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UTILIZATION OF HUMUS-RICH FOREST SOIL (MULL) IN GEOCHEMICAL EXPLORATION FOR GOLD

By GARY C. CURTIN, HUBERT W. LAKIN, GEORGE J. NEUERBURG, and ARTHUR E. HUBERT

Abstract

Distribution of gold in humus-rich forest soil (mull) reflects the known distribution of gold deposits in bedrock in the Empire district, Colorado. Gold from the bedrock is accumulated by pine and aspen trees and is concentrated in the mull by the decay of organic litter from the trees. Anomalies in mull which do not coincide with known gold deposits merit further exploration.

The gold anomalies in soil (6- to 12-inch depth) and in float pebbles and cobbles poorly reflect the known distribution of gold deposits in bedrock beneath the extensive cover of colluvium and glacial drift.

INTRODUCTION

This report presents preliminary information on the distribution of gold within the zone of weathering in the Empire district, Colorado. The Empire district is a compact, moderately productive gold district in the Front Range mineral belt that is being used as a site for studies of ore-weathering processes being conducted under the Geological Survey's Heavy Metals program. The investigation reported here consisted of the collection and analysis of humus-rich forest soil (mull), of soil below the mull at 962 localities, and of float pebbles and cobbles from the colluvial and morainal cover at 847 localities. The results indicate that determination of the gold content of mull may be useful to delineate gold deposits in bedrock in areas covered by colluvium and glacial drift.

The Empire district is in the southern part of the Empire 7½-minute quadrangle, Clear Creek County, Colo., about 37 miles west of Denver, in the Front Range of the Rocky Mountains (fig. 1). Altitude ranges from 9,000 to 11,000 feet in the district.

Mining began in the district in 1862 (Spurr and Garrey, 1908, p. 401) with the discovery of gold in the oxidized and decomposed rock of the Silver Mountain ore zone (fig. 2). This rock was washed in sluices and treated in the same way as placer gravels and yielded approximately $2 million in gold during 1862–65 (Harrison, 1964, p. 93). These placer operations decreased in economic importance in the 1870's, but they continued on a small scale for many years.

Lode mining was conducted intermittently from the 1860's to 1943. Some of the more important mines in the north half of the district are the Minnesota, the Silver Mountain, and the Conqueror. During 1933–43 more than 90,000 ounces of gold was produced from lode deposits in the district, mostly from the Minnesota mine.

The geology of the Empire district has been described by Ball (in Spurr and Garrey, 1908), Lovering and Goddard (1950), and Braddock (1967). The ore deposits have been described by Spurr and Garrey (1908) and Lovering and Goddard (1950).

In the present investigation, gold was measured by atomic absorption (Thompson and others, 1968). Most of the analyses were made in the field in a mobile laboratory. Rock and soil samples were ground and pulverized before they were analyzed. Mull samples were sieved and the minus 2-millimeter fraction was ashed and analyzed. The gold content of the mull samples is reported on an ashed-weight basis.

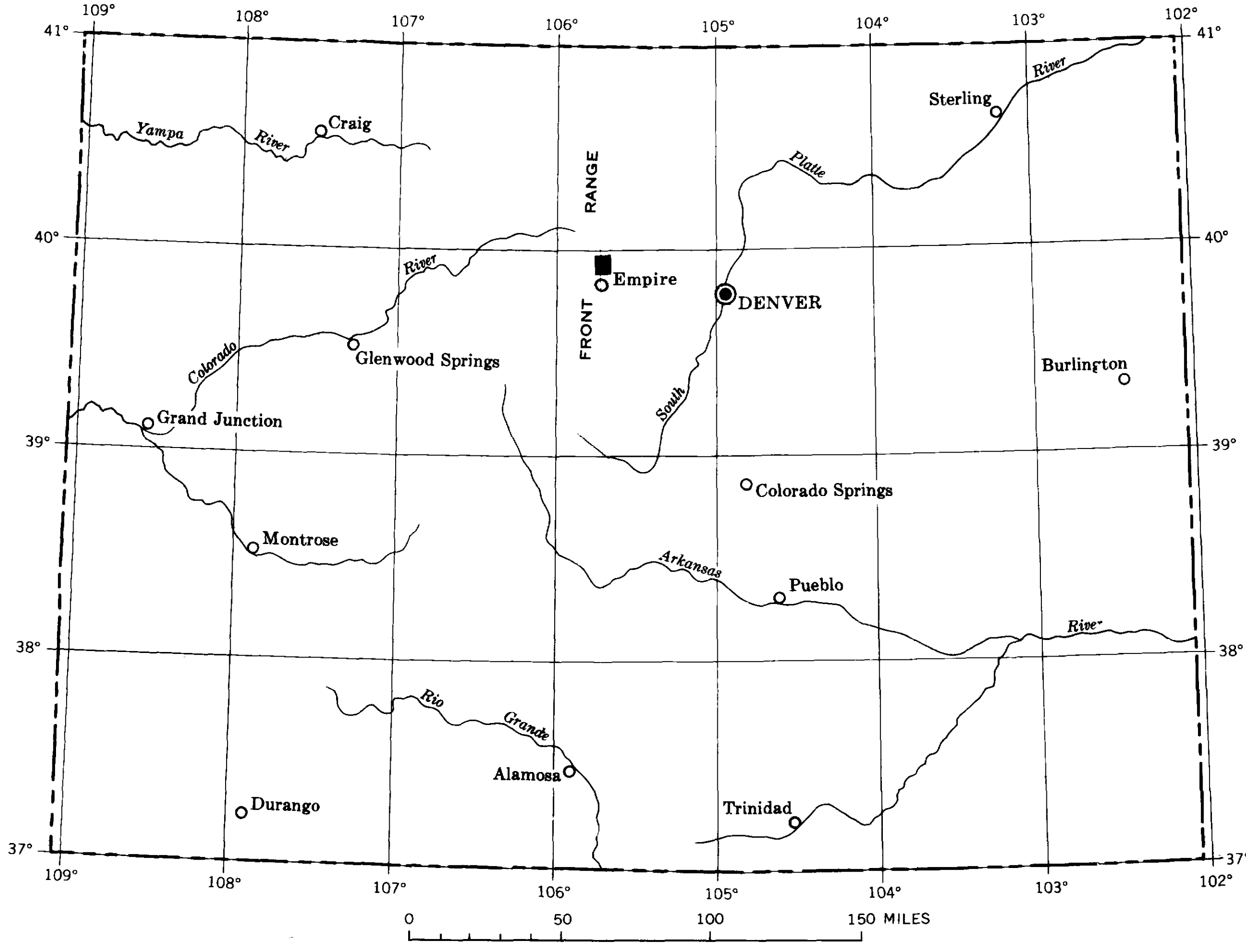

FIGURE 1.—Index map of Colorado showing location of Empire district.

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GEOLOGIC SETTING

The Empire district is underlain by igneous and metamorphic rocks of Precambrian and Tertiary age (fig. 2). The Precambrian rocks are biotite gneiss and microcline gneiss that have been intruded by Boulder Creek Granite and Silver Plume Granite. A small stock of hornblende granodiorite porphyry and dikes of granodiorite porphyry, hornblende granodiorite porphyry, biotite granodiorite porphyry, biotite quartz monzonite prophyry, and bostonite porphyry, all of Tertiary age, intrude the Precambrian rocks. The bedrock in most of the area is covered either by Quaternary colluvium or by glacial drift which ranges from about 3 feet to at least 40 feet in thickness.

The ore deposits of the north half of the Empire district are mostly fissure fillings and disseminated deposits of the pyritic gold type

(Lovering and Goddard, 1950). The principal vein minerals are pyrite, chalcopyrite, and quartz. The gold tenor increases with chalcopyrite. The veins form an encircling pattern around the small stock of hornblende granodiorite porphyry. Lovering and Goddard (1950, p. 156) suggested that this encircling zone was formed by the stresses related to the intrusion of the stock and subsequent collapse of the roof when some of the underlying magma was withdrawn after late-stage consolidation of the stock. The ore bodies occur as irregular shoots along the veins and range from a few feet to at least 100 feet in length and height and from less than 1 foot to at least 20 feet in width. One vein in the Minnesota mine, however, has been stoped for a distance of 1,800 feet along its strike. The vein system shown on the geologic map and geochemical maps (figs. 2, 4, 5, 6) was derived from field mapping during the summer of 1967 and from maps by Braddock (1967), by Lovering and Goddard (1950, fig. 59, p. 157, pl. 13), and by Spurr and Garrey (1908, pl. 81).

MATERIALS SAMPLED

Mull and underlying soil (6- to 12-inch depth) were collected at 962 localities (fig. 3). Float pebbles and cobbles were collected in the colluvial and morainal cover at 847 localities. At many localities two or more pebbles or cobbles were collected, each representing a different rock type. Where more than one rock type was collected a weighted average gold value was calculated.

The forest cover of the Empire district is chiefly lodgepole pine (*Pinus contorta*), but limber pine (*Pinus flexilis*) and groves of aspen (*Populus tremuloides*) are present locally. Mull (forest humus layer) is defined by the U.S. Department of Agriculture (1951, p. 245) as "a humus-rich layer consisting of mixed organic and mineral matter, generally with a gradational boundary to the underlying mineral horizon." Pine mull is present as pads, 1–3 inches thick, beneath individual trees. Aspen mull is present as a diffuse layer rarely more than 1 inch thick. Mull samples were collected beneath pine trees where possible, but about 100 samples of aspen mull were collected at localities where pine trees were absent.

Beneath the mull layer is a layer 2–6 inches thick of gray, ash-textured material that contains abundant small roots. Below this layer is a mixture of yellow to yellow-brown sand or a mixture of fine sand and cobbles, of colluvial or morainal origin, that does not change noticeably in composition or texture downward to bedrock. Soil samples were collected in the colluvium or glacial drift below the layer of ash-textured material at a depth of 6–12 inches.

RESULTS OF INVESTIGATION

Several areas that contain anomalous amounts of gold (0.6 part per million or more) in the ash of mull were detected in this investigation (fig. 4). The distribution of these gold anomalies appears to delineate the known gold deposits in the Silver Mountain area and to point out additional areas that merit exploration. The gold anomalies west of Lion Creek (fig. 4) suggest that the Silver Mountain and Minnesota mines vein systems extend westward under the glacial drift.

In most places in the north half of the Empire district the roots of trees extend through the cover of colluvium or glacial drift into the underlying bedrock. Tree roots were observed in bedrock at several localities, and in one place, at least 50 feet below the surface, in one of the mine workings. The gold, which may be present in ground water either in a complex ion or in the colloidal state, is taken into the trees and then in part deposited in the leaves and needles; it is finally concentrated in the mull as the leaves and needles decay. That this is an effective process was demonstrated by the identification of gold in vegetation collected at numerous localities in the area studied. The ash of wood from the interior of large roots (as much as 6 inches in diameter) contains as much as 3 ppm gold, the ash of wood from the interior of tree branches contains as much as 2 ppm gold, the ash of pine needles contains as much as 0.7 ppm gold, and the ash of aspen leaves contains at least 0.1 ppm gold.

The organic fractions of all the mull samples studied in detail contained most of the total gold. Locally, gold may be contributed to the mull by windblown auriferous pyrite from mine dumps. For example, of the total gold in a mull sample collected below the dump of the Conqueror mine, 52 percent was in the heavy mineral fraction and could have been contributed principally by windblown auriferous pyrite.

With few exceptions, the gold content of soil (6- to 12-inch depth) is lower than the gold content of the ash of the overlying mull. Of the mull ash samples, 62 percent contained 0.2 ppm or more gold, but only 22 percent of the soil samples contained 0.2 ppm or more gold.

The relatively small, isolated gold anomalies in soil (fig. 5) are probably due chiefly to the inclusion of gold-bearing vein material in otherwise barren colluvial or morainal cover. However, most of the 23 scattered high gold values in soil coincide with known gold deposits in bedrock. These high values may reflect, in part, gold enrichment in the soil by the biogeochemical cycle.

The irregular distribution of float pebbles and cobbles that contain anomalous amounts of gold (fig. 6) reflects mechanical dispersion of vein material in the colluvial or morainal cover and shows little relation to known ore deposits. However, the high gold content of some of the float (21 samples contain 10 ppm or more gold) suggests that undetected gold deposits concealed by the colluvial or morainal cover may exist in the Silver Mountain area. The scattered anomalous gold values in the periphery of the area (fig. 3) reflect the presence of small, individual veins in unaltered country rock.

SUMMARY

In the Empire district, gold deposits in bedrock beneath the colluvial and glacial cover are delineated much better by the gold anomalies in mull than by the gold anomalies in float pebbles and cobbles and in the soil below the mull. Gold anomalies in mull which do not coincide with known gold deposits merit further exploration.

The accumulation of gold by trees is demonstrated by the presence of gold in the interior of roots and branches and in pine needles and aspen leaves; this process accounts for most of the gold found in the mull.

Mull may be an effective geochemical sampling medium in forested areas blanketed by colluvium or glacial drift where the transported material offers no clue to the nature of the underlying bedrock.

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FIGURES 2–6

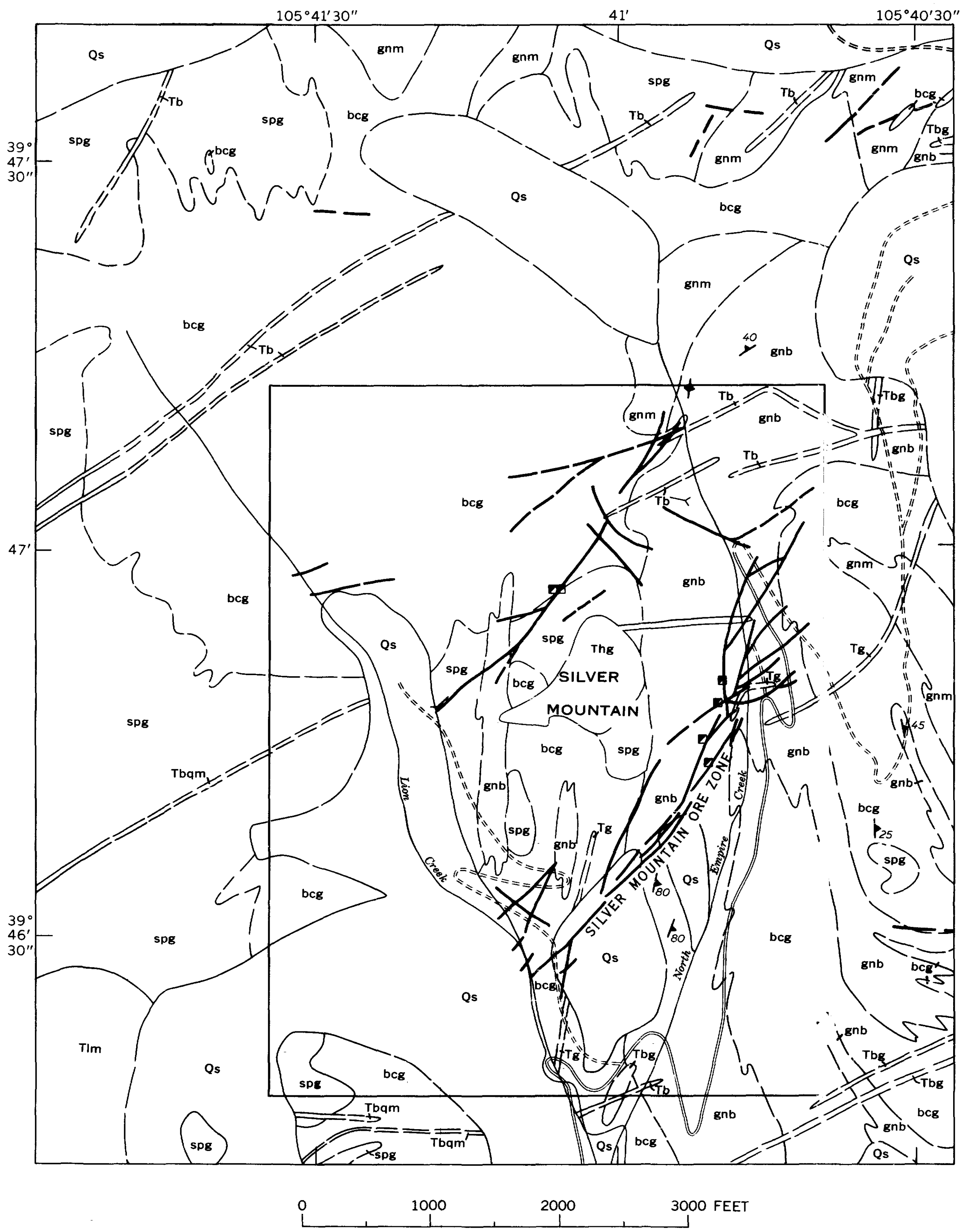

FIGURE 2.—Geologic map of the north half of the Empire district. Geology modified from Braddock (1967). Area of figures 4, 5, and 6 shown by rectangle.

EXPLANATION

QUATERNARY

Qs

Solifluction debris and morainal deposits

TERTIARY

Tb

Bostonite porphyry

Tbqm

Biotite quartz monzonite porphyry

Relative age not known

Tlm

Leucocratic monzonite

Tg | Thg | Tbg

Granodiorite group

Tg, *granodiorite porphyry, undivided*

Thg, *hornblende granodiorite porphyry*

Tbg, *biotite granodiorite porphyry*

PRECAMBRIAN

spg

Silver Plume Granite

bcg

Boulder Creek Granite

Order does not reflect age

gnm

Microcline gneiss

gnb

Biotite gneiss

Contact

Dashed where approximately located

Vein or mineralized fault

Dashed where approximately located

45

Inclined Vertical

Strike and dip of foliation

Adit

Shaft

FIGURE 2.—Continued.

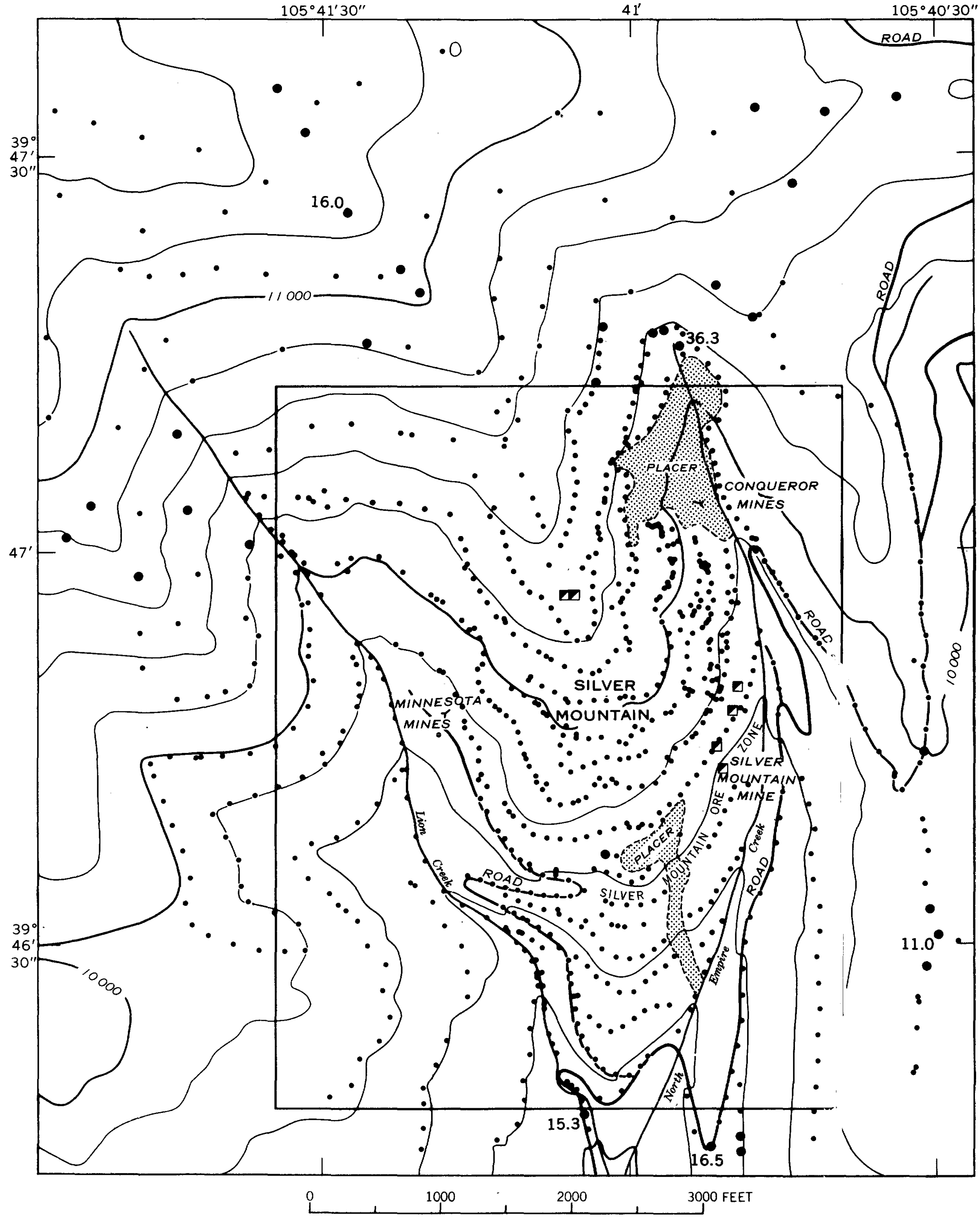

FIGURE 3.—Topographic map showing sampled localities (small dots) and area of figures 4, 5, and 6 (rectangle). Gold concentration of 0.2 ppm (part per million) or more in colluvial pebbles and cobbles and bedrock is shown by large dots in localities outside the area covered by figures 4, 5, and 6. Value shown if greater than 10 ppm.

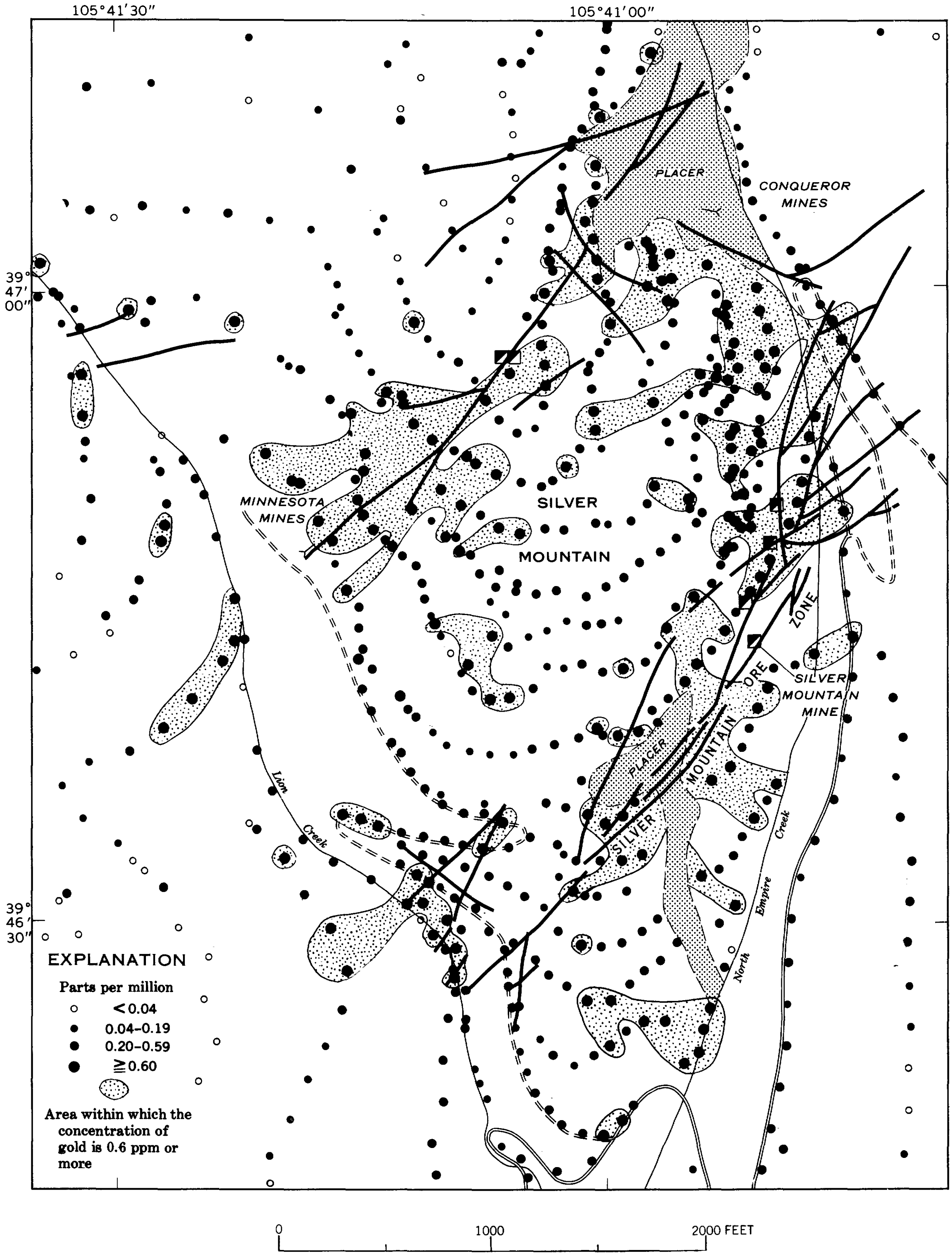

FIGURE 4.—Distribution of gold in the ash of mull. Heavy lines are veins.

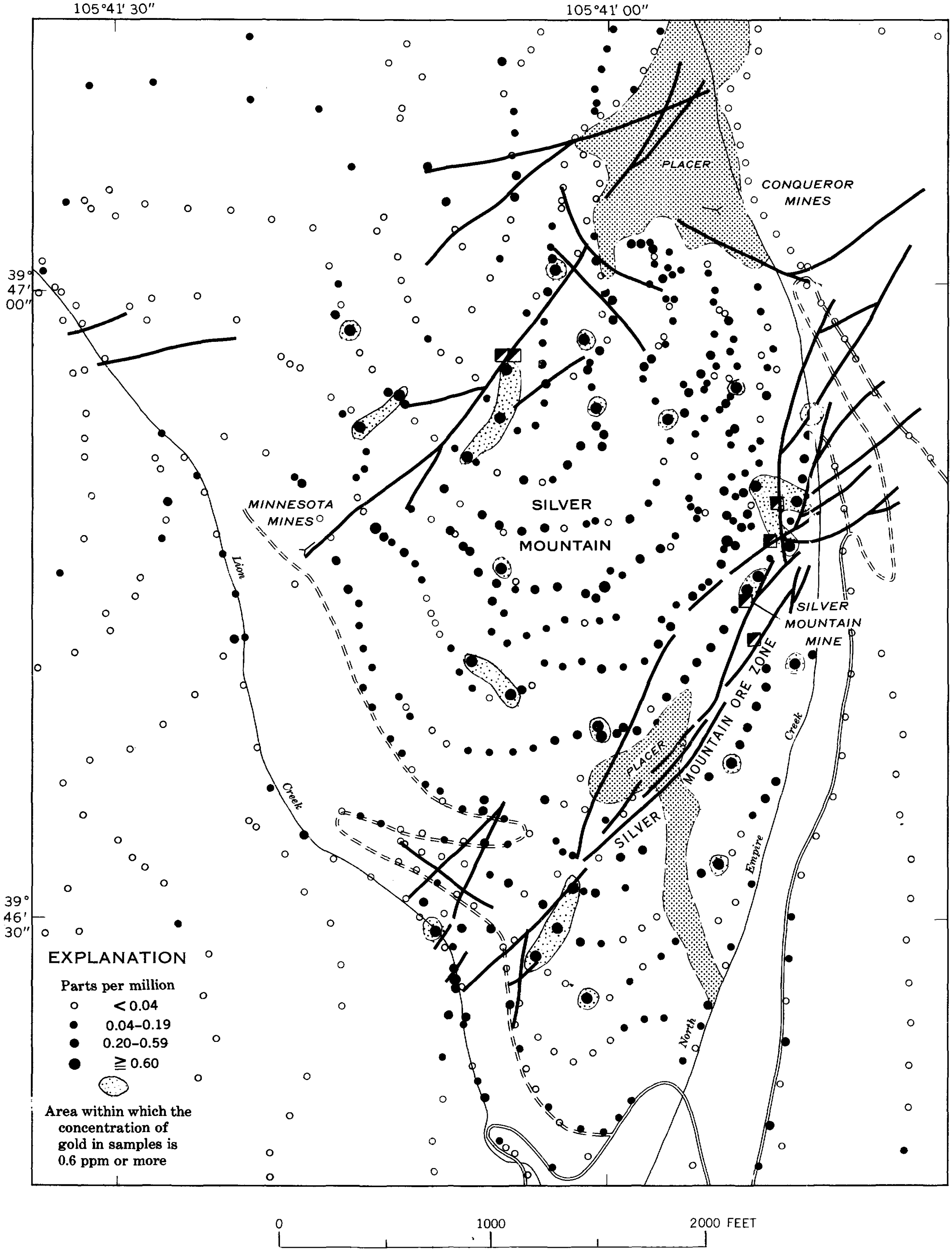

FIGURE 5.—Distribution of gold in soil (6- to 12-inch depth). Heavy lines are veins.

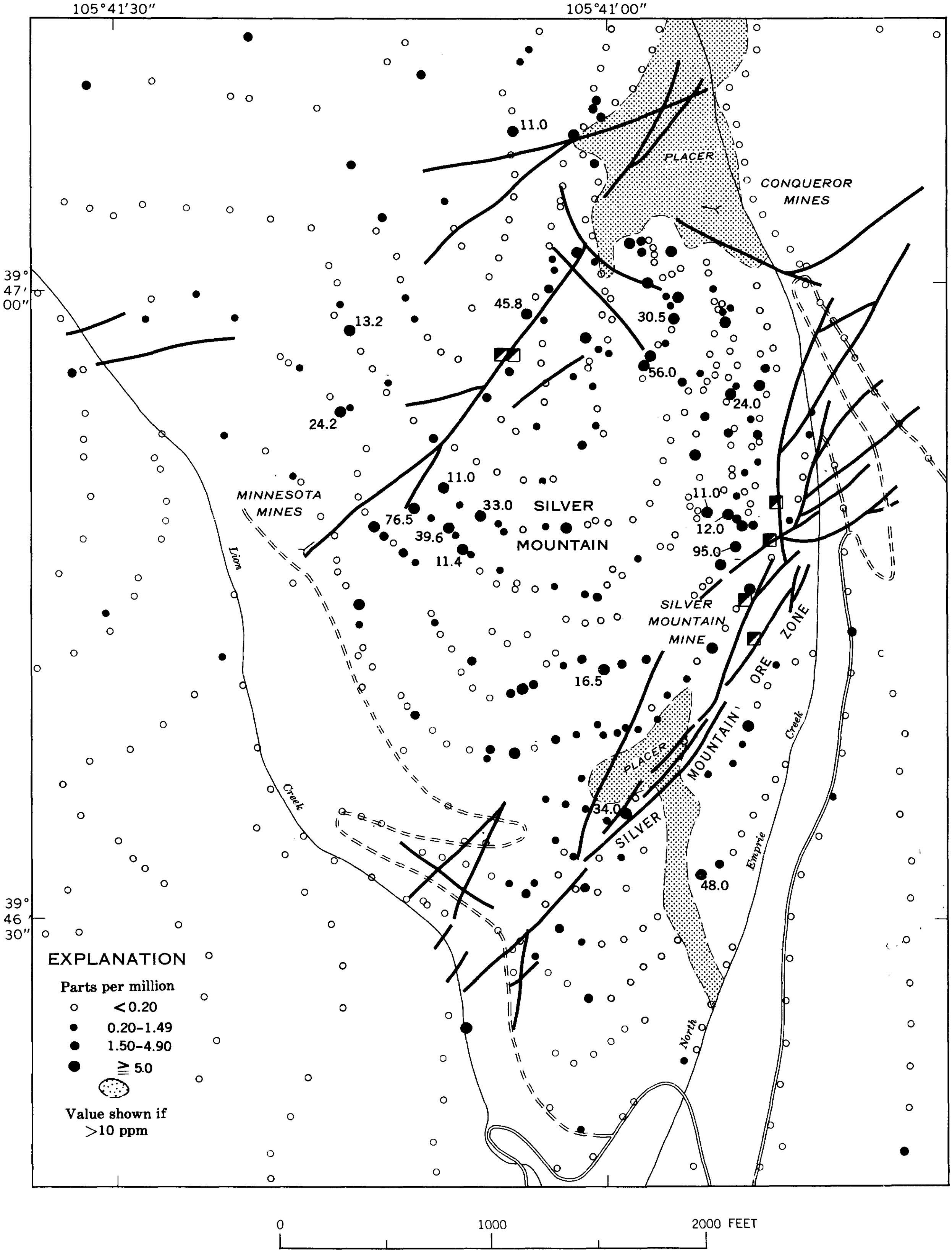

FIGURE 6.—Distribution of gold in pebbles and cobbles collected in colluvium or glacial drift. Heavy lines are veins.

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