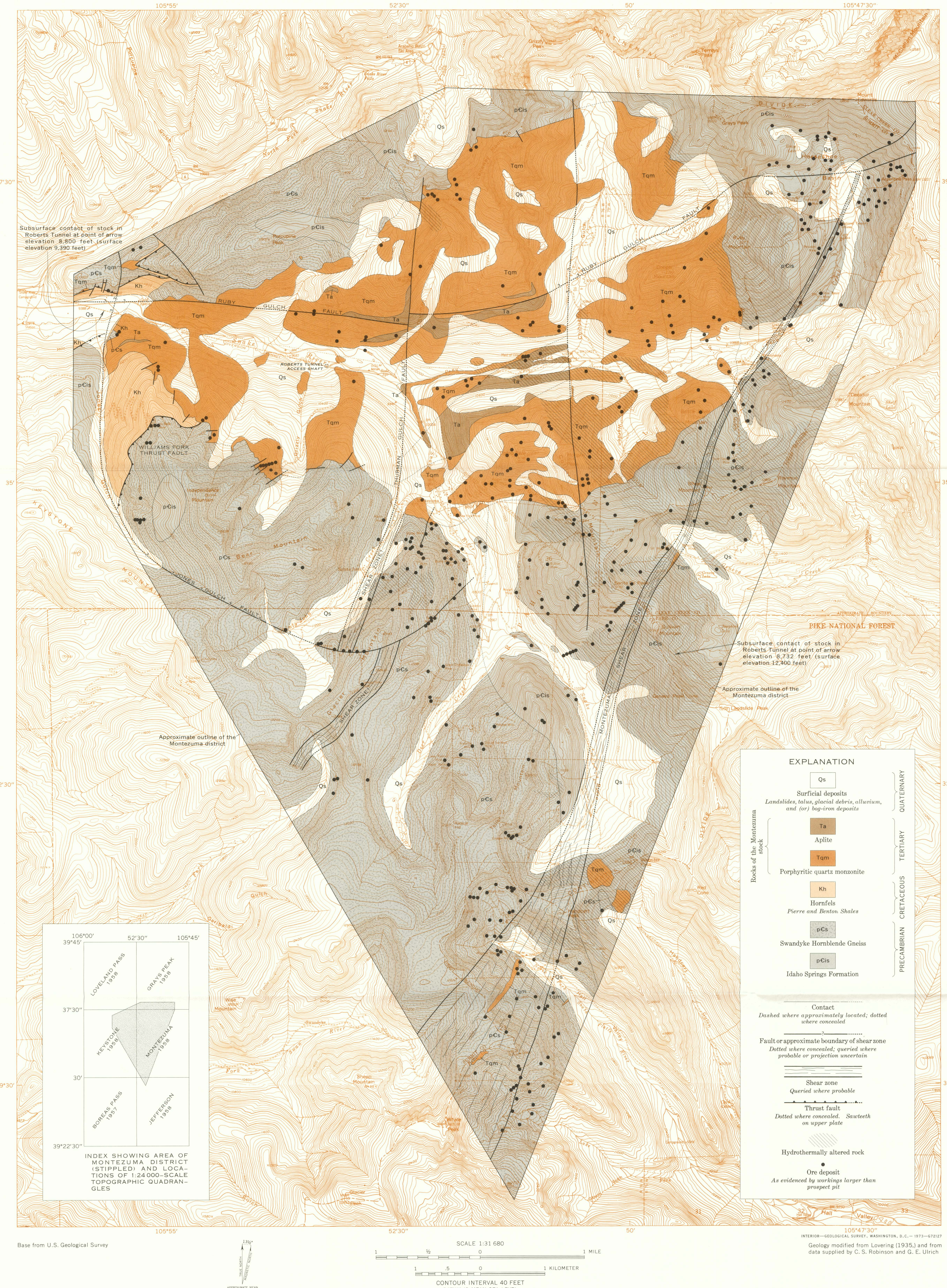
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I–750




# MAP SHOWING GEOLOGIC AND STRUCTURAL CONTROL OF ORE DEPOSITS, MONTEZUMA DISTRICT, CENTRAL COLORADO

The Montezuma district, as outlined on the accompanying map, includes parts of Clear Creek, Park, and Summit Counties, central Colorado, and is a segment of the Colorado mineral belt. The district contains a large number of argentiferous lead-zinc veins, cogenetic with the Montezuma stock, in Precambrian, Cretaceous, and Tertiary rocks. It is a mineralogically separable group of ore deposits within the mineral belt. The veins of the district contain very little gold in contrast to the deposits of the Breckenridge area to the southwest and they contain no fluorite, in contrast to the deposits of McClellan Mountain to the northeast. No ore deposits are known in the remaining bounding areas. The Montezuma district, as here defined, comprises the historical Argentine (Summit County), Beaver Dam, Geneva, Hall Valley, Middle Swan (part), Montezuma, North Swan (part), Peru, Platte, and Snake River mining districts (Henderson, 1926, p. 62–68).

The Montezuma district is one of the irregularly shaped areas of mineral deposits and associated Tertiary intrusives that comprise the Colorado mineral belt, a belt that coincides with a Precambrian structural element expressed as zones of recurrent shearing (Tweto and Sims, 1963). The porphyry intrusives determine the location of mineralized areas (mining districts) within the mineral belt (Spurr and Garrey, 1908, p. 68, 101). In the individual districts, "early faults" (Lovering, 1933, p. 306) control the locations of the porphyry intrusives and of the ore deposits. Individual deposits and their ore shoots are localized by a variety of smaller scale petrographic and structural features (Lovering and Goddard, 1950, p. 90–98; Lovering, 1935, p. 63–64; Lovering, 1930; Patton, 1909, p. 143).

The geology of the Montezuma district is dominated by the Montezuma stock, whose areal extent is shown by the outcrop pattern of its two main rock types, aplite and porphyritic quartz monzonite, and by four structural discontinuities: the Montezuma shear zone, the Thurman Gulch fault, the Williams Fork thrust fault, and the Ruby Gulch fault. Numerous other faults and both small- and large-scale folds are present (Lovering, 1935; Ulrich, 1963; Wahlstrom and Kim, 1959; Wahlstrom and Hornback, 1962; Warner and Robinson, 1967). The district is largely underlain by Precambrian metamorphic and igneous rocks: the Idaho Springs Formation, composed of sillimanitic micaceous gneisses and schists underlies the eastern half, and the Swandyke Hornblende Gneiss underlies the western half of the district. Small, irregular masses of quartz-feldspar pegmatite and of Silver Plume Granite intrude the metamorphic rocks, mostly in the eastern half. Dikes of a variety of fine-grained, mostly felsic porphyries are common in the metamorphic rocks and sparse in the Tertiary Montezuma stock; the dikes are prominently associated with ore deposits (Patton, 1909, p. 143). Along the Williams Fork thrust fault, the Precambrian rocks are thrust over Cretaceous Benton and Pierre Shales. Quaternary glacial debris, talus, landslide debris, and both preglacial and postglacial alluvium and bog-iron deposits mantle the bedrock of much of the district.

The Montezuma stock is a porphyritic biotite quartz monzonite, and is essentially mineralogically homogeneous but texturally varied. The textural diversity is interpreted (Neuerburg, 1971a) as evidence of a thin roof over the part of the stock east of the Thurman Gulch fault. Tabular aplite bodies are found in the central and western surface exposures of the stock; they were also found in the Roberts Tunnel access shaft and in the tunnel itself. Most of the aplites are horizontal sheets, and the larger ones grade into the porphyry of the stock on their undersurfaces. Apophyses of the stock occur in Hall Valley; the stock may also be represented by extremely altered porphyritic rocks exposed near Webster Pass and in the Geneva Creek cirque; float and dump samples of Montezuma Quartz Monzonite occur on the west side of Glacier Mountain near the intersection of the Jones Gulch and the Thurman Gulch faults. The stock, evidently a cupola on a batholith (Lovering and Goddard, 1950, p. 82; Wahlstrom and Hornback, 1962, p. 1497; Warner and Robinson, 1967, p. 101), may be within a few hundred feet of the present surface under most of the Montezuma district. The stock metamorphosed the Cretaceous Benton and Pierre Shales to hornfels, but it had little effect on the Precambrian metamorphic rocks.

The Williams Fork thrust fault localized the intrusion of the stock on the west (Wahlstrom and Hornback, 1962, p. 1497); the Montezuma shear zone provided a boundary on the east (Warner and Robinson, 1967, p. 109). The Thurman Gulch fault probably also predated and played a role in the intrusion of the stock, as indicated by the fact that it divides the stock into areas of significantly contrasting mineral distribution patterns (Neuerburg, 1971a; Neuerburg and others, 1971). The Thurman Gulch fault may be an expression of the steep root of the Williams Fork thrust fault. The role, if any, of the Jones Gulch and Ruby Gulch faults in the intrusion of the stock is not apparent. Both faults are mineralized, but they separate areas of contrasting abundance of ore deposits. These five faults virtually outline the Montezuma district, and, as regards areal abundance and compositional details, they compartmentalize the distribution of ore deposits within the district.

The Montezuma ore deposits are thin, discontinuous, crustified drusy veins along faults, joints, shear zones, and contact surfaces, expecially intrusive contacts; dikes and veins are commonly localized by the same structure. Many deposits are zones of short, subparallel to interwoven, discontinuous veinlets rather than single veins. The mineralized structures have vertical dimensions as much as at least 4,000 feet and some are traceable horizontally for several thousand feet; vein matter aggregates at most only a few feet. Genetically, the deposits are separable into hydrothermal and pneumatolytic types. The hydrothermal vein fillings are predominantly pyrite, sphalerite, galena, quartz, manganiferous carbonates, and barite. Appreciably less abundant and less evenly distributed minerals, in apparent order of frequency, are gray copper, chalcopyrite, silver minerals, lead-copper-silver sulfosalts, and alabandite.

The pneumatolytic deposits, only recently recognized in the district (Neuerburg and others, 1971), are characterized by the presence of bismuth minerals, specularite, molybdenite, wolframite, and arsenopyrite, but they also contain pyrite, chalcopyrite, galena, ruby silver, gold, and sphalerite. The pneumatolytic deposits are chemically more varied than the hydrothermal deposits because the pneumatolytic ore fluid contains several additional elements that are otherwise fixed in igneous rock minerals before separation of the hydrothermal ore fluid begins. Most of the known pneumatolytic ore occurs in the same structures as hydrothermal ore, although the two types of ore are usually in separate veins within the structure. Several small mines and prospects in the western third of the stock are mainly pneumatolytic vein deposits. Data from the Roberts Tunnel access shaft, supplied by P. K. Theobald, U.S. Geological Survey, show an increased number of these pneumatolytic veins with depth. Also, the amount of molybdenite increases with depth in the shaft.

Large areas of hydrothermally altered rock are the most conspicuous feature of the Montezuma district, occurring not only as altered wallrock around nearly all veins but also as a large-scale regional phenomenon. Much of the eastern two-thirds of the stock is deuterically altered (Neuerburg, 1971a). Hydrothermally pyritized, silicified, and sericitized rocks are areally extensive along the Montezuma shear zone and, to a lesser degree, along the Thurman Gulch fault. Small amounts of disseminated ore and gangue minerals are common in all these altered rocks. Sericitized and propylitized rock in and adjacent to vein structures grades rapidly into unaltered rock, and it ranges in thickness from zero to several feet; greisen is a common type of sericitized rock adjacent to pneumatolytic veins. This combination of regional alteration and of alteration along vein structures is common in the Colorado mineral belt.

The ore deposits of the Montezuma district are zoned (Neuerburg, 1971b), both horizontally and vertically, outward from an inferred batholithic source below the Montezuma stock. For both pneumatolytic and hydrothermal veins, the amount and intensity of wallrock alteration diminish, molybdenite, pyrite, and sphalerite become less abundant, whereas barite, galena, and the rarer minerals become more abundant, in the cation sequence: lead, copper, bismuth, antimony, arsenic, silver, and tungsten. The manganese content of gangue carbonate abruptly diminishes near the outer edges of the district. The observed zoning order presumably reflects the inverse order of metal concentrations in the ore fluids.

The distribution of ore deposits within the Montezuma district is systematically related to major faults and to the roof of the stock. Most of the hydrothermal deposits are near the roof of the stock in a "box" outlined by the Thurman Gulch and Ruby Gulch faults and the Montezuma shear zone. Much ore occurs on the fringes of the regionally hydrothermally altered rock along the Montezuma shear zone and the Thurman Gulch fault. The distribution of hydrothermal ore within the stock is related not only to alteration along these faults but also to the intensity of deuteric alteration (Neuerburg, 1971a) and to the lower contacts of large aplite bodies. The pneumatolytic deposits are largely restricted to the part of the stock west of the Thurman Gulch fault and to the vicinity of the Montezuma shear zone.

Faults that localized the intrusion of the Montezuma stock also served as principal conduits for ore fluids derived from the underlying batholith. The Williams Fork thrust fault, the Montezuma shear zone, and probably also the Thurman Gulch fault periodically afforded the necessary "sudden" pressure relief for the separation of a pneumatolytic ore fluid from the magma (Neuerburg and others, 1971); the Montezuma shear zone and the Thurman Gulch and Ruby Gulch faults provided the necessary pressure relief for hydrothermal ore fluids to collect and to migrate from the cooling and shrinking parts of the batholith that had already crystallized (Neuerburg, 1971a). Whenever these major conduits became clogged, minor faults and permeable zones in the thin cover over the stock provided continuing outlets for the ore fluids. Shearing and brecciation of vein fillings and the distribution of ore deposits and of accessory minerals in the quartz monzonite indicate that movement recurred along the faults contemporaneously with intrusion and during crystallization of the stock. The "box" defined by the Montezuma shear zone, the Thurman Gulch fault, and the Ruby Gulch fault may in fact outline the connecting root of the Montezuma stock with the batholith.

Fractionation of an ore fluid is possible at two stages in the crystallization of an igneous intrusive. In the first stage, fractionation is by exsolution of a vapor phase from magma, upon sudden relief of confining pressure, to yield pneumatolytic ore fluids. Such a process apparently operated in the western exposures of the stock and at depth along the Montezuma shear zone (Neuerburg and others, 1971). In the second stage, fractionation of ore fluids occurs after crystallization and thermal contraction of the cooling igneous rock renders it sufficiently permeable for deuteric fluids (*the hydrothermal ore fluids*) to move in response to the development of pressure gradients. This was the major process in the origin of the ore deposits of the Montezuma district (Neuerburg, 1971a).

Inasmuch as an intrusive crystallizes by parts, fractionation of ore fluids may take place repeatedly over the entire span of the consolidation of the intrusives. Crystallization generally progresses downward. Concomitantly, potential pneumatolytic and hydrothermal ore fluid sources move downward, as do also potential sites of deposition in the crystallized parts of the intrusive; for example, the western third of the Montezuma stock was both a source of and a site of deposition for pneumatolytic fluids. The location and timing of fault movements, in controlling the pressure distribution, determine if an ore source is activated and whether the source is pneumatolytic or hydrothermal. Repeated fault movements may thus cause intermingling of pneumatolytic and hydrothermal deposits, as occurs in the Montezuma district. The juxtaposition of differing mineral assemblages in the same and neighboring hydrothermal ore deposits in the Montezuma district resulted from multiple sources, corresponding to successively deeper batholithic levels supplying fluids to constantly shifting conduits over a limited area, the Montezuma "box."

Hydrothermally altered rocks along conduit and vein structures are conspicuous evidence of the reaction of ore fluids with country rock, a reaction which most importantly resulted in a concomitant compositional alteration of the ore fluids: an exchange wherein water, carbon dioxide, and sulfur were added to the rock, and sodium and calcium were added to the ore fluid. These exchanges result in an increase of pH of the ore fluid and a decrease in the solvent-solute ratio that is equivalent to evaporation. Both changes effectively promote precipitation of the ore-metal sulfides. This exchange is necessary for ore deposition, and where the walls of the conduit already consist of mineral assemblages equivalent to the products of hydrothermal alteration, no reaction will ensue and no ore will in general be deposited. Thus, argillaceous sediments and rocks already hydrated by retrograde metamorphism, by deuteric alteration, or by reaction with earlier hydrothermal fluids are not likely to enter into the ore depositional process; ore deposits in such rocks as these are from ore fluids already brought to the point of precipitation through alteration of reactive rocks elsewhere. Structure determined the disposition of ore fluids in the Montezuma district, but lithology determined the sites of ore deposition—not only along vein structures but also *areally* as on the fringes of the regionally altered rocks—and, negatively, the scarcity of ore deposits in the Cretaceous shales.

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