DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I–608

DISTRIBUTION OF SELECTED ACCESSORY MINERALS IN THE MONTEZUMA STOCK, SUMMIT COUNTY, COLORADO

The Montezuma stock is one of several igneous bodies whose minor accessory minerals distribution is being studied for possible use as a prospecting guide. (See Neuerburg, 1956, 1967).

The concept that minor accessory minerals, particularly sulfides, in igneous rocks may be a guide to ore is based on the premises that the late magmatic fluids of an igneous body are the mineralizing fluids, that most minor accessory minerals crystallize from these residual fluids, and that the amount and variety of accessory minerals increase with time during crystallization of the residual fluids. Once an igneous body has virtually crystallized to a solid mass, further cooling results in contraction and microfracturing of single crystals, thereby loosening the rock fabric (Neuerburg, 1958, p. 296; Neuerburg and Granger, 1960, p. 777). The permeability thus induced permits movement of residual fluids in response to pressure differences. Where pressure differences exist, the dispersed fluids collect and migrate through the intrusive body, simultaneously precipitating minor accessory minerals. The distribution patterns of concentration and variety of accessory minerals in an igneous body should, therefore, record the conduits through which the late magmatic mineralizing fluids moved.

Loosening of the fabric and movement of residual fluids begin at the upper contacts of an igneous mass and proceeds downward. Thus, the source of mineralizing fluids moves gradually downward and earlier crystallized parts of the intrusive mass become potential thoroughfares and hosts for ore deposits formed from these endogenous fluids. Later fluids derived from deeper within the intrusive mass carry not only metals from which ore deposits might form but also heat needed to bring about hydrothermal alterations in the earlier crystallized but still warm parts of the intrusive body (Neuerburg, 1958, p. 296).

Where fortuitous and timely pressure differences are lacking, residual fluids do not circulate significantly before they completely crystallize; the resulting accessory mineral distribution patterns are spatially random and they record any original compositional heterogeneity and (or) minor pressure variations, as in the Caribou stock (Neuerburg, 1967). Where pressure differences have brought about migration of residual fluids during their period of crystallization, the resulting mineral distribution patterns are expected to show concentration and variety gradients controlled by structural features and directed toward sites of ore deposition, as in the Osgood Mountains stock (Neuerburg, 1966). Either of these types of patterns may be modified by the effects of migration of mineralizing fluids from below, with or without deposition of ore, as in the Montezuma stock.

The Montezuma stock of Tertiary age, one of several porphyritic quartz monzonites in the Front Range mineral belt, intruded complexly folded and faulted Precambrian metamorphic and igneous rocks and Cretaceous Pierre Shale (Lovering, 1935). The stock widens appreciably with depth, as shown in the Roberts Tunnel, and is probably a cupola off a much larger batholithic mass (Wahlstrom and Hornback, 1962, p. 1497; Warner and Robinson, 1967, p. 101). The stock covers about 16 square miles in a deeply glaciated region; about half its area is covered with glacial debris. Elevation ranges from 9,400 to 13,200 feet.

The bulk of the stock is a coarse-grained, largely porphyritic rock that contains as much as 20 percent phenocrysts of K-feldspar. Phenocrysts are least abundant in the west end of the stock and in the Roberts Tunnel, though rarely entirely absent. Eastern and topographically high parts of the exposed stock consist of biporphyritic quartz monzonite—small fragments of porphyritic quartz monzonite in a markedly finer grained, in places aplanitic, and sparsely miarolitic matrix of quartz monzonite. The biporphyritic quartz monzonite is apparently intruded by porphyritic quartz monzonite. The fine-grained matrix probably owes its origin to the loss, relatively sudden, of volatiles (Neuerburg, 1958, p. 293) during silicate crystallization, and is suggestive of a thin roof.

Alteration, which has occurred in much of the stock, particularly in the southeastern part, has resulted in chloritization of biotite, formation of sparse epidote and locally of allanite, and saussuritization of plagioclase. This alteration is deuteric and probably resulted from mineralizing fluids originating in lower levels of the stock. The serizitization and argillization in Warden Gulch is part of a regional hydrothermal alteration zone in the Precambrian rocks.

Ore deposits spatially and probably genetically associated with the Montezuma stock are a segment of the Front Range mineral belt. The deposits are largely located in the upper part of the stock and in the Precambrian rocks above its gently plunging southeastward extension. Ore mineralogy is not unique for the mineral belt as a whole, but these deposits are a separable group by reason of their collected characteristics of structural form, texture, paragenesis, and alteration. They are generally thin, discontinuous fissure fillings, drusy and irregularly and poorly banded. Sulfides are principally pyrite, galena, and sphalerite, commonly with gray copper and chalcopyrite, and less commonly with silver and bismuth sulfosalts; other metallic minerals rarely occur, and gold is notably insignificant. Molybdenite is apparently a vein mineral only in the Roberts Tunnel. Gangue minerals are quartz, manganiferous carbonates, and very commonly barite.

Envelopes of altered wallrock around the vein ranges in thickness from virtually nil to several times the vein width. The alteration is largely saussuritic-chloritic in quartz monzonite and sericitic in metamorphic rocks, and usually exceeds in intensity the deuteric alteration of the stock. Small amounts of disseminated pyrite and manganiferous carbonate, commonly with sphalerite and galena, are characteristic of the alteration envelopes, although in places these disseminations extend beyond the envelope and in other places are restricted to a narrow zone adjacent to the vein.

Argillic wallrock alteration occurs in many deposits, but is most conspicuously expressed by a wide irregular zone in the Precambrian rocks extending from the vicinity of Grays Peak, south at least through Handcart Gulch, with a branch extending into the southeast corner of the stock. Most of the rocks in this zone are variously argillized, sericitized, and pyritized. Surface exposures are extensively oxidized and leached; ochreous spring deposits and bog iron ore deposits (Lovering, 1935, pl. 3) are common. Although some of the richest mines are in this alteration zone, signs of surface prospecting are remarkably few.

The Montezuma stock is divided into three areas characterized by distinct habits or combinations of habits of ore occurrence, wallrock alteration, and accessory mineral distribution patterns. Area I mineralization is indicated by widely scattered small prospects and few mines, differing greatly in the extent and details of wallrock alteration. Excepting a small group of mines at the head of Grizzly Gulch, there seems to have been no significant ore production from this area. Area II is almost devoid of mines and prospects. The existing workings are all small, including those of the rich deposits of argentian sulfosalts on Lenawee Mountain, and wallrock alteration is minimal. Area III is characterized by numerous mines, extensive prospects, and small diggings which account for most of the ore production from within the stock. In this area, wallrock alteration is prominent and the ores are predominantly galena and sphalerite, commonly with abundant pyrite; sulfosalts are distinctly subordinate.

Over the entire stock, the random distribution of sulfides in concentrations of less than 850 grams per ton and the random occurrence of molybdenite and chalcopyrite suggest that residual fluids from the now-exposed part of the stock did not migrate to become ore fluids. The few sporadic sulfide concentrations and the near lack of wallrock alteration are evidence that area I of the stock was not a significant thoroughfare for residual fluids from below, although the few ore deposits indicate some minor access by such fluids. In area II, significant volumes of high sulfide-bearing rock together with a prevalence of moderately altered rock indicate that large volumes of mineralizing fluids passed upward through vertically oriented conduits which are defined by the high sulfide concentrations. In area III, extensive areas of high sulfide concentrations in intensely altered rock plus widespread ore deposits indicate that here also existed a conduit system which later became enriched with ore minerals. The sporadic occurrence of accessory fluorite, not shown on the maps, is almost entirely confined to area II and indicates some slight compositional differences between the fluids passing through area II and the rest of the stock.

Accessory magnetite and zircon evidently were destroyed in significant amounts by hydrothermal and deuteric alterations, and therefore their distribution patterns are only partly preserved. Magnetite is sparse or lacking in unaltered rock adjacent to the southwest corner of the stock, a striking, and perhaps significant, similarity with the Osgood Mountains stock (Neuerburg, 1966) where a peripheral depletion of magnetite accompanies tungsten deposits. The small concentrations of magnetite and zircon in aplite are original, but even here depletion has resulted from alteration by mineralizing fluids.

Gangue minerals, being a product of the mineralizing fluids, should also be precipitated by the residual fluids while still dispersed in the rock fabric. The only gangue minerals in significant amount in the ore deposits related to the Montezuma stock are quartz, barite, and manganiferous carbonates. Quartz deposited from residual fluids is hardly separable from rock quartz, although total SiO_2 may be an indicator of migrating residual fluids (Gross, 1952). Barite was recovered from only one sample; perhaps, like galena and gold—each also recovered from a single sample—barite is too sparse to be dependably found in grab samples of unmineralized rock.

Accessory manganiferous carbonate cannot practically be quantitatively recovered from igneous rocks, but its concentration can be approximated by leaching it with an appropriate solvent (48 hours with 2N HNO_3 on coarsely crushed rock) that will not also dissolve manganese from other minerals. The resulting pattern has the identical significance as the sulfide patterns. The manganese oxide stain shown on the map probably derives mostly from vein carbonates, as indicated by the heavy black stain on vein outcrops and surroundings and on mine dumps and by the large amounts of manganese oxide cementing soil and gravel on the west slope of Morgan Peak.

In general, distribution patterns of accessory minerals are a guide to ore in that they identify areas in which prospecting by more detailed and direct methods is likely to have an optimum success ratio. In the Montezuma stock, the patterns indicate areas, particularly in the southeast quarter, where horizontally shifting, upward-migrating mineralizing fluids passed in such volumes as to appreciably alter the metal content of the rock through which they passed. Thus, prospecting will be most profitable in and near the roof of the stock on its gentle southeastward plunge. In the remainder of the stock, these patterns do not correlate directly with known deposits, but point only to large areas in which a scattered few deposits might occur. Such areas might be successfully prospected, but at such a low discovery ratio as to be uneconomic. The fact that the areal distribution of mines and prospects has the same value for successful prospecting as does the geologic-geochemical data is perhaps the best evidence for the essential soundness of this theoretical approach to prospecting.

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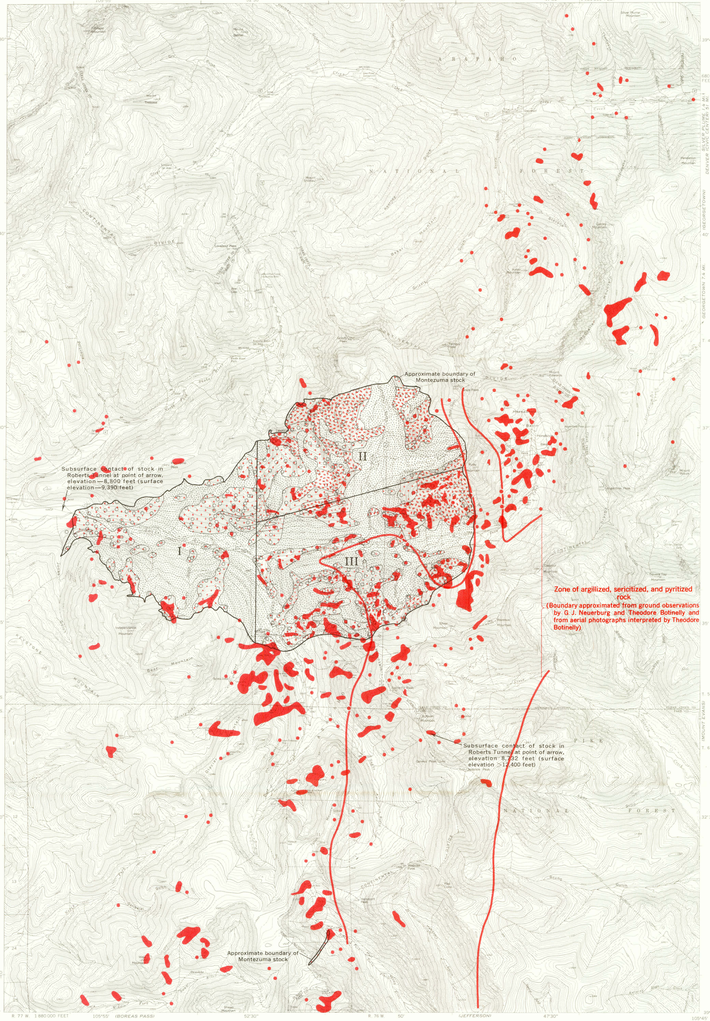


Base from U.S. Geological Survey 1:24,000
Loveland Pass, Grays Peak, Keystone, and Montezuma, 1958
10,000-foot grid based on Colorado coordinate system, central and north zones

Geology modified from data supplied by C. S. Robinson and G. E. Ulrich

SCALE 1:48 000
1 0 1 2 3 MILES
1 0 1 2 3 KILOMETERS
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

GEOLOGIC MAP OF THE MONTEZUMA STOCK SHOWING SAMPLE LOCALITIES, MINERALIZED AREAS, AND A ZONE OF ALTERED ROCK

EXPLANATION

QUATERNARY
- Alluvium and glacial debris
- Aplite

TERTIARY
- Biporphyritic quartz monzonite
- Medium-grained mostly porphyritic quartz monzonite

Montezuma Quartz Monzonite

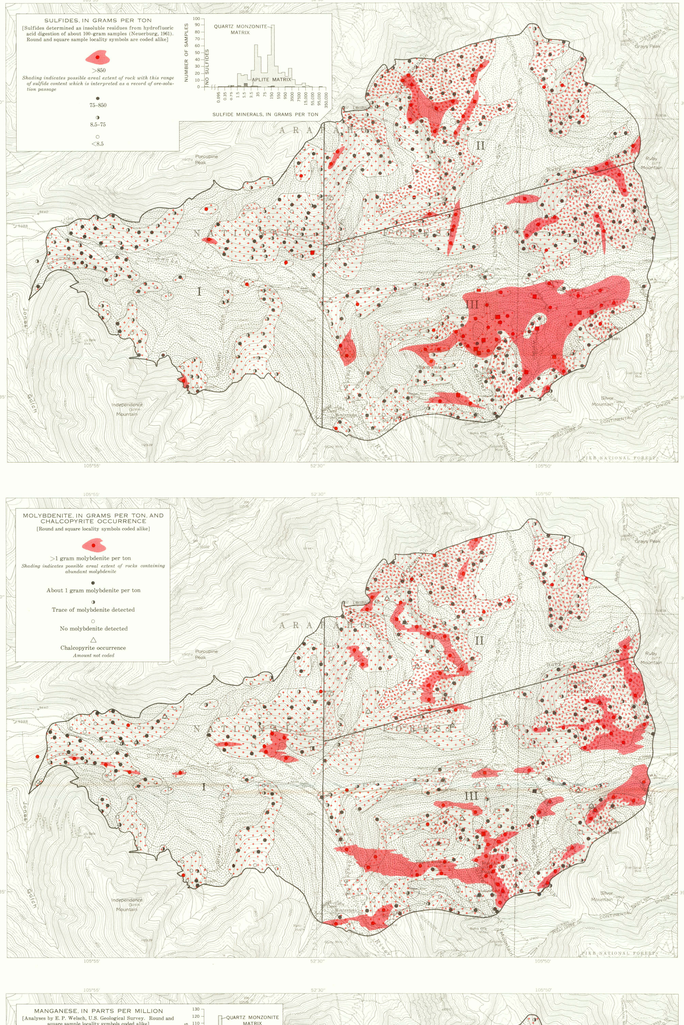
Contact
Alluvium and glacial debris contacts approximately located

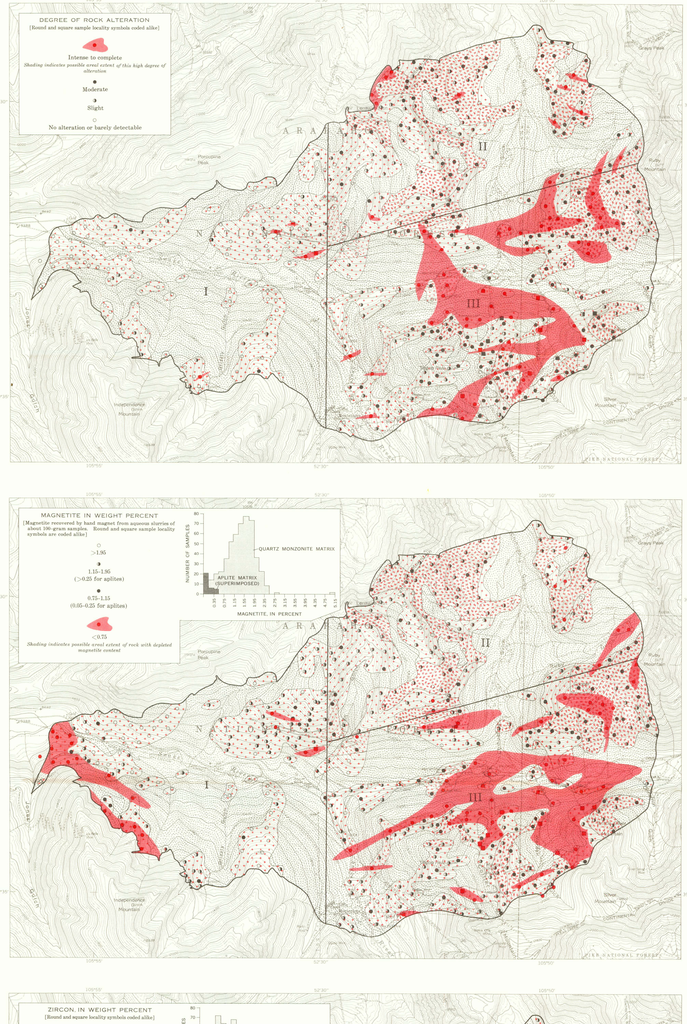
Mineralized areas as evidenced by mines and intensive prospecting
Compiled from ground surveys by G. J. Neuerburg, Theodore Botinelly, and data from C. S. Robinson and G. E. Ulrich and from aerial photographs interpreted by Theodore Botinelly

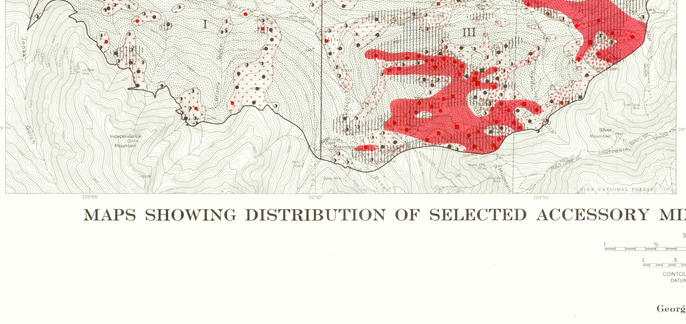
Area of distinctive mineral distribution pattern within Montezuma stock
I, *random pattern*
II, *conduit pattern*
III, *ore-enriched conduit pattern*

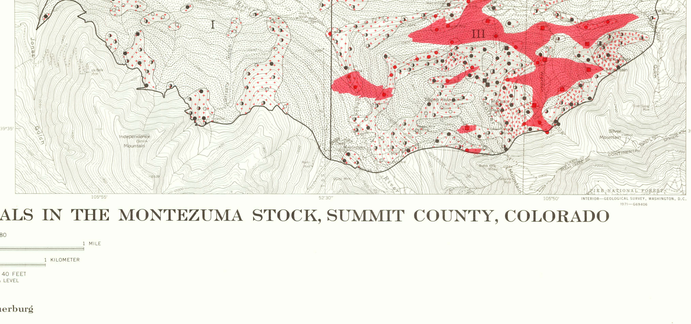
In random location
Within vein structure
Sample locality

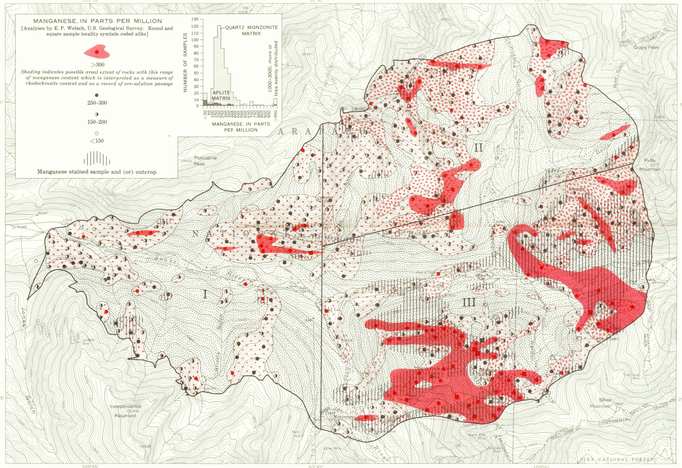
INDEX SHOWING QUADRANGLE LOCATIONS, AREA OF RE-SEARCH, AND AREA OF SMALL MAPS

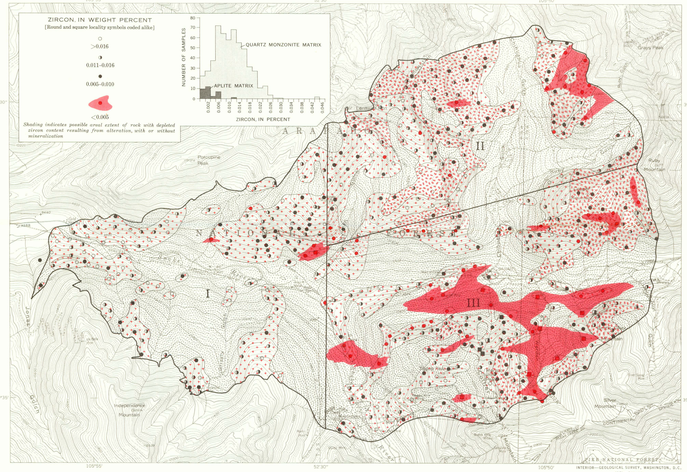












MAPS SHOWING DISTRIBUTION OF SELECTED ACCESSORY MINERALS IN THE MONTEZUMA STOCK, SUMMIT COUNTY, COLORADO

SCALE 1:31 680
1 0 1 MILE
1 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

By
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1971

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