Nature, age, and genesis of quartz-sulfide-precious-metal vein systems in the Virginia City Mining District, Madison County, Montana
by Marshall Morris Cole

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
In the Virginia City mining district, pre-Belt gneisses and the Late Cretaceous granitic Browns Gulch stock host numerous quartz vein systems. Hypogene mineralization is chiefly gold- and silver-bearing base-metal sulfides.

The U.S. Grant 3-level vein system, N40°-50°E; 35°-50&deg,NW, 0.3 to 5.0 m wide, is contained in a shear zone exhibiting about 10 m of syn-ore right-lateral movement. The vein system is composed of elongate quartz lenses, quartz stringers, tabular quartz bodies, and variable amounts of crushed and altered gneiss. Altered wall rock gneiss exhibits early potassic alteration (microcline and possibly quartz) and a subsequent propylitic assemblage (carbonate, pyrite, quartz, chlorite, other phyllosilicates, and a zeolite?). Post-alteration mineralization occurs as pyrite, followed by variable amounts of contemporaneous galena, sphalerite, chalcopyrite, sparse tetrahedrite, and rare specular (?) hematite. Additionally, some (latest) sphalerite replaces pyrite, galena, and chalcopyrite. Observable gold is very rare. Quartz deposition is pre-, syn-, and post-sulfide mineralization.

The Virginia City district is one of several districts in the Tobacco Root precious-metal mining region. The region is cored by the 77-72 m.y. old quartz monzonite Tobacco Root batholith. A regional zoning is present with respect to the batholith in the form of low silver-to-gold and high copper-to-silver ratios near the batholith, and high silver-to-gold and low copper-to-silver ratios far from the batholith (Virginia City district).

It is proposed that ores of the district are of Latest Cretaceous to Early Tertiary age (70-60 m.y.B.P.), based on the occurrence of deposits in the Late Cretaceous Browns Gulch stock, the crosscutting of the El Fleeda 4-level vein system by a 51 m.y. old andesite plug, and the regional zoning with respect to the batholith.

An epithermal precious-metal genesis model has been applied to the ores of the district. A geothermal convection cell powered by heat from Late Cretaceous plutonism, produced large-scale regional circulation of hydrothermal fluids at shallow crustal levels. These fluids collected (remobilized ?), transported, and deposited the ore constituents.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Marshall Cole August 3, 1996

Bozeman, MT

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ABSTRACT

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INTRODUCTION

Location, Access, and Physiography

The Virginia City mining district, located southwest of Virginia City, Madison County, Montana, is the southernmost district in the Tobacco Root precious-metal mining region (Fig. 1). It may be subdivided into the Fairweather (located at Virginia City), Highland (3 km south of Virginia City), Summit (10 km south of Virginia City), Nevada (at Nevada City), and Browns Gulch districts.

The district extends from Alder Gulch on the north and east, to west of Browns Gulch, and to the flanks of the Gravelly Range on the south (Plate 1). It covers an area of approximately 90 square km.

The Virginia City area is approachable via Montana Highway 287. Numerous dirt and gravel roads provide access within the district. Winter access is difficult in the south part of the district but is relatively easy in the north half.

Virginia City, elevation 1767 m, sits in a topographic low between two major mountain ranges. The Tobacco Root Mountains (summit elevations greater than 3000 m) are located to the north, and the Gravelly Range (summit elevations greater than 2900 m) to the south (Fig. 1). West of Virginia City is the Ruby River Valley, elevation about 1525 m; to the east is the Madison River Valley, elevation about 1500 m.

The major drainages of the district, Alder and Browns Creeks (Plate 1), head in the southern portion of the district where they

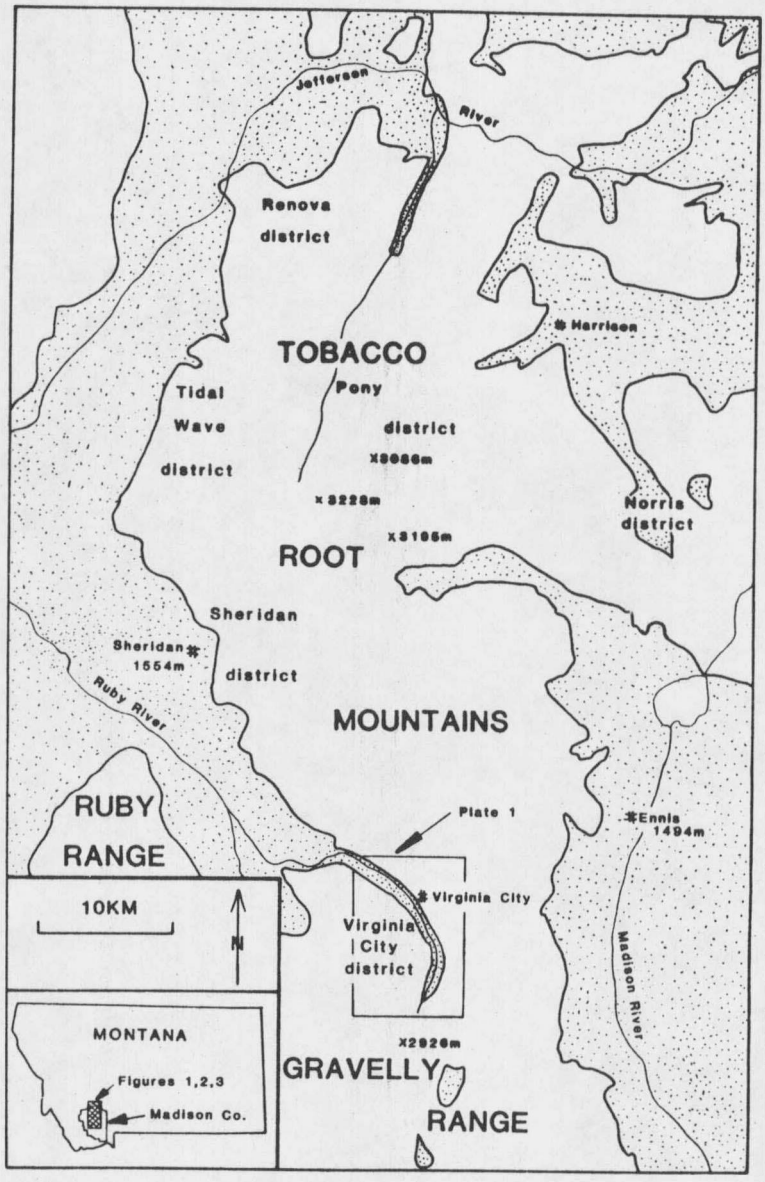

Figure 1. Mining districts and physiography of the Tobacco Root precious-metal mining region. Patterned areas are Late Tertiary and Quaternary unconsolidated or poorly consolidated sediments. Blank areas are older sedimentary, igneous, or metamorphic rocks.

are deeply incised in the foothills of the Gravelly Range. Alder Creek flows north to Virginia City where it turns and flows northwest for 16 km until it joins the Ruby River. Browns Creek flows north until it joins Alder Creek at Nevada City (3.2 km northwest of Virginia City).

Purpose and Method of Study

The major problem addressed in this thesis is what processes are responsible for ore genesis in the mining district? Precambrian metamorphism and possible igneous activity, along with Laramide plutonism and volcanism, play important roles in the geologic history of the district. Hydrothermal activity related to either group of processes is capable of producing ore bodies.

A detailed study involving above- and below-ground mapping, ore and wallrock microscopy, and K-Ar radiometric dating, were done in an attempt to determine the processes responsible for ore genesis.

Previous Study

Previous work in the mining district is minimal. Winchell (1914), Tansley, Schafer, and Hart (1933), and Lorain (1937) briefly described the general geology and various mines of the Tobacco Root region and the Virginia City district. The southern part of the district was mapped by Hadley (1969) in the 15 minute Varney quadrangle. A preliminary bedrock map of the northern part of the district was published by Weir (1982). Vitaliano and Cordua (1979) mapped the southern Tobacco Root Mountains, located north of the mining district.

MINING HISTORY

Placer gold was discovered in Alder Gulch in 1863 approximately 0.4 km south of the present site of Virginia City. Within one year, auriferous and argentiferous quartz lodes were discovered and developed. Most of the lodes were in secondarily enriched oxidized ores. In the late 19th century, these ores were exhausted and lower grade primary ores were encountered. As a result many of the mines were abandoned. Mines that continued to operate had contained relatively high-grade hypogene ores. Mining in the 20th century has been sporadic and never at the scale achieved in the late 19th century.

Production figures from Lorain (1937) indicate the total value of lode gold from the entire Tobacco Root precious-metal mining region is about 17 million dollars, including 2.5 million dollars from the Virginia City district. However, this is minor when compared to 50 million dollars of placer gold from Alder Gulch (Lorain, 1937).

REGIONAL GEOLOGIC SETTING

The Tobacco Root Mountains, a large northwest-plunging domal uplift of multiple deformed and metamorphosed pre-Belt rocks (Mueller and Cordua, 1976), is a major geologic feature in the region of the Virginia City district (Fig. 2). The mining district is located in the southernmost part of this pre-Belt terrain.

The Tobacco Root Mountains are cored by the Late Cretaceous (72-77 m.y.B.P.; Vitaliano and others, 1980) quartz monzonite Tobacco Root batholith (Fig. 2). This pluton crops out within a 310 square km area. It is thought to be genetically related to the Boulder batholith (Smith, 1970) located 22 km to the northwest (Fig. 2). This interpretation is supported by low Sr^{87}/Sr^{86} values (indicative of a lower-crust or upper-mantle magma origin; Krauskopf, 1979) for the Boulder (Doe and others, 1968) and Tobacco Root (Vitaliano and others, 1980) batholiths.

Scattered throughout the pre-Belt rocks are numerous smaller plutons similar in age and composition to the Tobacco Root batholith (Vitaliano and Cordua, 1979). Numerous base- and precious-metal deposits are associated with these igneous bodies.

Proterozoic, Paleozoic, and Mesozoic sedimentary rocks crop out on the north and west flanks of the Tobacco Root pre-Belt terrain (Fig. 2). Paleozoic, Mesozoic, and Early Tertiary sedimentary rocks crop out in the Gravelly Range. Cretaceous and Tertiary volcanic rocks