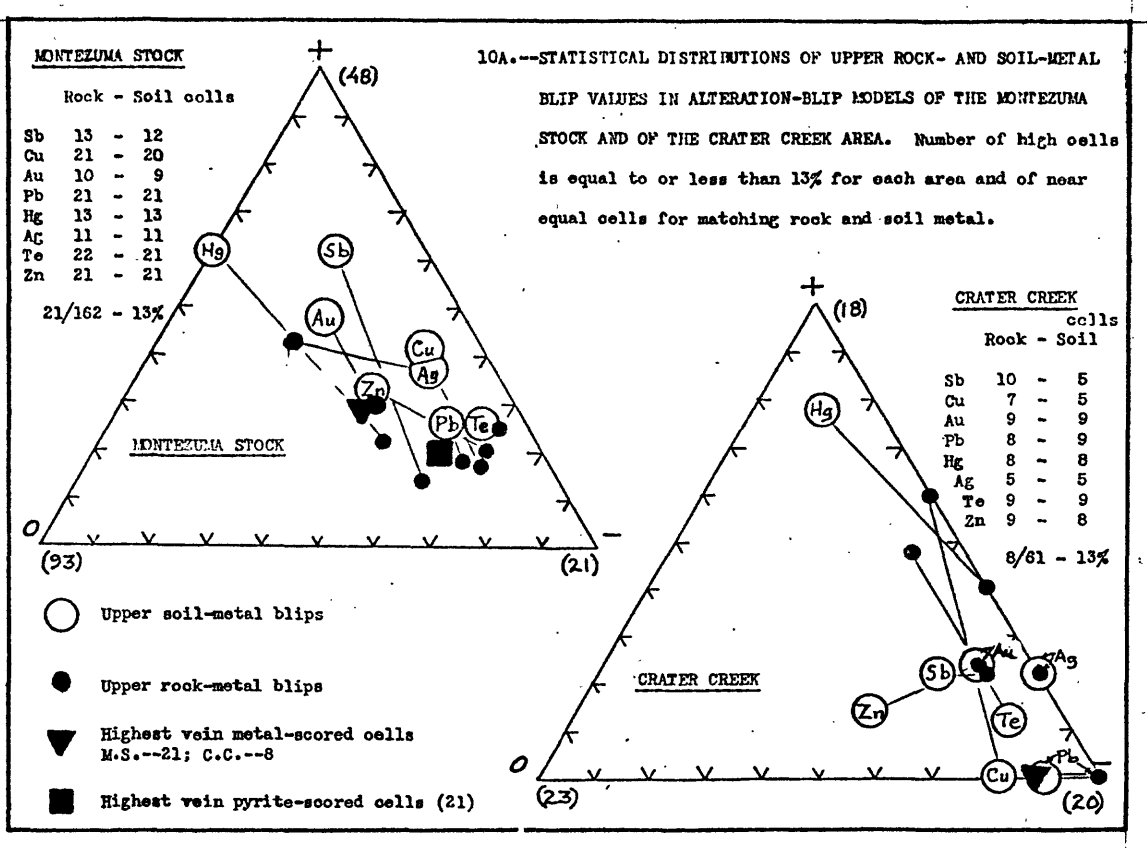
Rocks and soils as map parameters.--Geochemical maps portray geographic variations in chemical attributes of rocks and soils in relation to geologic attributes. These maps are drawn on a 480 m grid (2 cm at 1:24,000). The maximum measure of chemical change by alteration or mineralization for each parameter in each grid cell is taken to represent that cell. The maximum measure or blip, is the lowest value for an element leached from the rock in alteration or the highest value for an element added in alteration or mineralization. The resulting data array is graphically depicted in three ways:

1.--The array is contoured (fig. 6), to produce a blip surface (Neuerburg and others, 1974), as an approximation of gradients of alteration or mineralization.

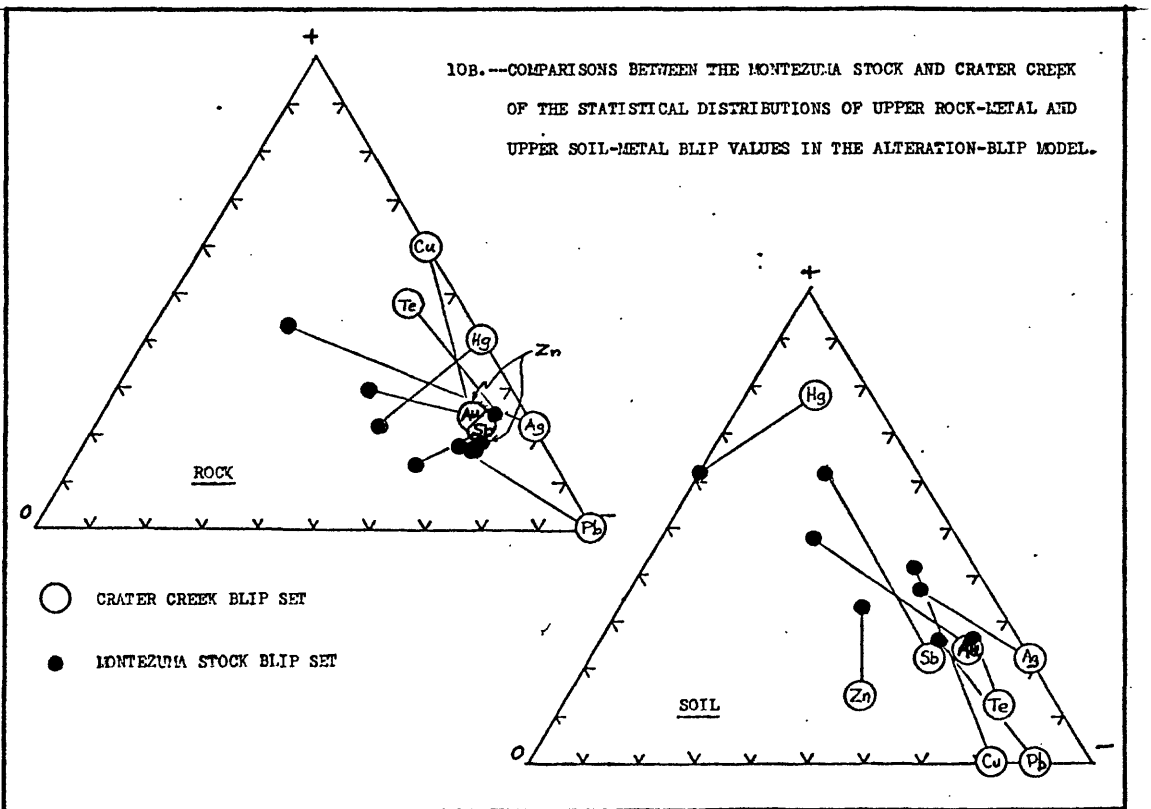
2.--Cells of a specified range of concentrations in rock, say the upper 10 percent of blip values, are plotted on a gridded geologic, alteration, or mineralization map of the area, together with an equal number of cells of a like range of metal concentrations in soil (fig. 7).

3.--A three-component model of a geographically dependent feature, such as rock type, mineral deposit type, or alteration zone is chosen. All sampled grid cells are apportioned among the three model components. A specific number of grid cells of a selected concentration range for an element are chosen. The distribution of these selected cells among the model components (fig. 8A) is determined and recalculated to 100 percent for plotting in a triangular diagram (fig. 8B).

The number of cells chosen here is equal to or less than the model component of fewest cells, which is 21--or 13 percent--for the phyllic component of the Montezuma stock alteration model. For comparisons within an area, as between Te in rock and Te in soil in the Montezuma stock, the number of cells for the compared items is equal and as near to 21 as the data permits. Where comparing two areas, the governing maximum number of cells is from the area with the fewest cells by proportion for any model component, here 21 cells (13 percent) of phyllic alteration for the Montezuma stock and thus 8 cells (13 percent) for the Crater Creek area.



10A.--STATISTICAL DISTRIBUTIONS OF UPPER ROCK- AND SOIL-METAL BLIP VALUES IN ALTERATION-BLIP MODELS OF THE MONTEZUMA STOCK AND OF THE CRATER CREEK AREA. Number of high cells is equal to or less than 13% for each area and of near equal cells for matching rock and soil metal.



10B.--COMPARISONS BETWEEN THE MONTEZUMA STOCK AND CRATER CREEK OF THE STATISTICAL DISTRIBUTIONS OF UPPER ROCK-METAL AND UPPER SOIL-METAL BLIP VALUES IN THE ALTERATION-BLIP MODEL.

FIGURE 10.

Figure 10.--Rock metal and soil metal distributions in the alteration model within (A) and between (B) the Montezuma stock and the Crater Creek area. (-, +. 0, as in figure 8.)

	RANGES (ppm)			
	MONTEZUMA STOCK		CRATER CREEK	
	Rocks	Soils	Rocks	Soils
Sb	1-3	6-150	1-40	2-8
Cu	11-110	65-590	300-1,500	150-500
Au	.01-.08	.06-1.4	.066-20	.094-130
Pb	24-440	1,000-5,500	700-3,000	200-700
Hg	.03-.08	1.6-2.7	.2-3.2	.3-2.0
Ag	.11-.15	5.2-300	2-50	.7-5
Te	.095-1.03	.8-4.4	.4-1.3	.39-3.0
Zn	200-1,600	980-13,000	130-480	140-250

The separation of rock and soil metals in these diagrams is a measure of element mobility in the local, or parochial weathering process and an indication of the source of the metal. Small separations, as with Pb and Te (fig. 10), reflect dispersion of the element in detritus, unchanged in form or as an insoluble oxidation product, and relate to nearby outcrop. Widely separated rock and soil metals, as Cu and Hg (fig. 10), reflect soluble or gaseous elements that empirically are largely derived from still-existing bedrock concentrations--so called leakage haloes--and may be precipitated in soils at some distance from their source, to show no apparent relation to their underlying lithologic environment. Elements that travel with detritus, evidently a dominant factor in enhancing the metal contents of weathering products (Neuerburg and others, 1976), are pragmatically equated with hypogene metal patterns of rocks and can be judiciously substituted for them in geochemical mapping where necessary.

Conclusions

Soil is a natural, fractionated sampling of existing as well as of vanished bedrock. The A_1 horizon of thin alpine soils over rocks of porphyry-metal edifices in Colorado yields metal values that apparently exaggerate the hypogene effects of both alteration and mineralization. The syngenetic, or detrital fractions of soils, derived from vanished bedrock, project in diffuse form the hypogene alteration patterns of leached lithophile elements. However, only a few of the hypogene mineralization patterns of added chalcophile elements are continued or augmented. Epigenetic, or adsorbed soil components represent existing bedrock, mainly in and adjacent to permeable vein- and stockwork- mineral deposits. Given the reasonable postulate of vanished bedrock being a continuation of existing bedrock, soil sampling may be used in place of rock sampling where necessary for mapping the porphyry-metal system. More importantly, soil data complements rock data to make for more complete and more accurate geochemical maps, where faced with the realities of limited and weathered outcrop.

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