UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Antimony and other metal anomalies south of Stibnite, Valley County, Idaho

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With a section on Geology
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Open-file Report
No. 74-111

1974

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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ABSTRACT

Results of geochemical investigations south of Stibnite, Valley County, Idaho, show that the distribution of Sb, As, Au, Zn, Ag, and Mo in mull ash and of Hg in soil forms a highly anomalous area which is more than 1.5 km long and 1 km wide along the trace of the Meadow Creek fault, a major north-striking fault zone. In the report area the Meadow Creek fault is covered by deposits of Quaternary glacial debris ranging in thickness from several meters to more than 30 meters. Two other highly anomalous areas--one of Au, Zn, and Hg, and one of Zn, Ag, Hg, and Mo--correlate with silicified granodiorite along the trace of the Meadow Creek fault. These anomalies are not related to known ore deposits and merit further investigation.

The enrichment of metals in mull ash in the area of thick glacial debris suggests that the metals migrate from bedrock upward through the glacial debris, are taken up by the forest vegetation, and are concentrated in the mull as the litter from the vegetation decays. The findings indicate that mull is the most useful geochemical sampling medium in the stibnite area because the bedrock is deeply buried beneath deposits of transported material such as colluvium or glacial debris.

INTRODUCTION

Geochemical investigations south of Stibnite, Idaho (fig. 1), show that high values of Sb, As, Au, Zn, Ag, and Mo in the ash of mull (the forest humus layer) and of Hg in soil outline an anomalous area which is more than 1.5 km long and 1 km wide along the trace of the Meadow Creek fault zone.

This major north-south-trending fault zone has yielded more than 27,800 tons of antimony, 250,200 oz. of gold, and 1,000,000 oz. of silver from two major mines, the Meadow Creek and the Yellow Pine, located 1.5 km and 4.5 km north of the anomalous area, respectively (Cole and Bailey, 1948, p. 4; U.S. Bureau of Mines, 1948-1951, 1953-1955). In addition, 831,829 units of tungsten (WO_3) were mined from the Yellow Pine mine between August 1941 and December 1945 (Cole and Bailey, 1948, p. 4).

The geochemical investigations included in this report consist of a study of the distribution and association of antimony, arsenic, silver, gold, zinc, and molybdenum in the ash of mull in soil (A and B horizons), and in float and bedrock; and of the distribution of mercury in the A and B horizons of the soil and in float and bedrock.

Local place names not defined in this report or shown on the accompanying illustrations are taken from the Yellow Pine 15-minute topographic map, edition of 1943.

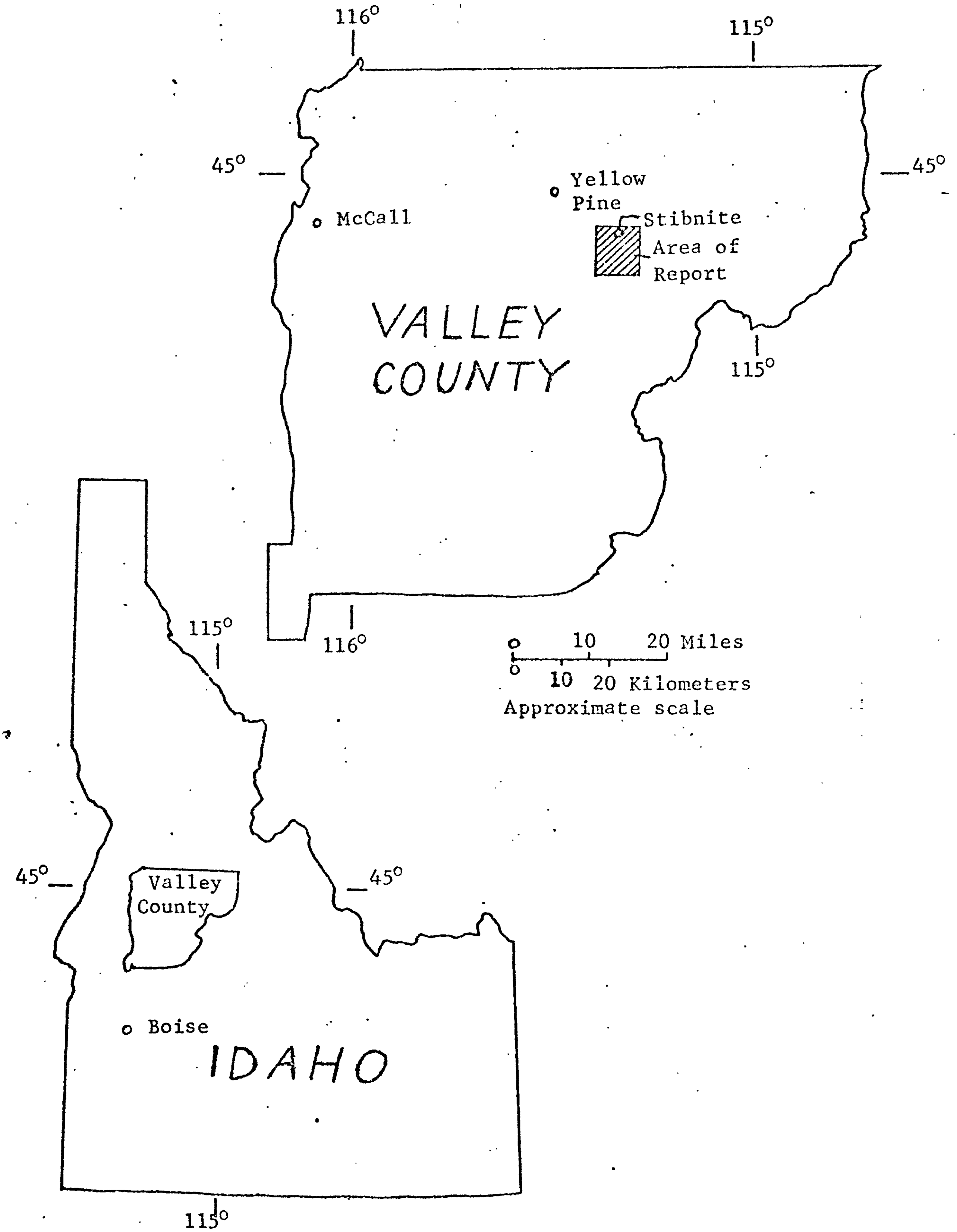

Figure 1.--Index maps showing location of Valley County and area of report.

The following members of the U.S. Geological Survey analyzed the samples collected during these investigations: E. L. Mosier, J. M. Nishi, J. R. Hassemer, J. B. Watterson, R. L. Turner, F. P. Welsch, R. M. O'Leary, J. A. Domenico, R. T. Hopkins, Jr., J. D. Hoffman, C. E. King, Jr., and P. N. Von Stein.

GEOLOGY

by B. F. Leonard

The geology of the sampled area and its environs is shown in figure 2. The principal map units are the plutonic complex, the silicified zone, the Challis Volcanics, and Quaternary deposits.

The plutonic complex here comprises granodiorite and alaskite of the Idaho batholith suite, in places coarsely interlayered with and intruded into Precambrian mica schist, quartzite, amphibolite, and carbonate rocks of high metamorphic grade. The complex is divisible into a dozen subunits, only three of which are shown in figure 2. The three subunite suffice to illustrate the internal structure of the complex and its relation to other map units. A brief description of the subunits accompanies the geologic map. Outcrops within the complex are sparse. Most of the area is thinly but extensively covered with grus and small rock fragments.

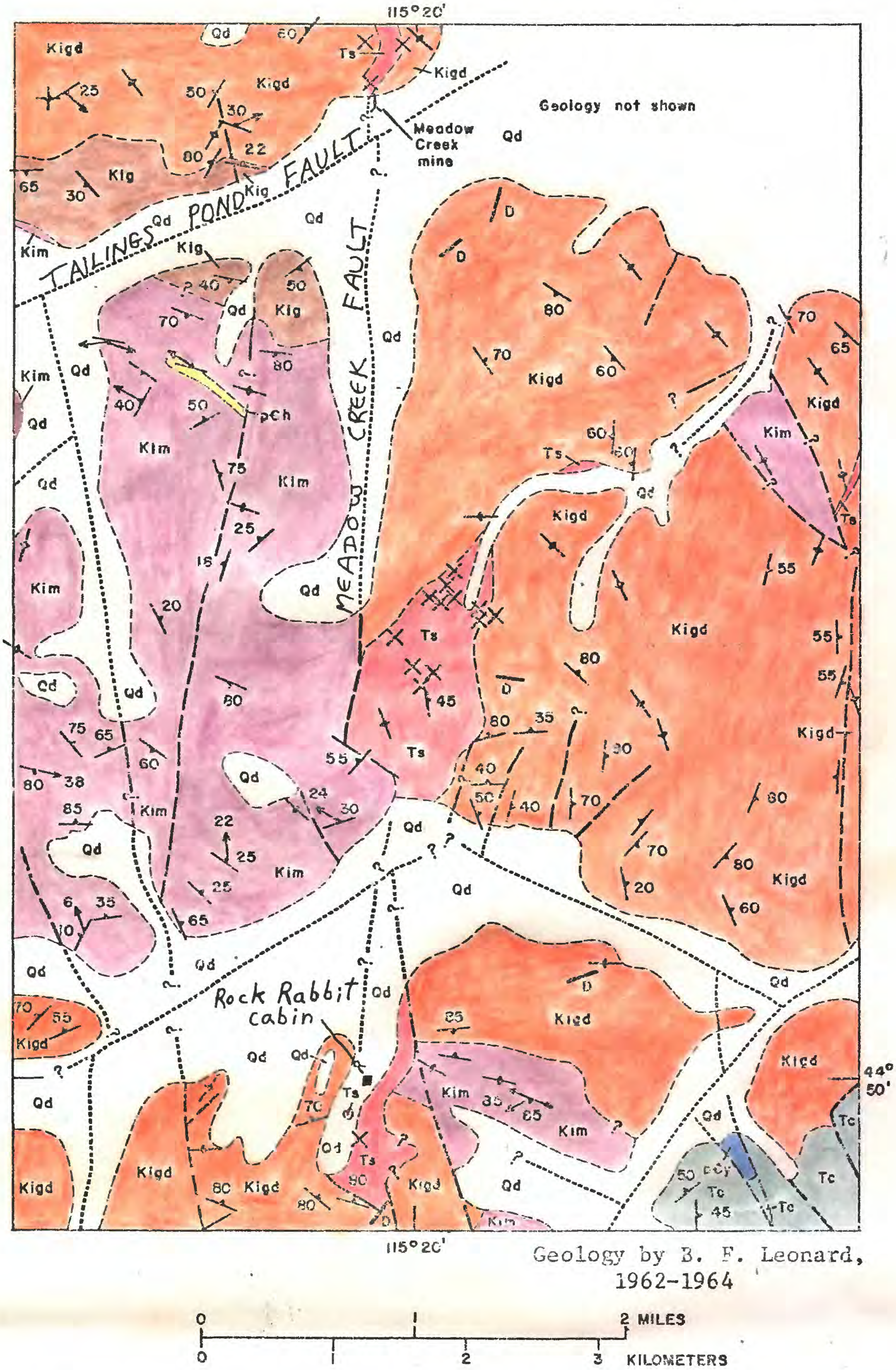

Figure 2. Geologic map of part of Yellow Pine 15-minute quadrangle, Valley County, Idaho

EXPLANATION

Qd

Quaternary deposits
Mainly glacial deposits and alluvium. Includes mill tailings along Meadow Creek

} QUATERNARY

Ts

Silicified zone
Contains both pre-dike and post-dike components

D

Dikes
Mainly rhyolite and latite

Tc

Challis Volcanics
Latite breccia and latite tuff

} TERTIARY

Kim | Kig | Kigd

Local facies of Idaho batholith

Kim--Mixed-rock unit, mainly of alaskite and Precambrian metasedimentary and metavolcanic rocks. Alaskite--generally medium-grained, equigranular, and seemingly massive--forms sheets, small intrusive bodies, agmatites, and dikes in the old country rock. A little granite pegmatite accompanies the alaskite locally. Metasedimentary rocks are quartzite, silicated marble, skarn, sillimanite-biotite schist, and their variants. Metavolcanic rocks are chiefly biotite hornfels and biotite-quartz-feldspar schist. Proportions of alaskite and old country rock vary widely, and ghost stratigraphy is locally preserved. Bodies of gneissoid and gneissic biotite granodiorite, not separately mappable, are presently locally

Kig--Garnet-bearing biotite granodiorite. Medium- to coarse-grained, commonly with a slightly curly foliation. Garnet is sparse; muscovite is rare. Locally intruded by alaskite and granite pegmatite

Kigd--Biotite granodiorite. Medium- to coarse-grained, porphyritic to subporphyritic, gneissoid to gneissic granodiorite, commonly containing sparse, small inclusions of biotite hornfels, biotite schist, and amphibolite. Locally intruded by alaskite and by small dikes of aplite and granite pegmatite. The dark inclusions, commonly elliptical or discoidal, rarely exceed 10 cm in length. Inclusions of other kinds of country rock are virtually absent. Inclusion content generally ≤ 1 percent

} CRETACEOUS

p€h

Hoodoo Quartzite
White quartzite, nearly pure, rarely with a little biotite

p€y

Yellowjacket Formation
Metamorphic rocks, undifferentiated

} PRECAMBRIAN

— — — ? — — Contact--Approximately located; queried where arbitrarily drawn

—— —— ? . . . Fault--Approximately located; dotted where concealed; queried where arbitrarily drawn or of doubtful continuation

Strike and dip of foliation

80 Inclined

Horizontal

Vertical

22 Trend and plunge of lineation--May be combined with foliation symbols

Mine

Prospect

A major silicified zone transects the synforms and antiforms of the plutonic complex. This zone is the southern extension of the Meadow Creek zone described by Cooper (1951). The Meadow Creek fault, a principal element of the structure here termed the Meadow Creek zone, shows on our figure 2 as a concealed fault just west of the portal of the Meadow Creek mine. A massive quartz lode is exposed along the cliffs east of Rock Rabbit Creek[1/], and silicified rock forms a few roches moutonnées near the

[1/] Rock Rabbit Creek, flowing north, enters Big Chief Creek 3.5 km upstream from the confluence of Big Chief and Indian Creeks. The Rock Rabbit cabin is 1.5 km south of the mouth of Rock Rabbit Creek.

head of the creek. Elsewhere outcrops are sparse, but small bits of quartz mixed with grus are widespread. The limits of the central part of the silicified zone can be determined by carefully mapping the quartz float. The rest of the zone is partly or wholly concealed by Quaternary deposits. By analogy with silicified zones well exposed elsewhere in the region, the silicified zone of the sampled area is inferred to consist of lodes, veins, veinlets, and stockworks of finely crystalline quartz and chalcedony interspersed with unsilicifed and weakly silicified relics of the plutonic complex. Most of the quartz and some of the granitic rock is stained yellow, brown, or pinkish, and some of the granitic rock is mylonitic. Clay minerals are seldom seen, and the dimensions of individual quartz-rich bodies are indeterminate. In addition to the main silicified zone shown in figure 2, areas of sparse quartz float too small to be mapped are scattered throughout the plutonic complex. The main parts of the silicified zone, from north to south, are described as follows; their relation to the structures that control their distribution is noted.

The northern part of the zone is mantled by Quaternary deposits in the reservoir area but indicated by float north and south of the divide between Meadow Creek and Big Chief Creek. The silicified zone generally follows a north-striking shear zone or system of faults on which the apparent right-lateral displacement of minor metamorphic rock units is at least 500 m and perhaps as much as 2,100 m. A conspicuous bulge in the silicified zone seems to represent stockworks of quartz veins and veinlets related to northeast-striking extension fractures developed by right-lateral movement along the meridional shear zone. Outside the sampled area, similar bulges along meridional silicified zones contain ore deposits. Within the sampled area, only part of the bulge has been prospected, evidently without success.

The southern part of the silicified zone is the tag end of the Meadow Creek structure, here partly concealed by glacial debris. The exposed lode, previously mentioned, has been prospected on the Rock Rabbit claims by a sizable adit, now caved, and by smaller workings. At the portal of the main adit, near a bulge in the silicified zone, the lode consists of fine white replacement quartz locally crackled and stained yellow-brown. Sparse outcrops 450 m south-southwest of the old cabin show bleached chalky alaskite and porphyritic granodiorite cut by a narrow dike of rhyolite. Here, molybdenite and powellite are present. The molybdenite, intergrown with powellite, a little jarosite, and unidentified brown alteration products, occurs as sparse small patches on joints in a quartz veinlet in the granite. A few flakes of molybdenite are present in a quartz veinlet in the rhyolite. A pale greenish mineral that may be powellite is present nearby as particles in bleached alaskite. Specimens found at the cabin and at one of the prospects show a little azurite, malachite, and copper pitch in green amphibole schist like that found in the belt of mixed rocks east of the silicified zone. The bedrock source of the copper-bearing specimens was not seen.

The silicified zone ends abruptly against a dike-bearing fault zone on the ridge 900 m south of the cabin. The horizontal offset of mixed-rock units suggests right-lateral displacement of 450-2,100 m along the silicified zone at this latitude. If, as the peculiar dead look of the altered alaskite suggests, a cover of Challis Volcanics has recently been stripped from the southeast end of the zone, vertical displacement on the zone may be about 100 m, with the east wall up.

Southward from the faulted end of the silicified zone, a bulbous area of gneissoid biotite granodiorite, extending almost to Indian Creek, is cut by many small faults. The granodiorite adjacent to these faults is stained yellowish brown, as if from oxidized pyrite, but no extensive area of staining and no specks of ore minerals suggestive of a disseminated sulfide deposit could be found, in spite of careful search. Other stained areas west-southwest of the faulted end of the silicified zone lie within a slight aeromagnetic high (peak intensity 1691 gammas) shown on the geologic map of the Idaho Primitive Area (Cater and others, 1973, pl. 1).

Dark-green latite breccias and tuffs of the Challis Volcanics are present in fault blocks downdropped along the southeast side of Indian Creek, and small slivers of buff rhyolite tuff are present along the transverse fault that cuts off the silicified zone on the divide at the head of Rock Rabbit Creek. The latitic rocks are part of the lower, latitic unit of the Challis of the Thunder Mountain caldera. At this latitude, they mark the west edge of the local Challis field. The slivers of rhyolite tuff (too small to show on the map) presumably belong to the upper, rhyolite unit of the Challis. If this inference is correct, and if the latitic rocks in this area have their usual thickness of 350-450 m, the slivers of rhyolite tuff have been downdropped at least 350 m along the transverse fault. The alternative hypothesis, that the slivers are tuff dikes emplaced along the fault or caught up in it, is unsupported by evidence, for tuff dikes have not been shown to exist within the local Challis field or its environs.

A few dikes of buff rhyolite and greenish latite crop out in and near the silicified zone. The dikes, 3 to 15 m wide, can seldom be traced more than 50-100 m. Most of the dikes strike northeast; two strike northwest. In appearance, composition, and slight alteration, these dikes are like thousands of others in the region. Five km southeast of the sampled area, rhyolite and latite dikes of the Little Pistol swarm cut the Challis Volcanics.

The relations among silicification, introduction of metals, and emplacement of dikes are inadequately known for this area and equivocal for other silicified zones in the region. (For a discussion of another silicified zone, see Leonard and others, 1968, p. C20.) For the sampled area, the critical facts are: Tertiary dikes cut the silicified zone, the dikes resemble those known to cut the Challis Volcanics nearby, and a dike near the head of Rock Rabbit Creek contains a little molybdenite in a quartz veinlet. The inference is that at least some quartz and some metals are younger than the dike.

Quaternary deposits mantle the glacial valley north and south of the former Stibnite Reservoir, fill the valley of Big Chief Creek, and cover the northern half of the U-shaped valley of Rock Rabbit Creek. From south to north in the reservoir area, in the direction of local ice movement, the deposits are mainly moraine debris and reworked colluvium, lake beds, and large iceworn and waterworn boulders gullied by floodwaters released when the reservoir dam broke in 1965. At and below the damsite, the thickness of coarse valley fill exceeds 30 m; it may be about 100 m locally. Above the damsite, in the flat stretch of the hanging valley, the thickness of stream, lake, and glacial deposits may range from some meters to more than thirty meters. Along Big Chief Creek, the thickness of valley fill--alluvium, reworked glacial deposits, small moraines, and local block streams--is at least some tens of meters. South of Big Chief Creek, small lateral and medial moraines from the local cirque converge northward to form a thick mass of morainal and snowslide debris whose components are not exposed. The considerable thickness of Quaternary deposits overlying the extension of the Meadow Creek fault zone in several areas of intense geochemical anomalies presents a problem if the anomalies are to be explored.

The faults of the area are representative of the large fractures of Tertiary and Quaternary age that dissect this part of Idaho. The Meadow Creek fault zone and its southern extension in the sampled area are part of a ring-fracture system related to the collapse of the Thunder Mountain caldera (see Leonard, B. F. in U.S. Geological Survey, 1971, p. A36, for a preliminary note on the caldera). Concealed faults of northeast strike in the valleys of Meadow Creek, the upper part of Big Chief Creek, and Indian Creek are segments of radial fractures related to caldera collapse. Rotational strain of regional extent followed collapse and was relieved in part by right-lateral shear along some of the meridional ring fractures, such as the Meadow Creek fault zone, and in part by the development of northeast-striking extension fractures. Block faulting related to renewed subsidence then occurred in multiple stages: developing new fractures, making use of old ones, and giving rise to small-scale topographic anomalies such as severed block streams and faulted stream terraces. For the region, repeated deformation according to different styles is the rule; for the area, recognition of the complexity of the regional fracture pattern is a desirable preliminary to exploration of the geochemical anomalies shown in the accompanying maps.

The radial fault along Meadow Creek has special significance for exploration because of its peculiar effect on the Meadow Creek fault zone. The radial fault, thought to be vertical, is here named the Tailings Pond fault. Along it, apparent right-lateral offset of structures or rock units increases toward the southwest: the Meadow Creek fault zone is perhaps offset 50-100 m; the unit of mixed rocks (fig. 2) is offset about 750 m. The amount of offset is not precisely determinable, owing to the uncertainty of projecting these features to the trace of the Tailings Pond fault; but within the limits of permissible assumptions, the offsets define a hinge fault whose pivot point is within 150 m east or west of the Meadow Creek-Thunder Mountain road junction at Stibnite. The total angular displacement defined by these crude data is 10°-25° in the plane of the Tailings Pond fault, and the relative motion is north block up, south block down. If displacement was of the same magnitude but opposite sense for each block, the angular displacement for each block was 5°-12°. Hypotheses of pull-apart or right-lateral shearing along the Tailings Pond fault do not adequately account for the southwestward increase in offset, noted above, and are not consonant with the style of displacement to be expected from recurring adjustment to subsidence along radial fractures.

Three correlatives of hinge movement on the Tailings Pond fault are of economic interest. First, the dip of the Meadow Creek fault zone at the Meadow Creek mine (Cooper, 1951; average dip of 75° west shown on cross section, pl. 44) must have been almost vertical before hinge faulting on the Tailings Pond fault. Second, the hinge movement would presumably have caused the south extension of the Meadow Creek fault zone to depart from the vertical and dip eastward. The dip angle cannot be determined from the geologic map, but an east dip at a high angle is consistent with the slight southeastward curving of the silicified zone as its centerline is followed downslope from the Old Thunder Mountain Road to Big Chief Creek. Third, hinge movement swinging the block south of the Tailings Pond fault <u>downward</u> increases the likelihood of preserving an ore shoot comparable to that at the Meadow Creek mine in the southern block, if a southern extension of the shoot ever existed.

GEOCHEMICAL INVESTIGATIONS

Material sampled

Samples of mull and soil were collected for this study at 229 sites; rocks were collected at 216 of these same sites. Sample sites are shown on the accompanying geochemical maps (figs. 3-5, 7-9, 11-13, 15, 17, 18, 20-22, 24-26). Nearly all the mull samples were collected beneath individual coniferous trees of species including alpine fir (*Abies lasiocarpa* Nutt.), lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmanni*), and limber pine (*Pinus flexilis*), or from beneath a combination of these species. Mull derived from conifers was collected at all except ten sites. Within the boundaries of the bed of the Stibnite Reservoir, the mull layer has been formed from sedges and other small plants.

The coniferous mull is present as pads, 2-10 cm thick. Varying quantities of mineral matter have been added to the pads by the activities of rodents, by sheetwash, and by wind.

A layer of gray to gray-brown, ash-textured soil (3-10 cm thick) that contains abundant small roots is present beneath the mull layer. This layer is the A soil horizon. The B soil horizon is composed of weathered cobbles and yellow to yellow-brown, coarse to fine sand of colluvial or glacial origin. At all sites except those in the bed of the drained reservoir, both horizons were sampled. The B horizon was sampled to an average depth of 30 cm. In the bed of the drained reservoir the A horizon (15-20 cm thick) is composed of black to dark-gray, highly organic, silty clay; the B horizon (20-25 cm thick) is composed of sandy silt and has a lower organic content than the A horizon. Both the A and B horizons were sampled at each of the ten sites.

Samples of rock were collected at all the sites except for 13 that are in and adjacent to the bed of the drained reservoir. Float was the main type of rock collected, because bedrock was exposed at only 14 of the sample sites.

Analytical procedures

Several analytical procedures were used. Au and Hg were determined by atomic absorption methods (Thompson and others, 1968; Vaughn and McCarthy, 1964). The other elements were determined in mull ash by a semiquantitative spectrographic method for organic materials (Mosier, 1972), and in soils and rocks by another semiquantitative spectrographic method (Grimes and Marranzino, 1968).

Soil samples were sieved, and the minus 2-millimeter fraction was ground and pulverized for analysis. Mull samples were sieved to remove rock fragments and large pieces of litter, and the minus 2-millimeter fraction was ashed. A small split was taken from the ashed sample and sieved through a 0.25-millimeter sieve to remove sand-sized grains, and the minus 0.25-millimeter fraction was analyzed. A 10-gram split from the sieved and ashed mull sample was analyzed for Au. The ash of the mull, as the term is used in this report, comprises the admixed mineral matter and the ash of the organic matter. The metal content of the mull samples is reported on an ashed-weight basis.

Geochemical anomalies

Results of the geochemical investigations are summarized in the geochemical maps of the distribution of Sb, As, Au, Ag, and Mo in mull ash and soil, of Zn in mull ash, and of Hg in soil (figs. 3-5, 7-9, 11-13, 15, 17, 18, 20-22, 24-26). The analytical data are summarized in the accompanying histograms which show the percent frequency distributions of these metals. Anomalous elemental values were picked arbitrarily from the percent frequency distributions of the elements as shown by the frequency histograms (figs. 6, 10, 14, 16, 19, 23, 27).

The north-central part of the mapped area contains conspicuous positive anomalies of Sb, As, Au, Zn, Ag, and Mo in mull ash (figs. 3, 7, 11, 15, 20, 24). The distribution of Sb in mull ash at a minimum concentration of 150 ppm (parts per million) is pervasive over a large part of the northern third of the mapped area (fig. 3). Antimony in mull ash at a minimum concentration of 300 ppm, however, delineates a positive anomaly about 1.5 km long that correlates in part with the trace of the Meadow Creek fault zone. Highly anomalous Sb values were detected in the ash of the coniferous mull but not in the ash of the mull formed from the small plants growing in the bed of the Stibnite Reservoir. The anomalous concentrations of As, Au, Zn, and Mo in mull ash (figs. 7, 11, 15, 24) are somewhat coextensive with the highly anomalous concentrations of Sb along the trace of the Meadow Creek fault zone. A positive anomaly of Ag in mull ash (fig. 20) also correlates, in part, with these anomalies. All these anomalies are primarily within an area where the Meadow Creek fault zone is concealed by rather thick deposits of glacial debris, and for the most part they are defined by high elemental concentrations in the ash of mull formed from trees growing in the glacial debris. In contrast to Sb concentrations in mull ash, highly anomalous As and Mo concentrations were found in the ash of the mull layer formed on the bed of the Stibnite Reservoir (figs. 7, 24).

A spatial correlation exists between the positive anomalies of Zn and Au in mull ash in part of the zone of silicified biotite granodiorite in the central part of the mapped areas (figs. 11, 15). These anomalies may be mostly derived from the silicified rock.

Positive anomalies of Ag and Zn in mull ash (figs. 15, 20) correlate spatially with each other in the southern part of the mapped area where the coextensive Ag and Zn amomalies roughly outline the boundaries of the southern end of the zone of silicified biotite granodiorite.

With the exceptions of Sb, Hg, and Ag, the anomalies in soil are relatively small and scattered. Antimony, one of the exceptions, forms extensive positive anomalies in the A horizon of the colluvial soil on the hillsides east and west of the Meadow Creek fault zone in the northern part of the mapped area (fig. 4). Mercury (fig. 17) forms positive anomalies in the A horizon soil that are coextensive with those of Sb, As, Au, Ag, and Mo in mull ash in the northern and central parts of the mapped area. Silver in the A and B horizons of the soil (figs. 21, 22) and Hg in the A horizon (fig. 17) form conspicuous anomalies that are coextensive with the Ag and Zn anomalies in mull ash that outline the southern part of the silicified zone.

Rock samples yielded little useful information. Most of the few samples that did contain anomalous amounts of metals (figs. 6, 10, 14, 19, 23, 27) were collected from bedrock or near bedrock, either in the extreme southern part of the area or in the vicinity of Indian Creek Point. Sampling was probably biased toward unaltered float in the areas of colluvium and glacial debris, because the altered float, where seen, had disintegrated into very small pieces which graded into soil-sized material (less than 2 mm in diameter).

Tungsten, a metal to be expected in the local assemblage, was not found in the samples of either mull or soil and was detected in only four samples of float. These four float samples that contained W were collected west of the trace of the Meadow Creek fault in the north-central part of the area (data not illustrated). The lack of W in the rest of the samples may be due either to the relative insensitivity of the analytical method used (lower limit of sensitivity 50 ppm) or to a lack of highly anomalous amounts of W in the bedrock.

Metal enrichment in mull ash

The geochemical maps and histograms (figs. 3-27) indicate the enrichment of elements in mull ash relative to soil. The minimum concentrations shown on the geochemical maps for Sb and As in mull ash are greater by a factor of 30 for Sb and by a factor of 7 for As than the minimum values shown for Sb and As in soil.

The histograms of the elements in mull ash and soil (figs. 6, 10, 14, 16, 19, 23, 27) show that mull ash is highly enriched in Sb and is somewhat enriched in As and Au. Mull ash is also enriched in Zn (data not illustrated). The results for Ag and Mo in mull ash are not directly comparable to those in soil, owing to the greater sensitivity of the method used for analyzing these elements in mull ash.

Contamination

We attribute the metal anomalies in mull and soil primarily to a local bedrock or bedrock-derived source. If, instead, the anomalies result from contamination, the three principal sources from which antimony could have been dispersed as a contaminant throughout the sampled area are (1) windblown dust from the milling operations at Stibnite, (2) windblown dust from the tailings pile, and (3) airborne particulates from the smelting operations at Stibnite. The possibility that some contamination has occurred in the sampled area cannot be eliminated. The point at issue is whether contamination by windborne particles accounts for the major metal anomalies. The following evidence indicates that it does not.

Wind direction and length of dry season are the critical factors in assessing post-milling redistribution of tailings. Wind records were not kept while a weather station operated at Stibnite, but the State Climatologist of the National Weather Service in Boise stated that the prevailing wind in this region in Idaho is from the southwest (K. A. Rice, oral commun., 1973). Certainly this is the observed direction during June to October, 1957-72 (B. F. Leonard, written commun., 1973). A north- or northwest-prevailing wind, however, would be required to contaminate the reservoir area with dust from the milling or smelting operations. The near-ground eddy motion shown by dust devils developed downwind of the tailings pile during the summer months is to and fro along Meadow Creek, with a strong northeast, down-valley component. Many of the dust devils are dissipated near the Meadow Creek-East Fork road junction, at less than 30 m above ground. Their contribution of dust to air circulating above 30 m is not visible; it is judged to be small. As the tailings were moist during the milling operation and are now snow-covered during 6 months of the year and damp for another 3 months, redistribution of the tailings by wind is effectively confined to the three dry summer months and restricted to the period between cessation of milling (June 1952) and the collection of geochemical samples (August 1970). In conclusion, climatic factors make windborne tailings an unlikely source of the major geochemical anomalies in the sampled area.

Just as there is no evidence for prevailing north and northwest winds, there is no evidence that large quantities of dust or fumes escaped during milling or smelting operations. The ore was coarsely crushed and grinding was wet (Bradley, 1942; Cole and Bailey, 1948). The smelter operated only from 1948 to 1952. During this period, the smelter yielded about 6,900 metric tons of antimony metal (U.S. Bureau of Mines, 1953-1955). About 1,800 metric tons of cathode Sb metal from the Sunshine mines, Coeur d'Alene district, was refined in the smelter in 1956 (U.S. Bureau of Mines, 1958). The amount of Sb released into the atmosphere from the smelter is unknown, but the data in Table 1 indicate that a loss of 60 metric tons of Sb would be required to account for the Sb present in mull and soil of the sampled area, or 35 metric tons of Sb in the mull alone. If that much particulate matter had to be transported southward from the smelter, a far larger quantity would presumably be borne directly downwind. Flue losses of this magnitude seem unreasonable to us.

The foregoing arguments against contamination have dealt with the antimony milling and smelting operations at Stibnite. Anomalous concentrations of Hg and Zn are present in soil and mull collected in the sampled area; yet significant quantities of these elements have not been reported to occur in ores of the Meadow Creek and Yellow Pine mines. The Hg and Zn anomalies can hardly have resulted from treatment of the local ores. However, the location of anomalies of these metals, as well as Sb, Au, and Ag anomalies, along the trace of the Meadow Creek fault, offers strong evidence that Hg and Zn, and probably Sb, As, Au, and Ag concentrations in mull ash are derived from mineralized rock in the fault zone beneath the glacial debris.

Table 1.--Data on the antimony content of mull and soil

Average concentration of antimony in mull and soil (ppm)		Weight of 0.4 hectare (one acre of mull and soil) (metric tons)		Amount of antimony per 0.4 hectare (one acre) (kilograms)		Hectares in sampled area	Total weight of soil and mull (metric tons)		Total weight of antimony (metric tons)		Total weight of antimony in both mull and soil (metric tons)
Soil	Mull	Soil[1] (30 cm depth)	Mull[2] (2.5 cm depth)	Soil	Mull		Soil	Mull	Soil	Mull	
3	150	1,800	50	6	8	1,840	8,200,000	230,000	25	35	60

1/Lyon and Buckman (1937, p. 44).

2/Based on unpublished studies showing mull weighs about 1/3 as much as soil by volume.

In order to gather further evidence on the source of the Sb, seven samples of mull containing 100-1,000 ppm Sb were studied in detail. Four samples were collected in the sampled area and three samples were collected in a mineralized area 5 km east of Stibnite, where contamination from the milling and smelting operations at Stibnite was judged to be insignificant. These samples were separated into fractions to determine whether the bulk of the Sb in them was in the organic fraction or in the sand-and-silt fraction. The organic fraction in all the samples contained about 90 percent of the total Sb. Moreover, needles of pine, spruce, and fir trees, and leaves of willow (salix sp.) and myrtle blueberry (vaccinium myrtillus) collected at the mull sample sites contained as much as 30 ppm Sb. These results do not confirm that Sb is coming from bedrock beneath the sample sites. They do suggest, however, that, because of the intimate relationship between Sb and the organic materials, Sb has been concentrated in the mull, not as a result of contamination, but as a result of a natural biogeochemical cycle. In this cycle, Sb is leached from bedrock, is taken up by the vegetation, and is concentrated in the mull as the needles, leaves, and other vegetation parts decay.

CONCLUSIONS

The areal overlap of positive anomalies of Sb, As, Au, Zn, Ag, and Mo in mull ash and of positive anomalies of Hg in soil with the concealed southward extension of the Meadow Creek fault zone indicates that these elements have been leached from the fault zone and have moved through the glacial debris to the root zone where they are taken up by the trees and accumulated in the needles, leaves, and possibly other tree parts. These elements may, in turn, be concentrated in the mull as the tree parts decay. This process is further substantiated by the presence of Sb in conifer needles and by the very high percentage of Sb found in the organic fractions of the fractionated mull samples. These findings indicate that this area is an attractive exploration target and suggest that mull is the most useful sampling medium in subalpine forested areas where the bedrock is deeply buried beneath thick deposits of transported material such as colluvium or glacial debris.

In the northern third of the mapped area, the pervasive distribution of Sb in mull ash at a minimum concentration of 150 ppm suggests that Sb may have been dispersed in part by windblown material from the mining, milling, and smelting activities at Stibnite. Another source for this anomaly may be antimony-bearing rock from small silicified zones and minor fractures related to both the major ring and radial fractures that dominate the structure of the area. These sources are further indicated by Sb anomalies in the A horizon soil, anomalies which are almost totally in the colluvium on the hillsides to the east and west of the fault zone. These anomalies are probably caused mainly by the inclusion of mineralized rock into otherwise barren soil. The lack of Sb anomalies in the soil on glacial drift may be accounted for by the fact that much of the glacial debris was derived from the south where the bedrock apparently contains relatively small amounts of Sb.

The positive anomalies of Au and Zn in mull ash and Hg in soil in the central part, and Ag and Zn in mull ash and Hg in soil in the southern part of the mapped area suggest the presence of mineralized bedrock within the poorly exposed silicified zone. These anomalies may also be attractive exploration targets.

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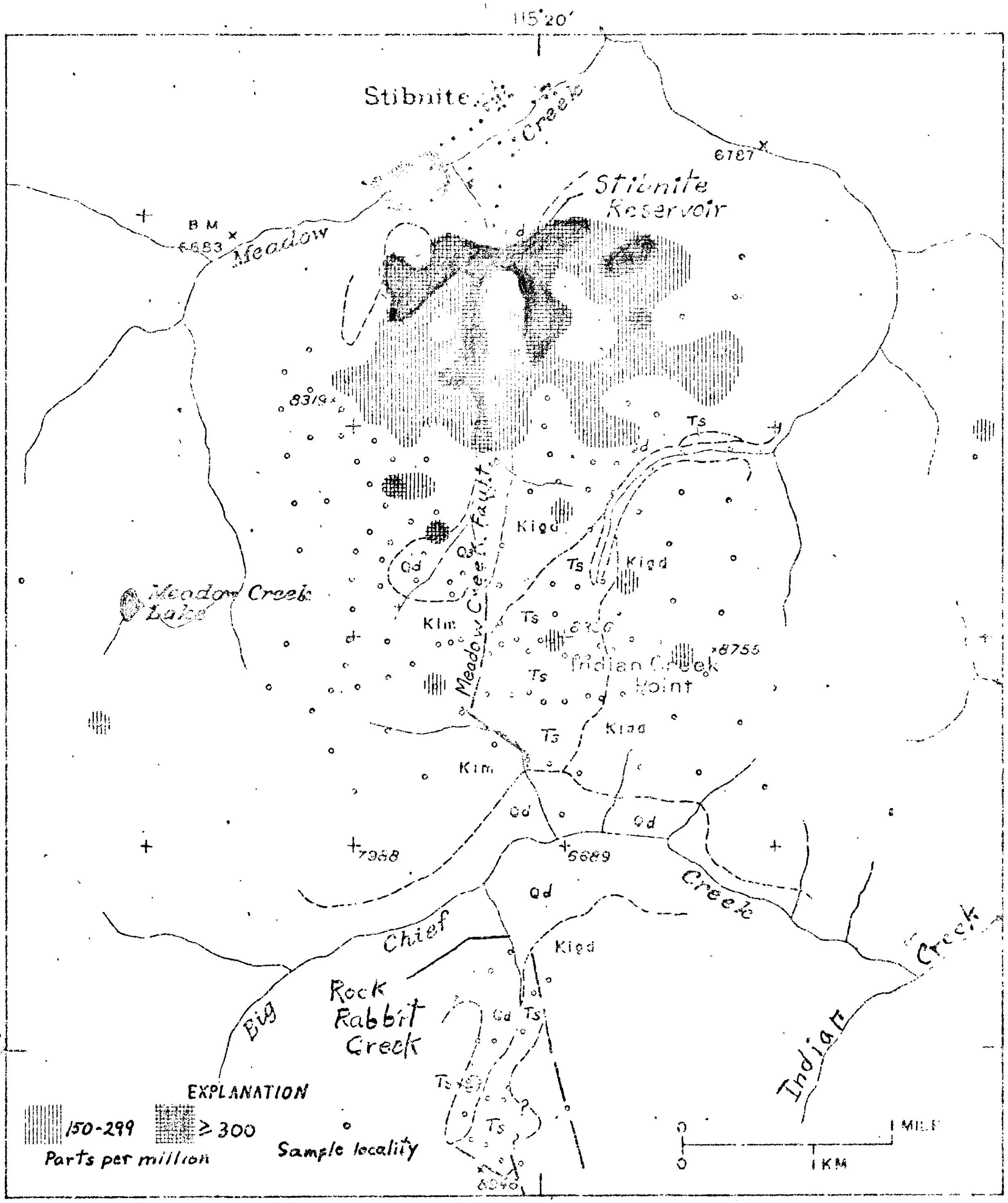

Figure 3. Geochemical map of Sb distribution in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

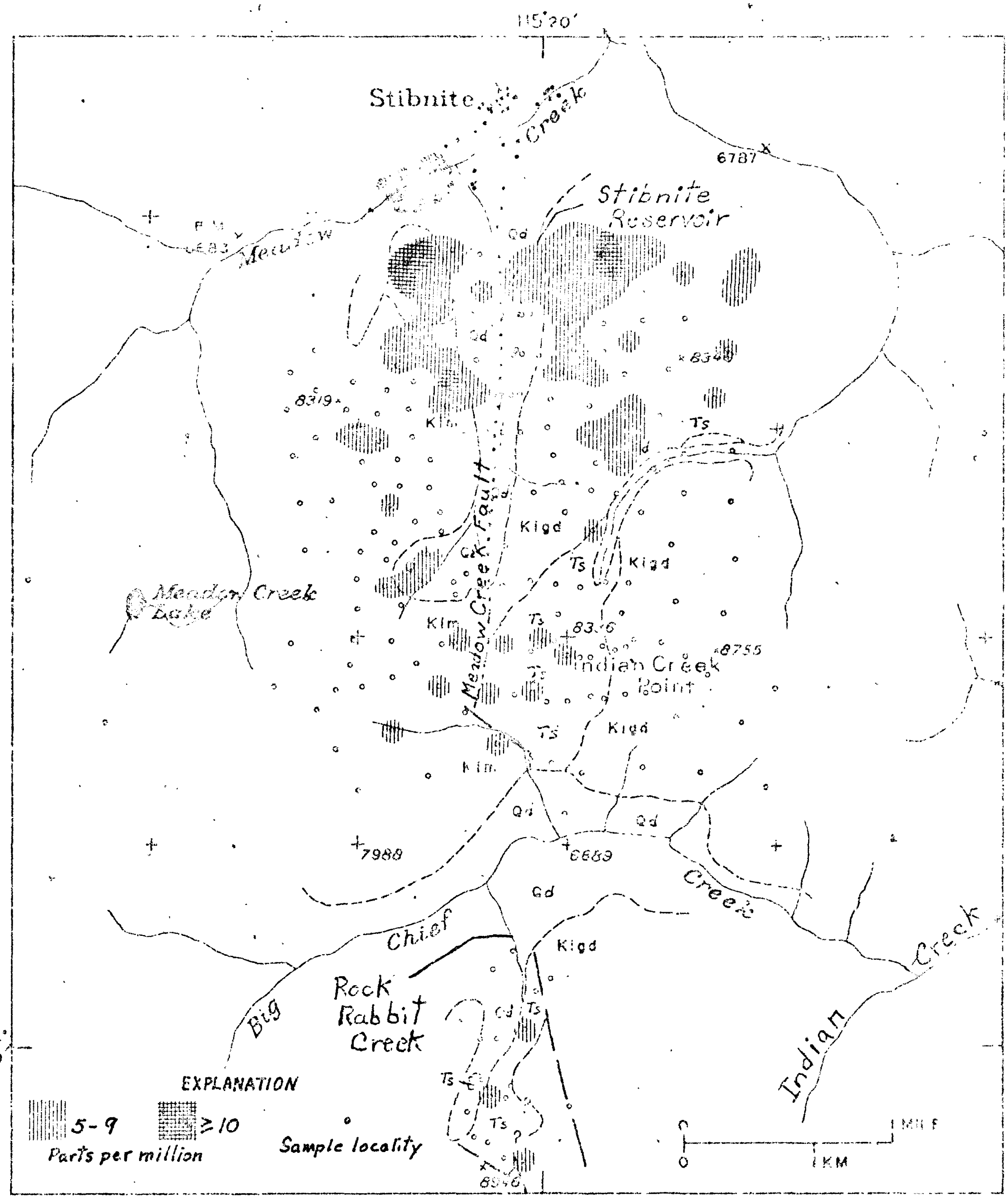

Figure 4. Geochemical map of Sb distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

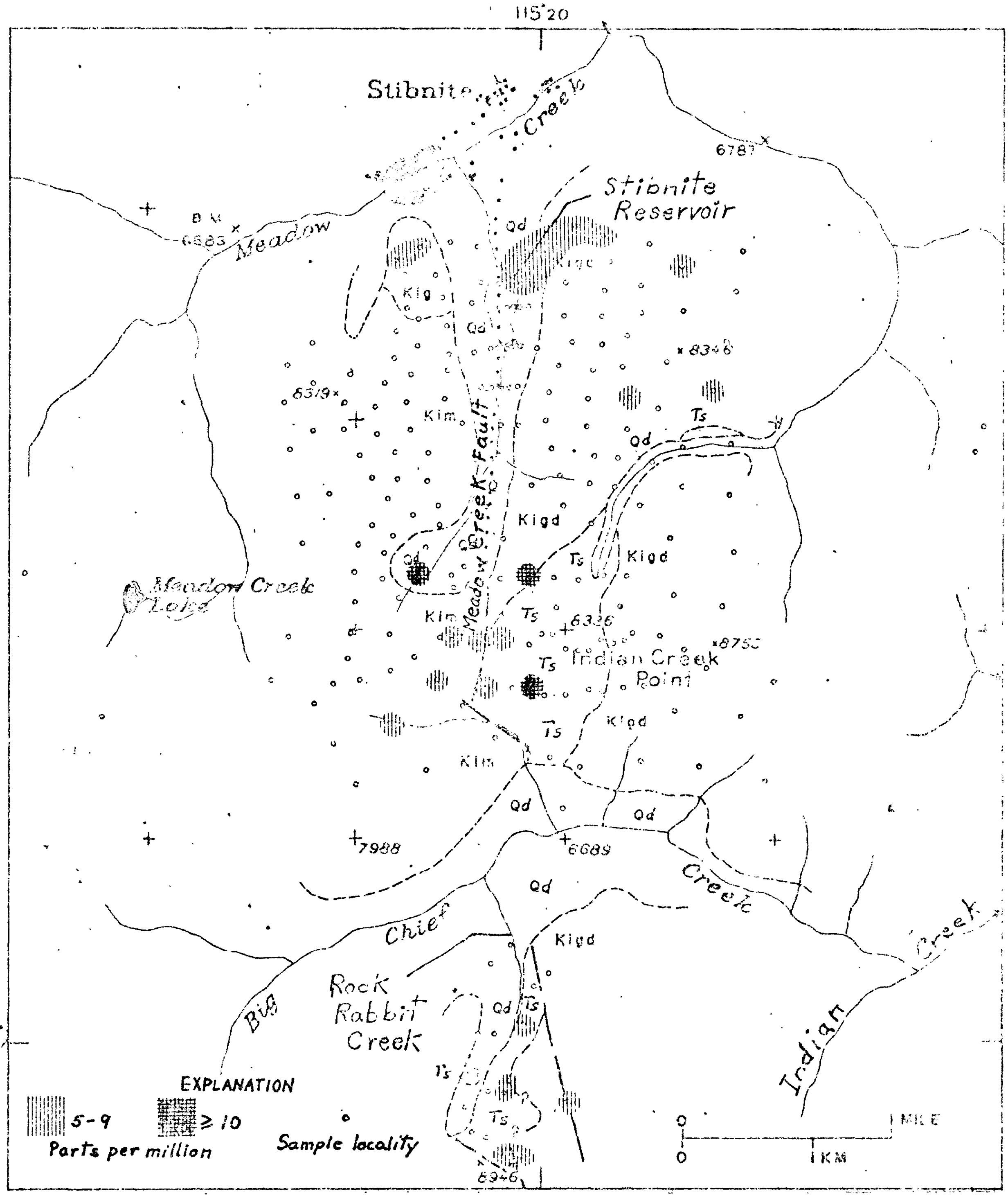

Figure 5. Geochemical map of Sb distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

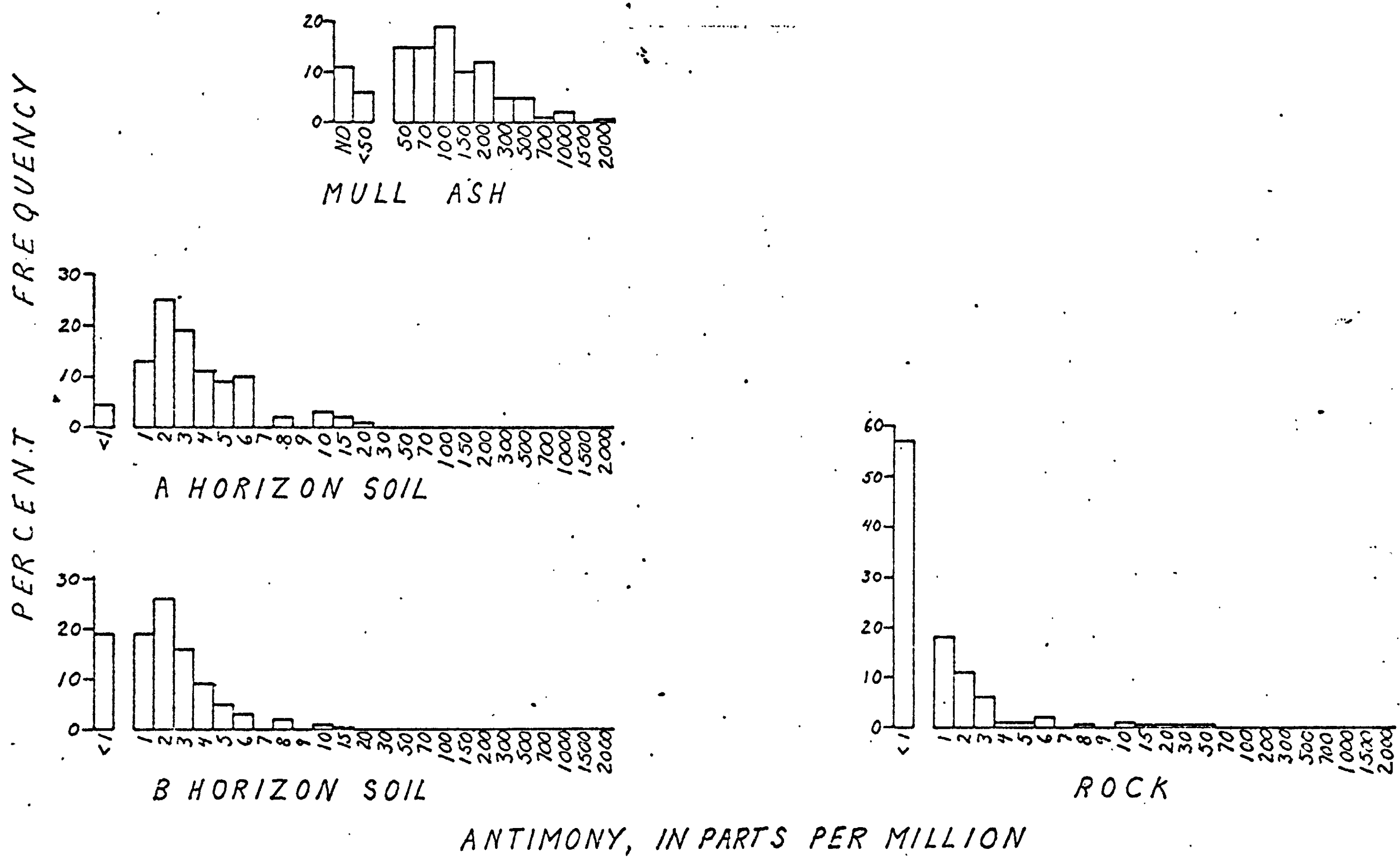

Figure 6.--Histograms of Sb distribution in mull ash, soil, and rock.

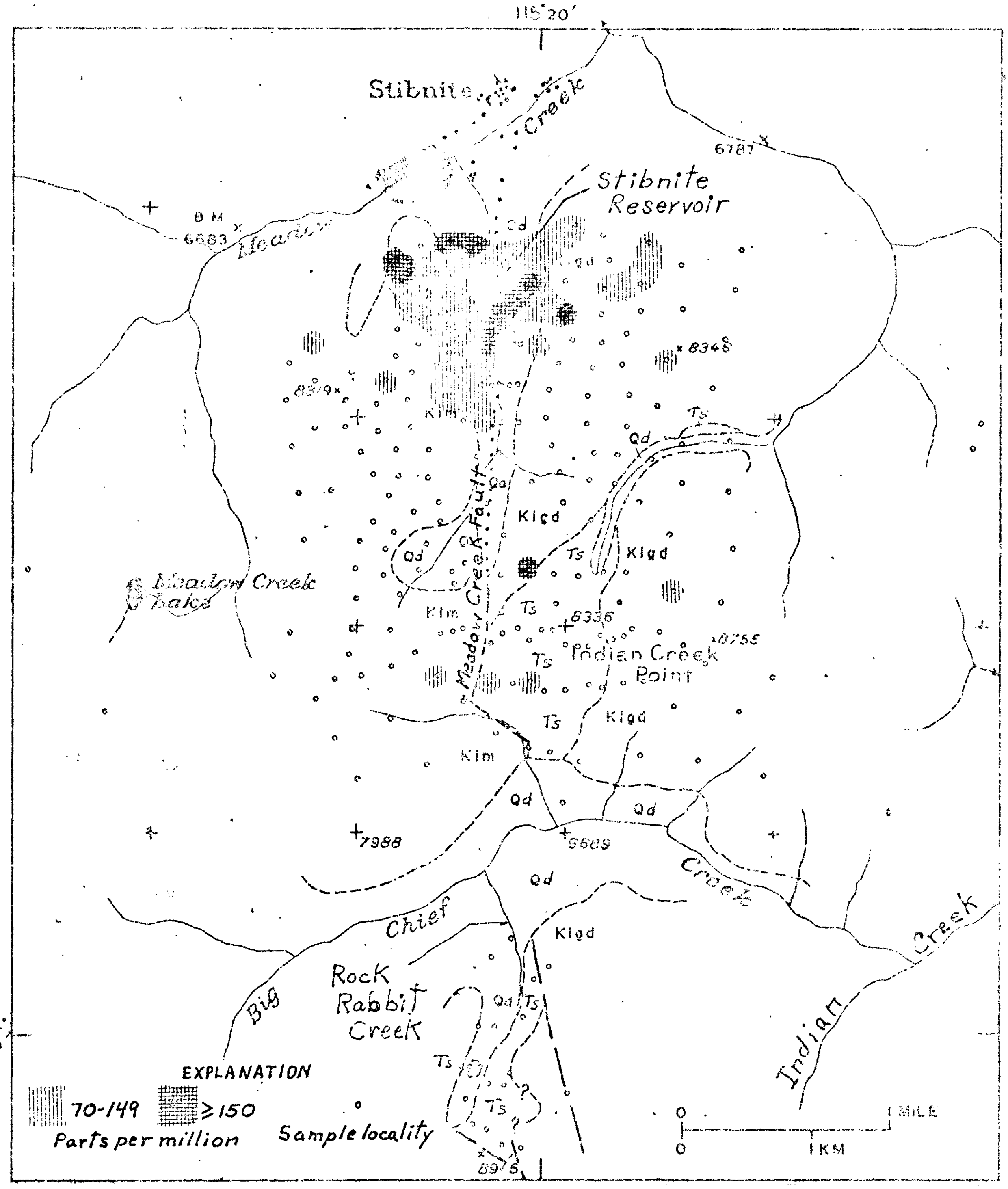

Figure 7. Geochemical map of As distribution in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

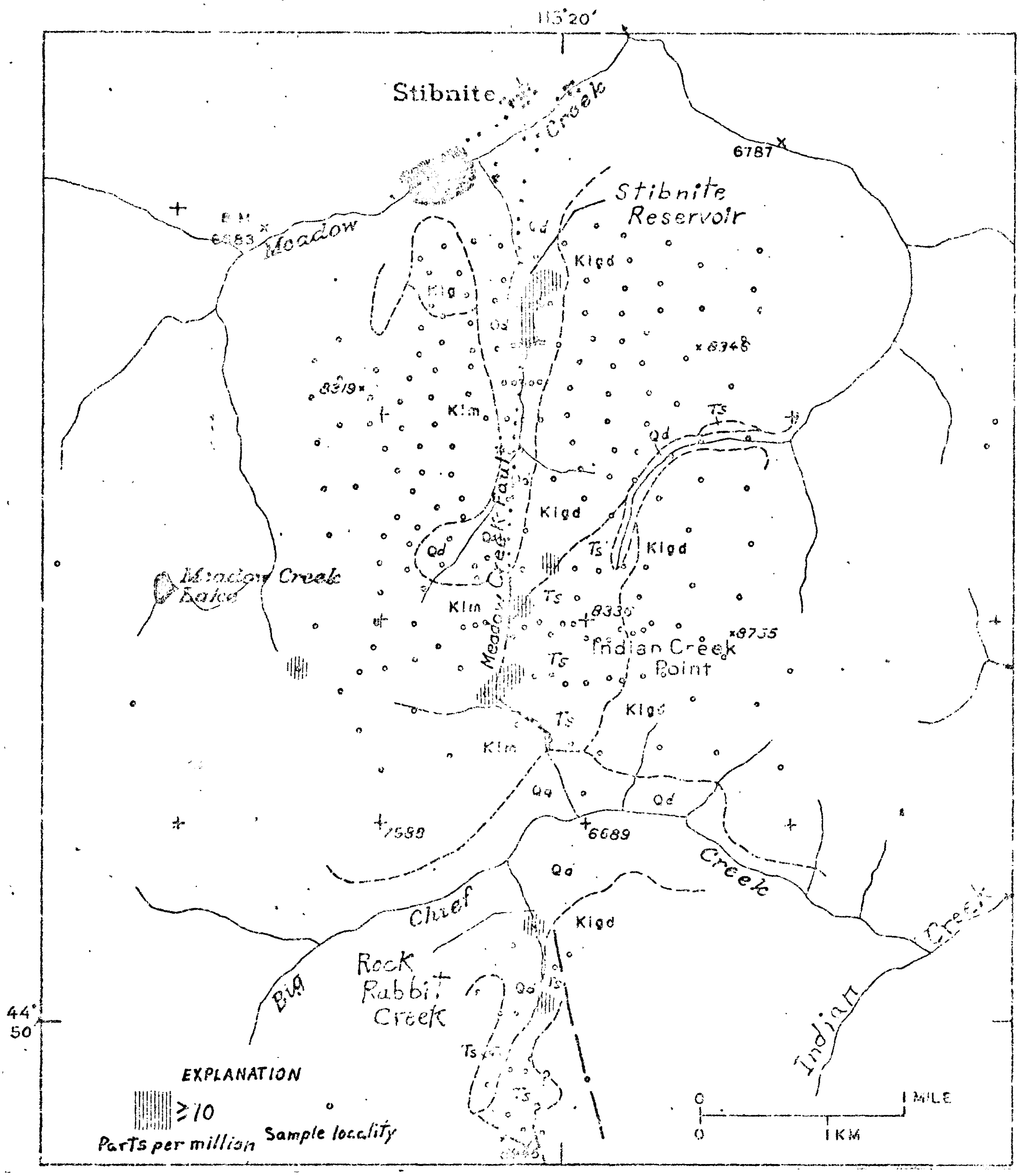

Figure 8. Geochemical map of As distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet=bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

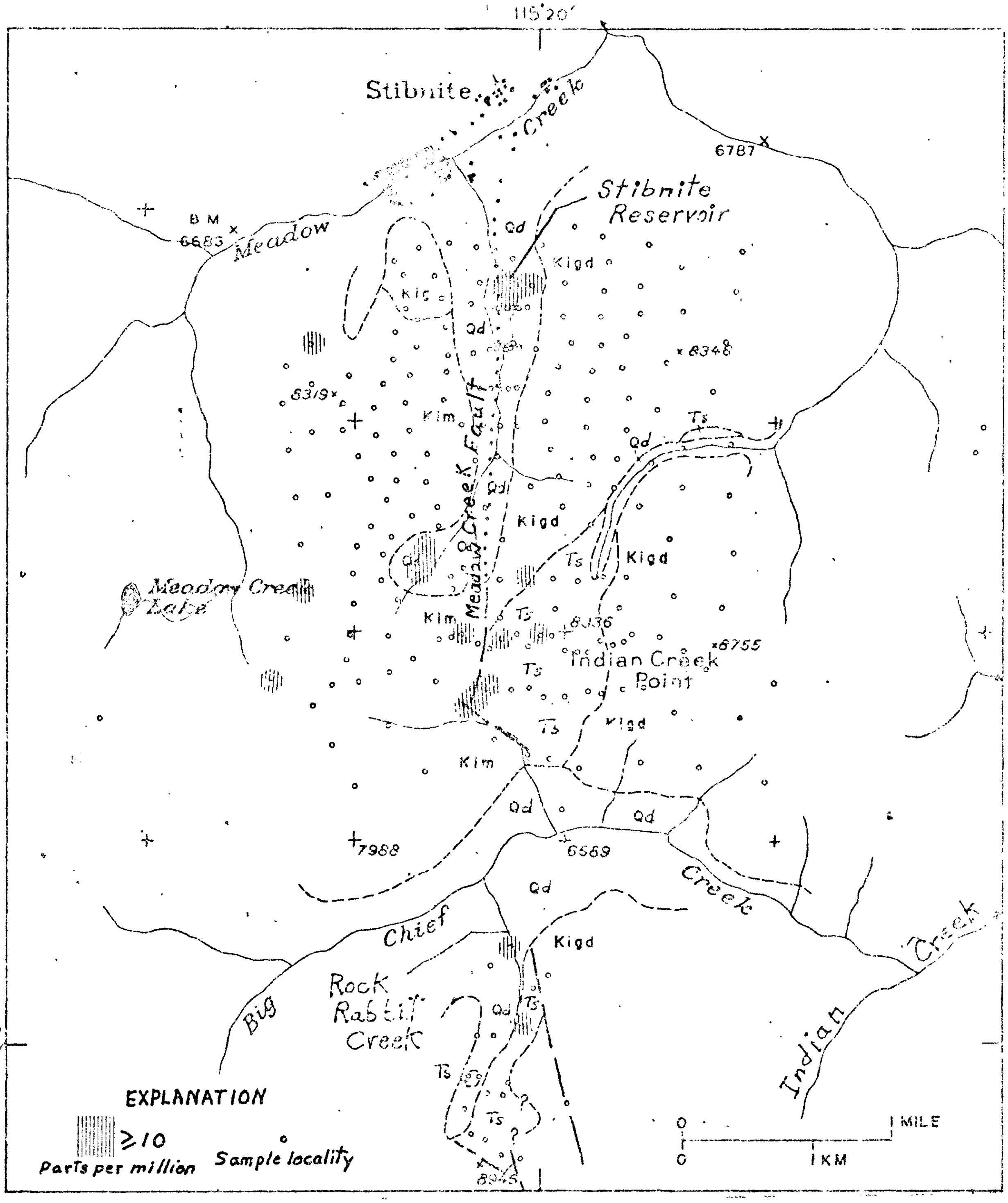

Figure 9. Geochemical map of As distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

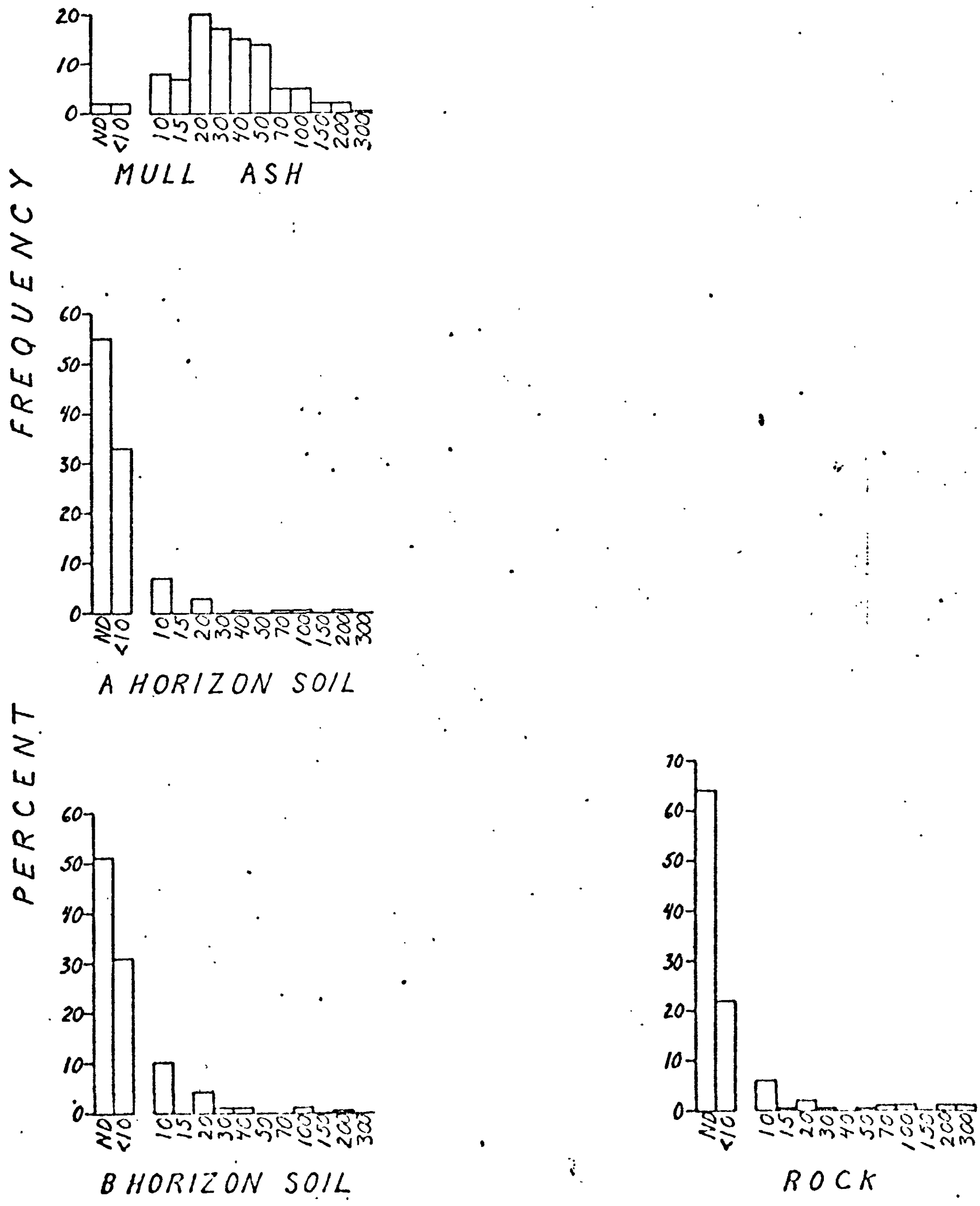

Figure 10. Histograms of As distribution in mull ash, soil, and rock. ND: Not detected at lower limit of determination for analytical method used.

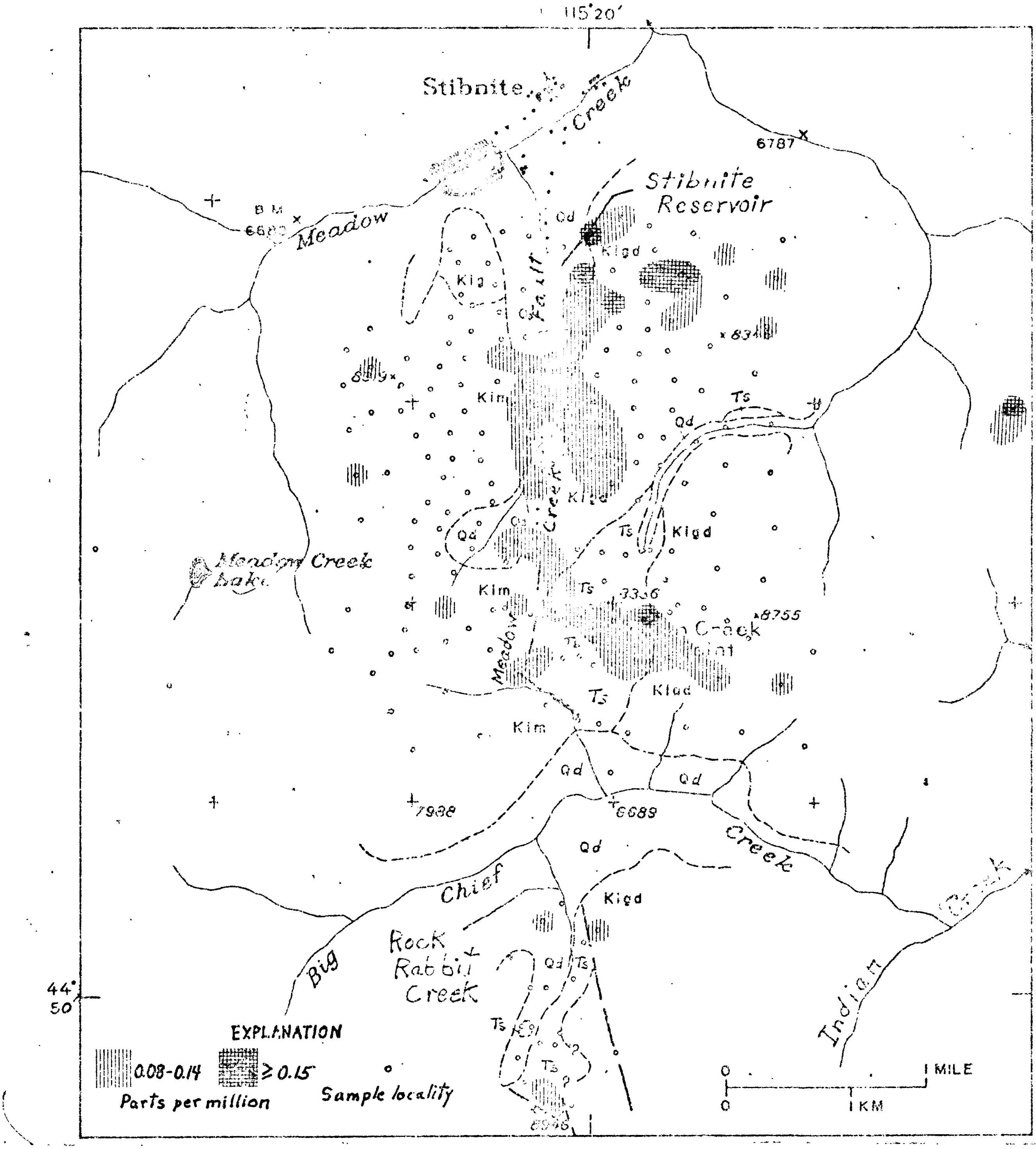

Figure 11. Geochemical map of Au distribution in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

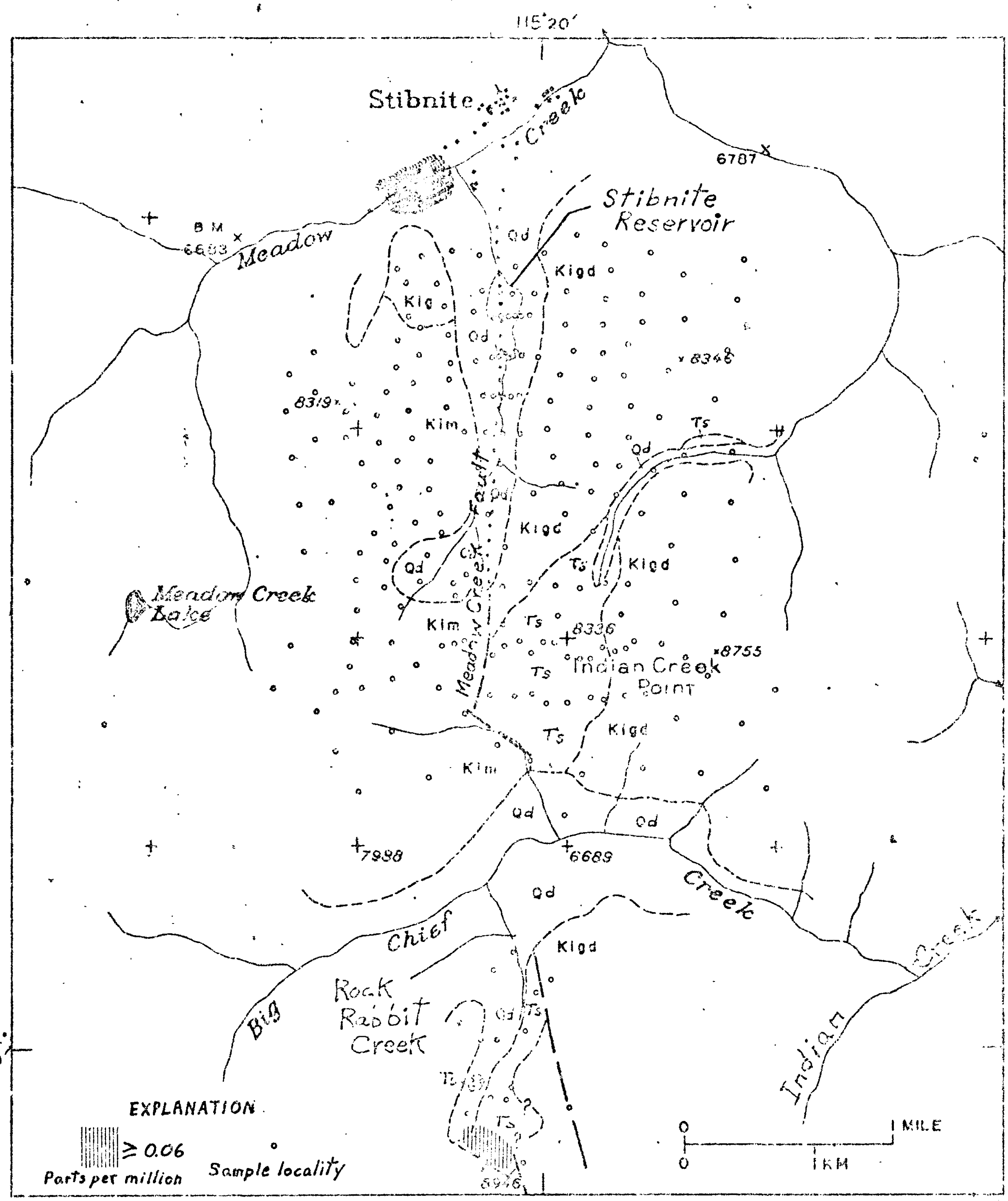

Figure 12. Geochemical map of Au distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

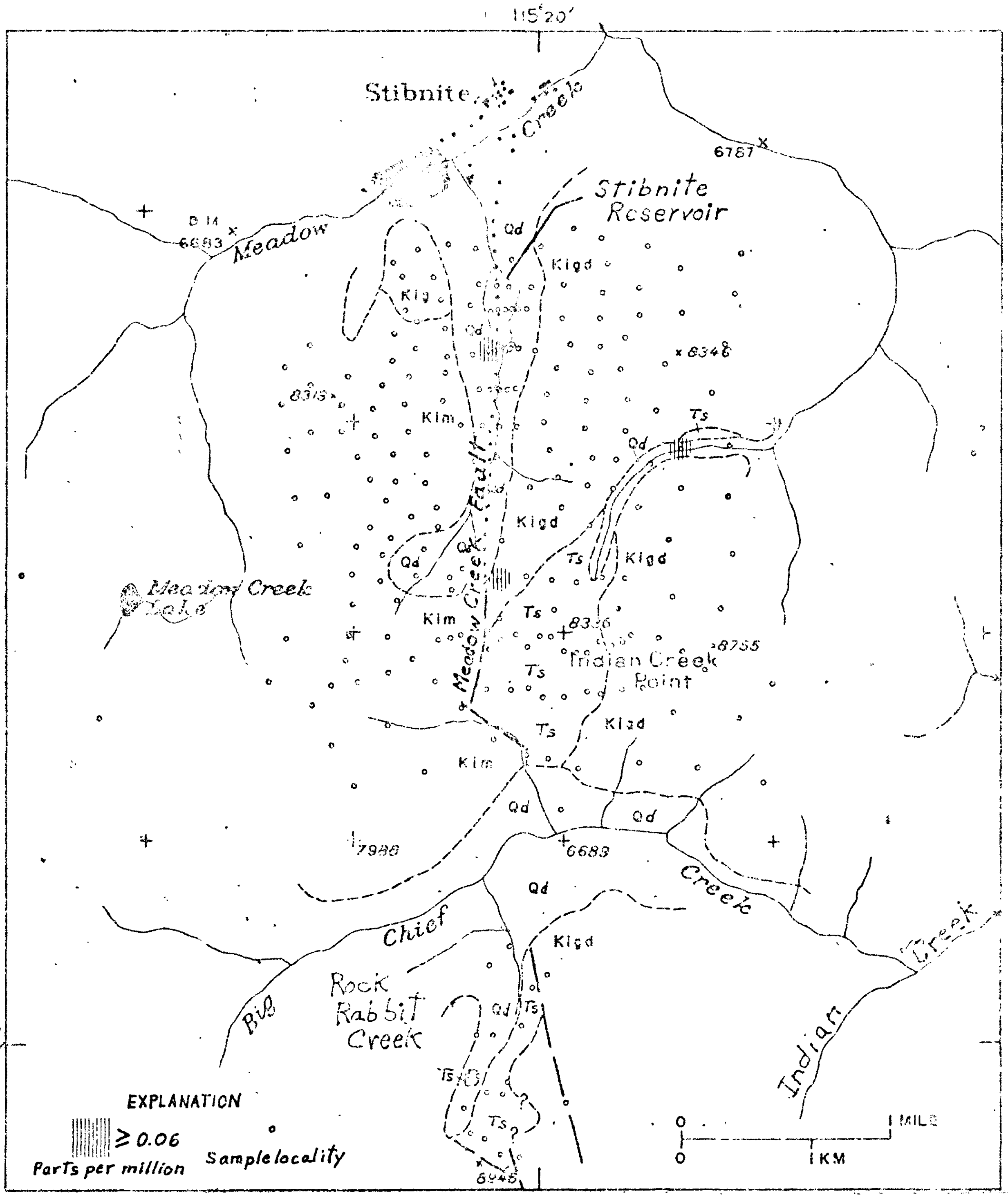

Figure 13. Geochemical map of Au distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

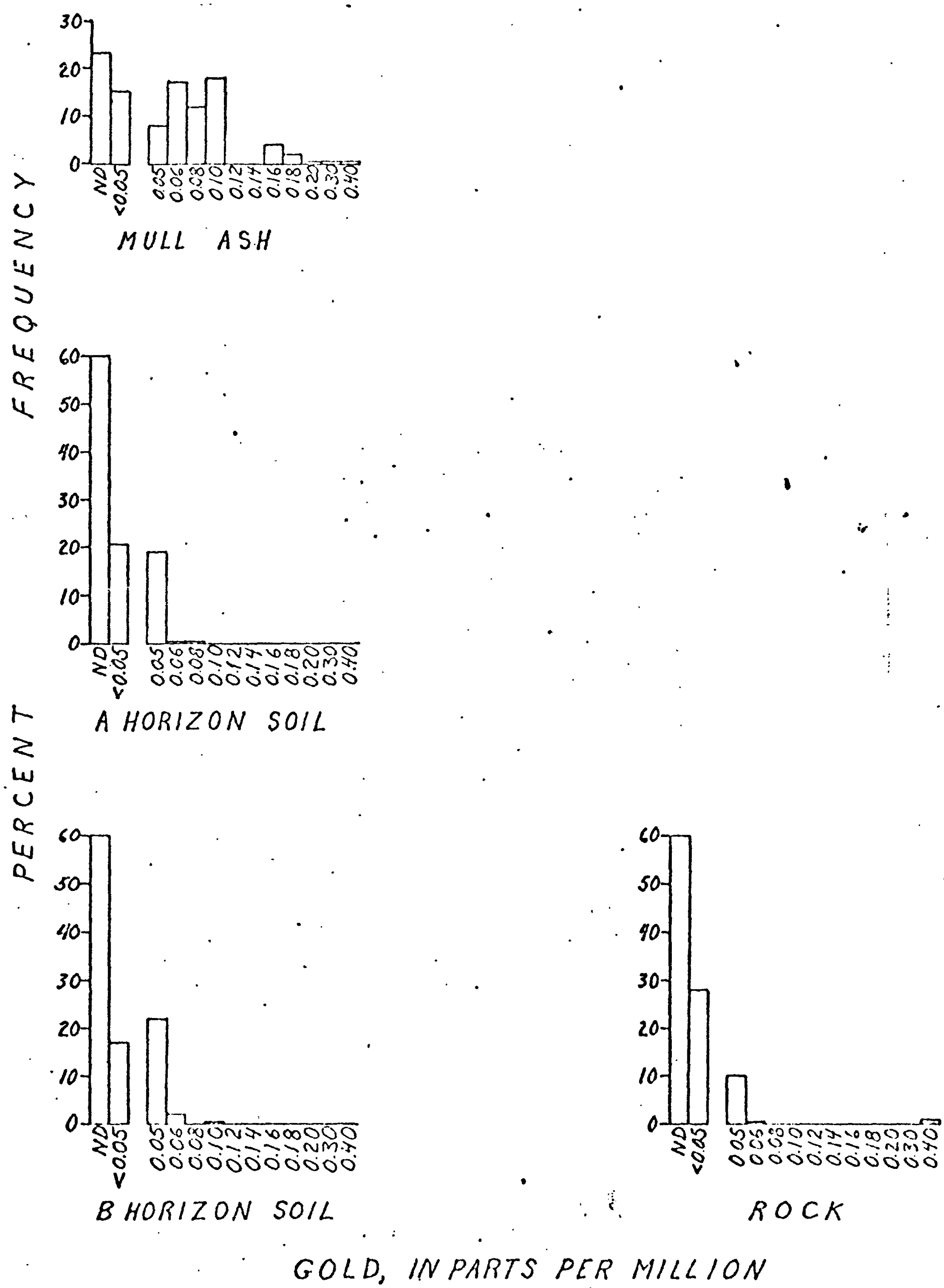

Figure 14. Histograms of Au distribution in mull ash, soil, and rock. ND: Not detected at lower limit of determination for analytical method used.

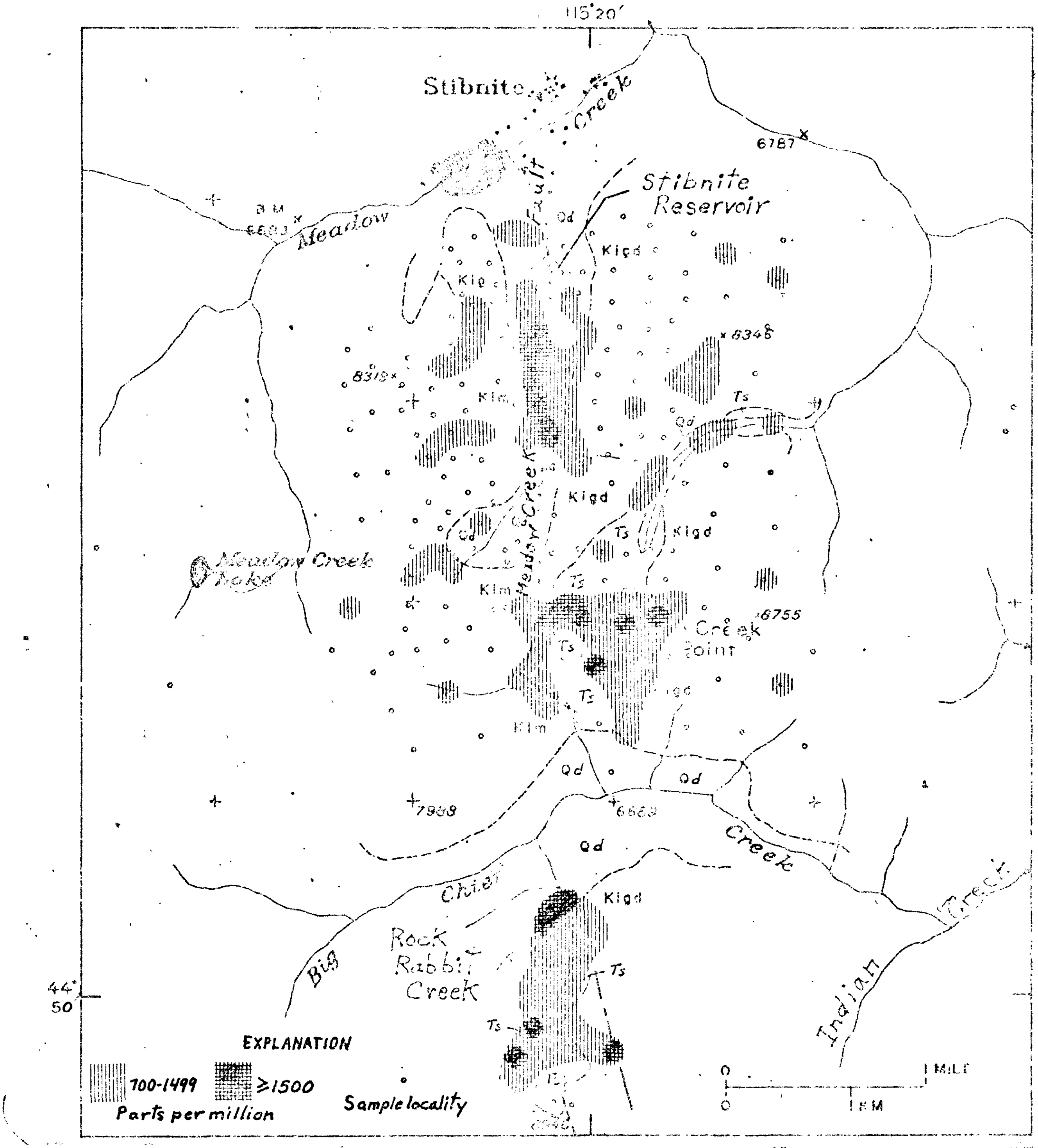

Figure 15. Geochemical map of zinc in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

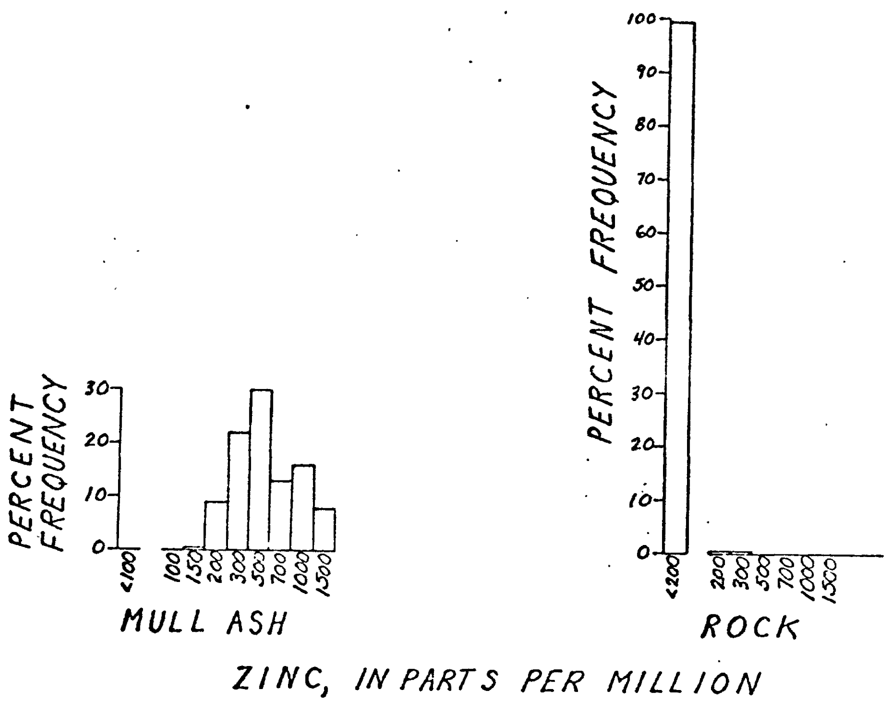

Figure 16.--Histograms of Zn distribution in mull ash and rock. Zn was not detected in soil.

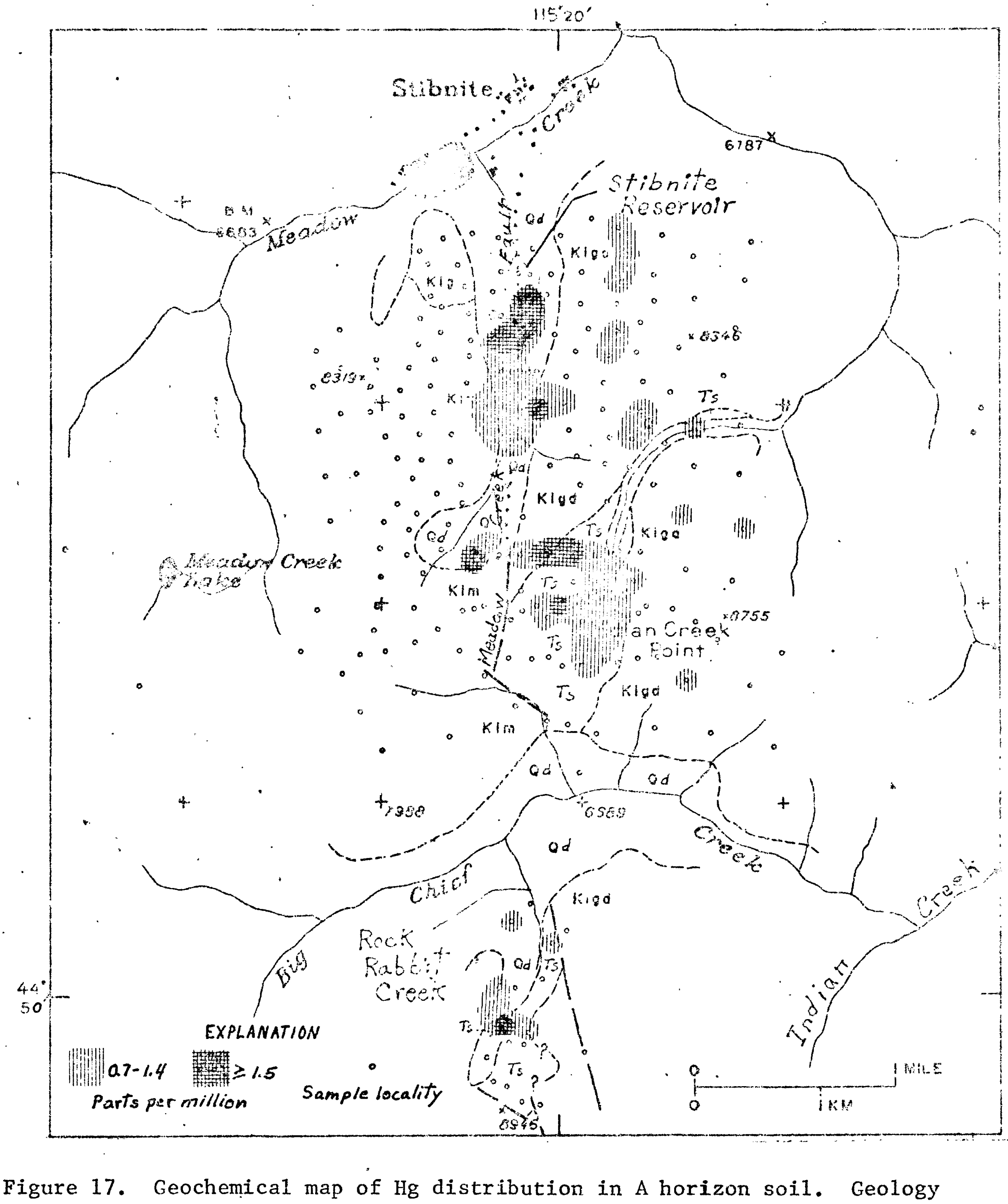

Figure 17. Geochemical map of Hg distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

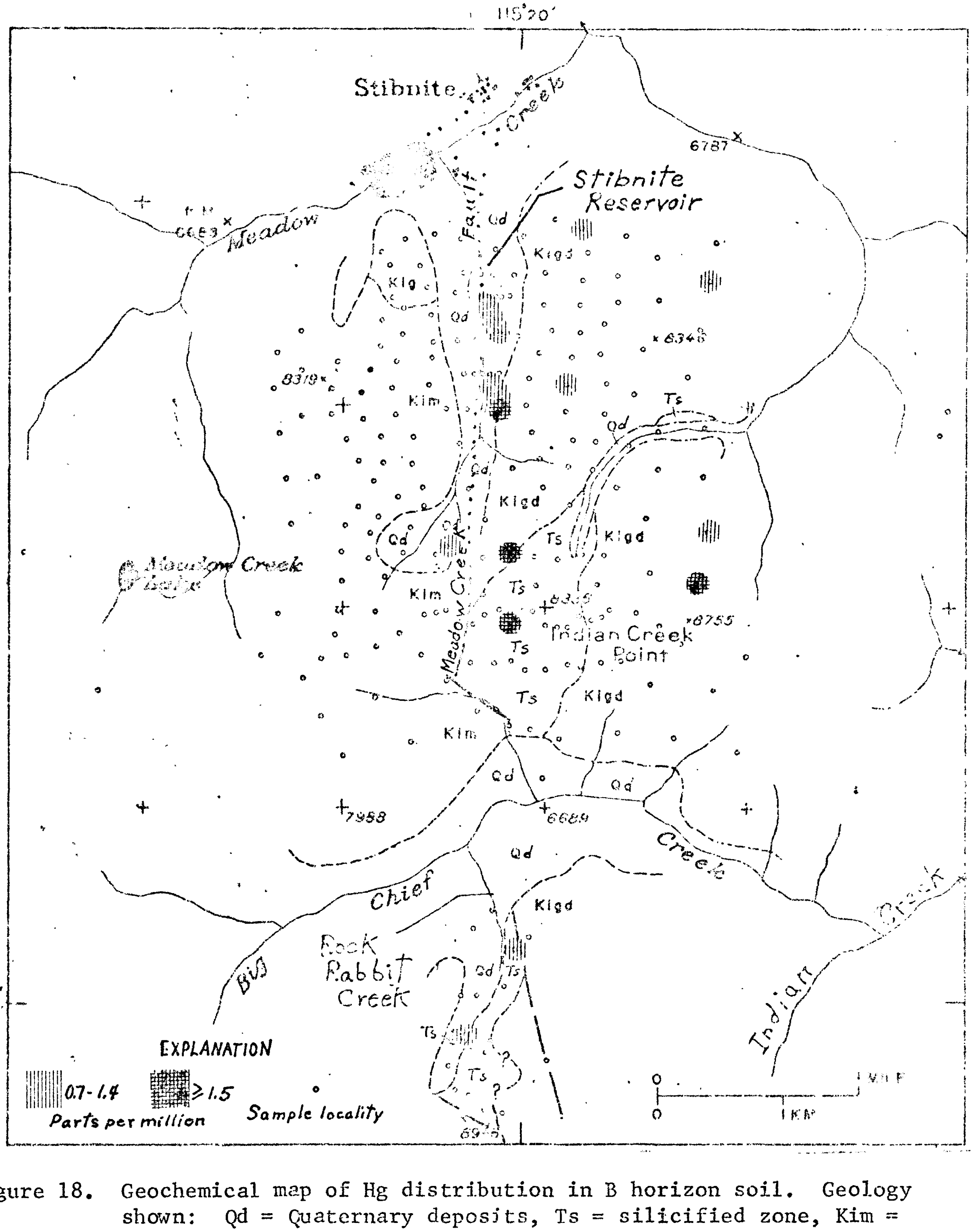

Figure 18. Geochemical map of Hg distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

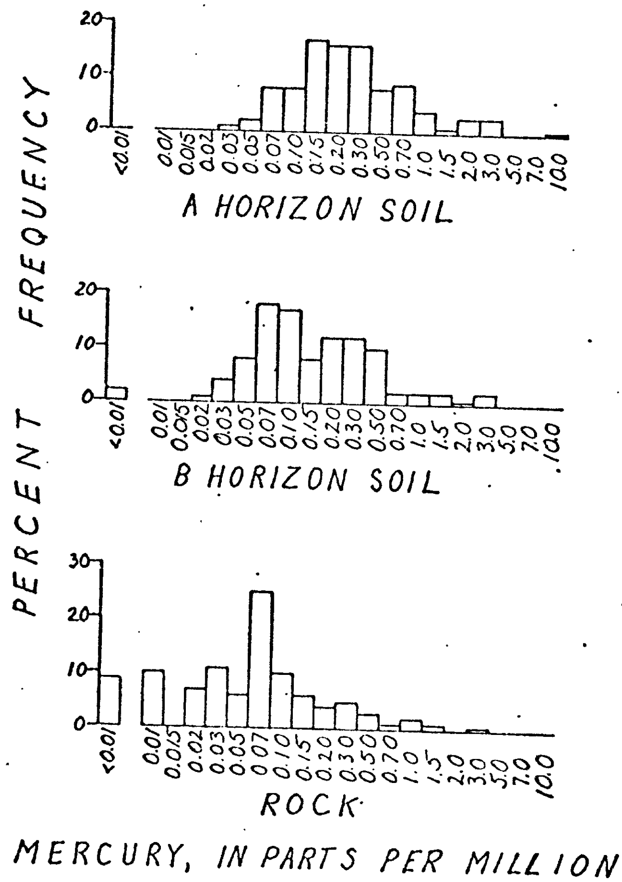

Figure 19.--Histograms of Hg distribution in soil and rock.

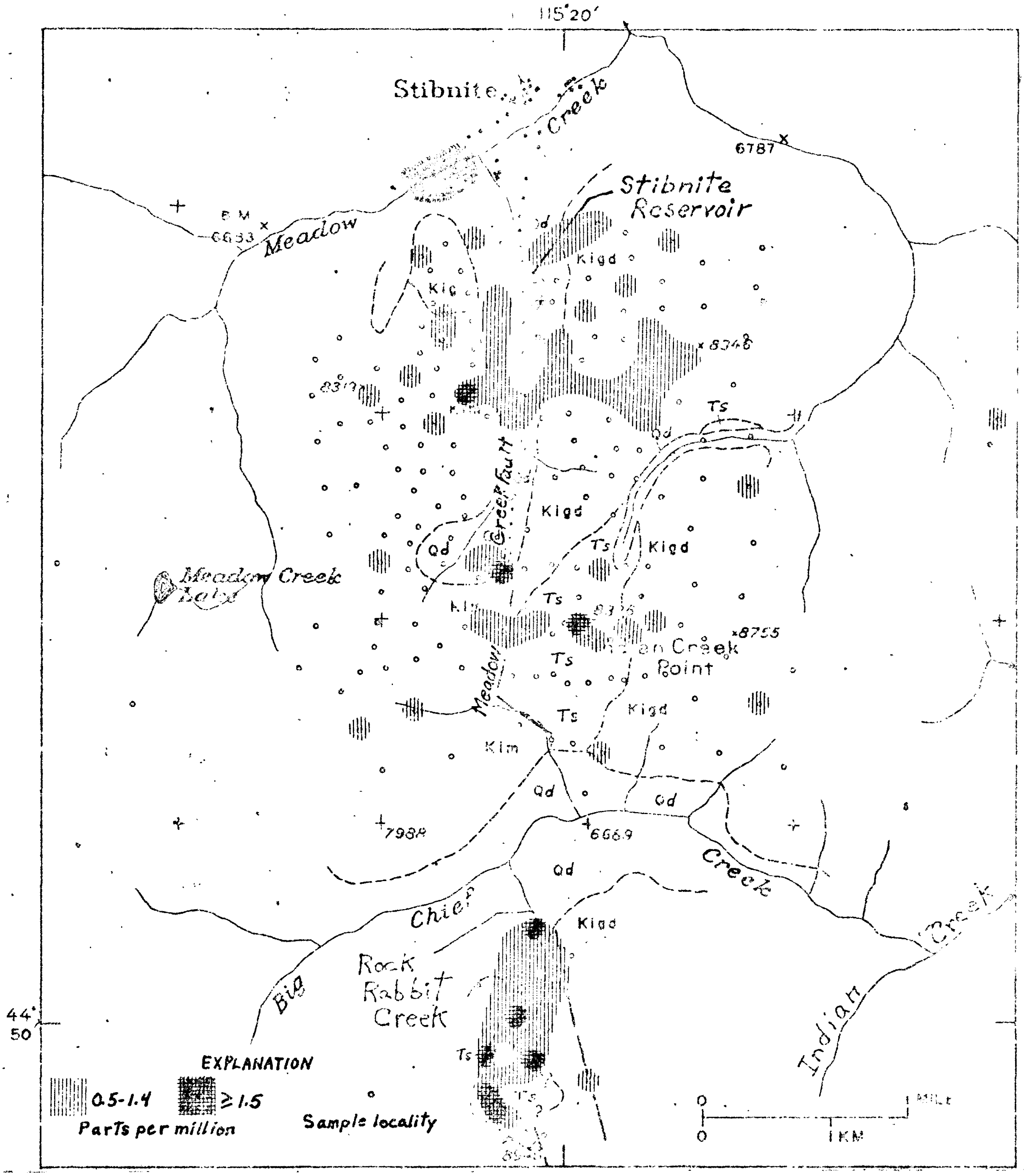

Figure 20. Geochemical map of Ag distribution in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

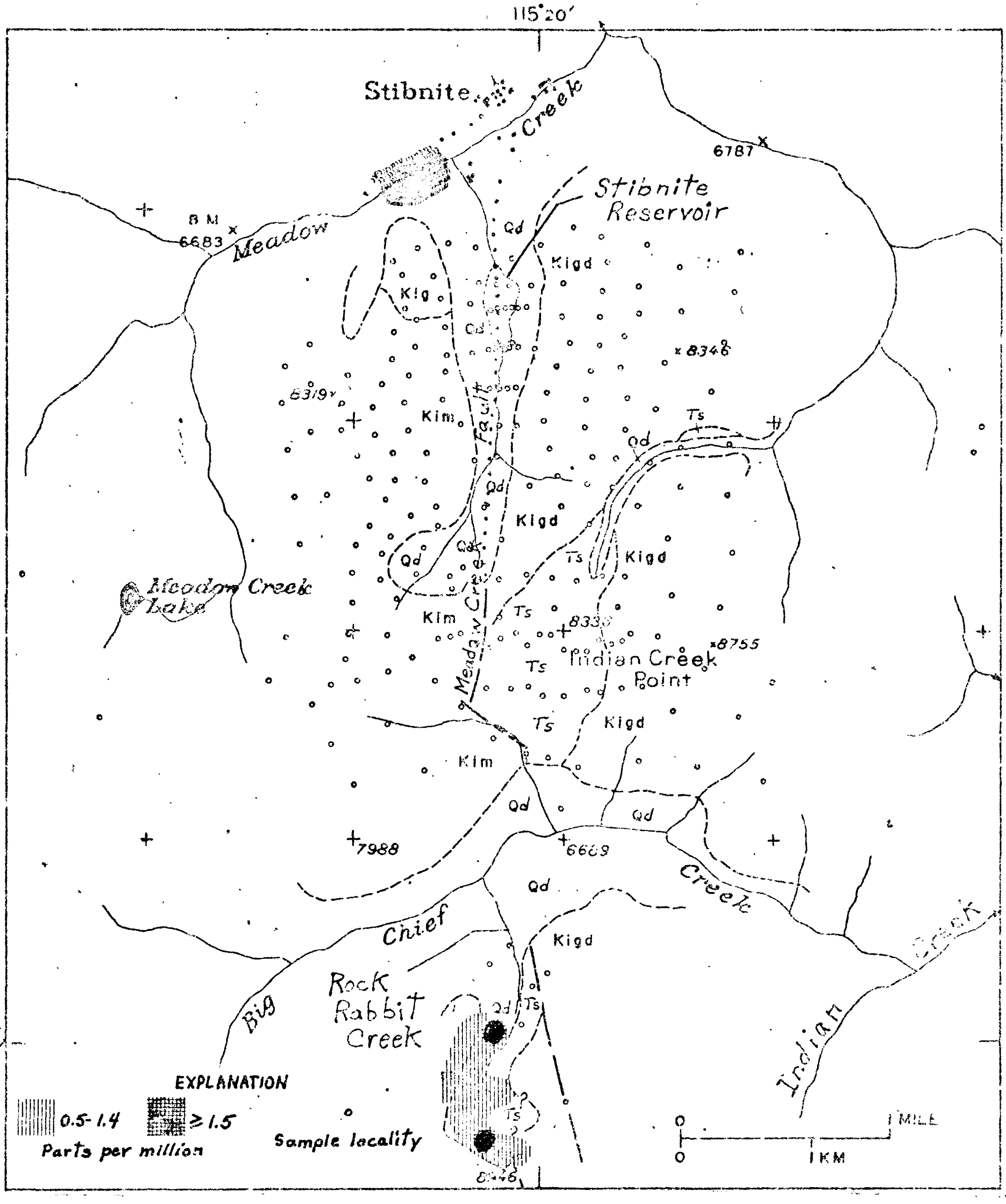

Figure 21. Geochemical map of Ag distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

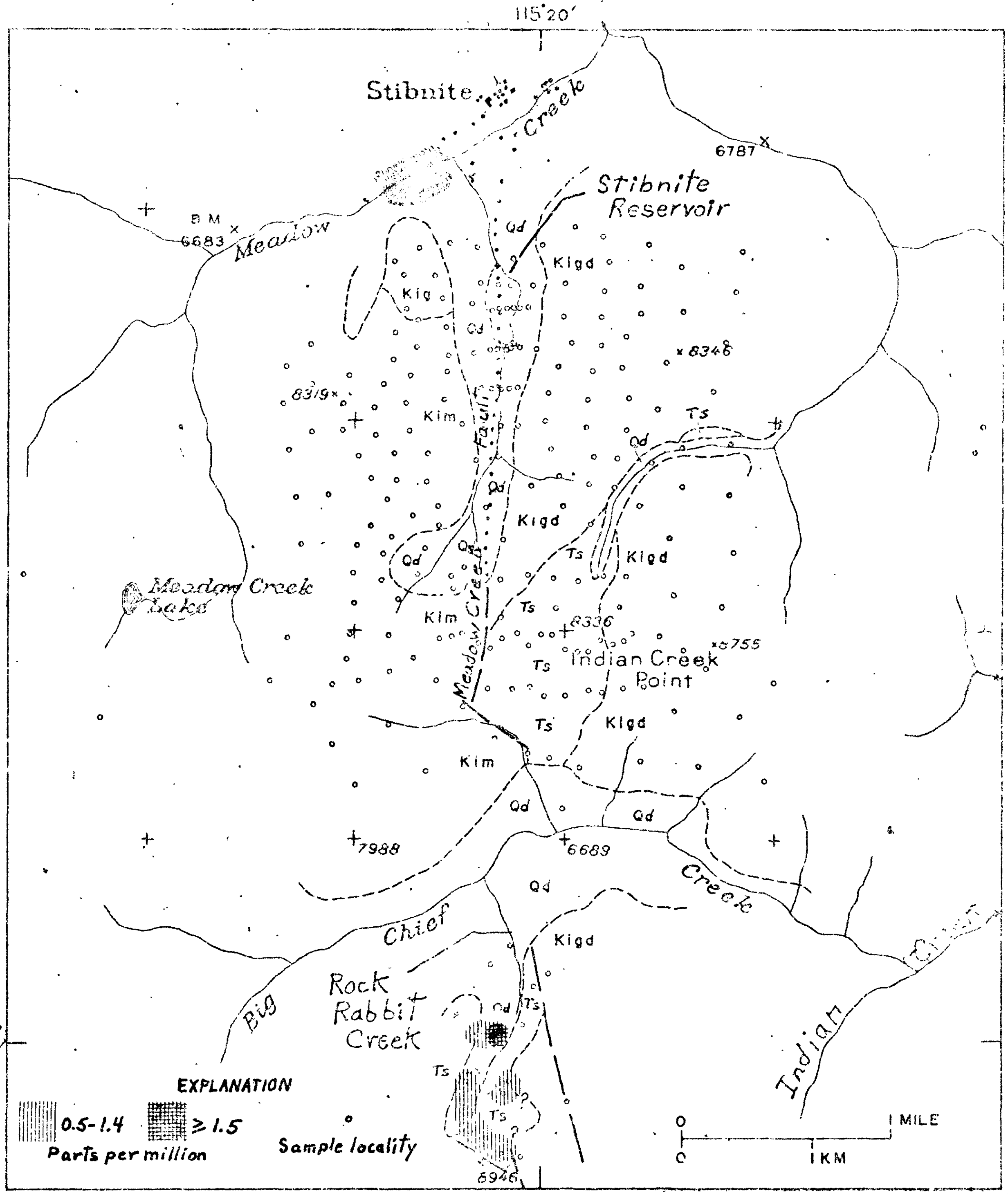

Figure 22. Geochemical map of Ag distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

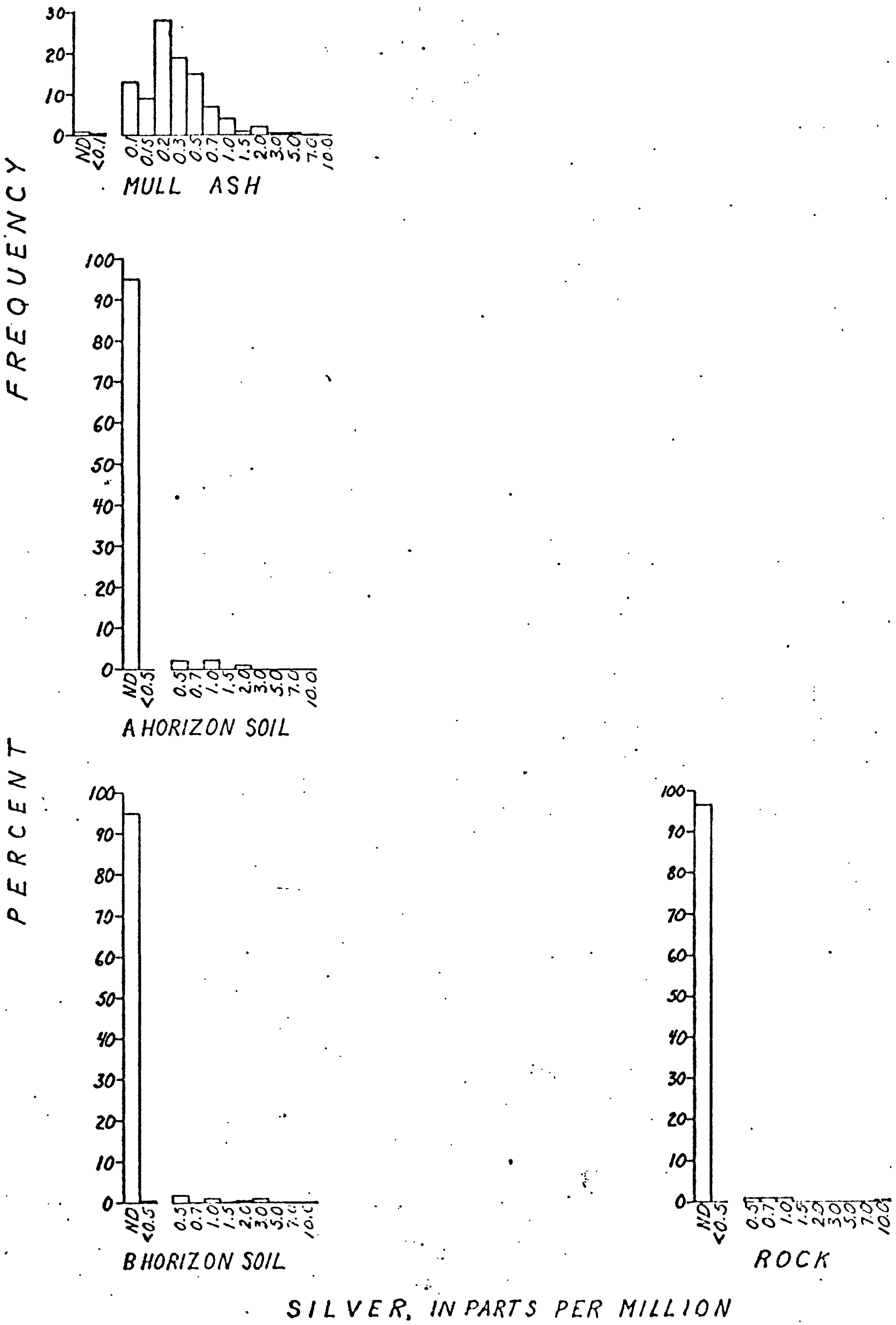

Figure 23. Histogram of Ag distribution in mull ash, soil, and rock. ND: Not detected at lower limit of determination for analytical method used.

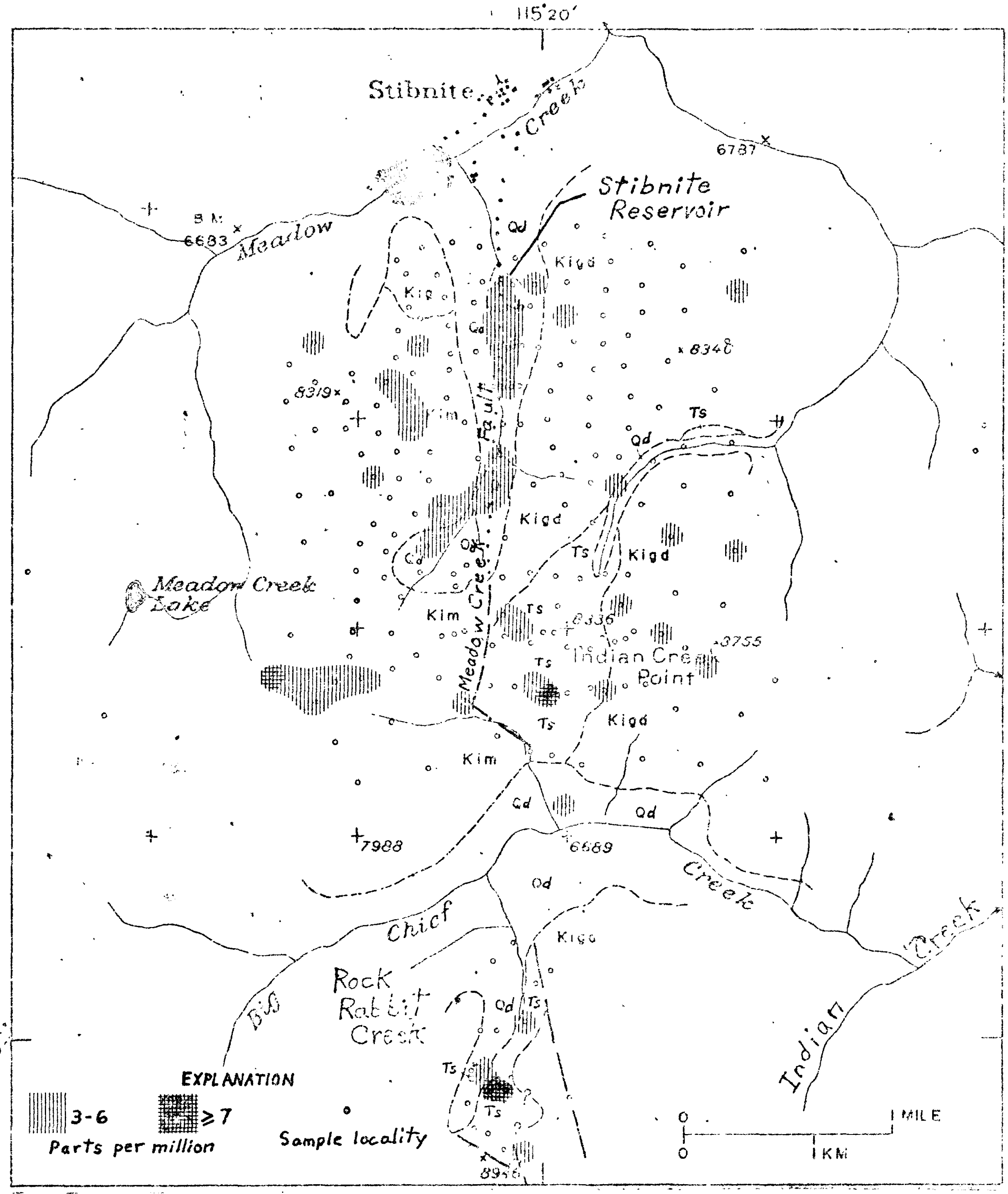

Figure 24. Geochemical map of Mo distribution in mull ash. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

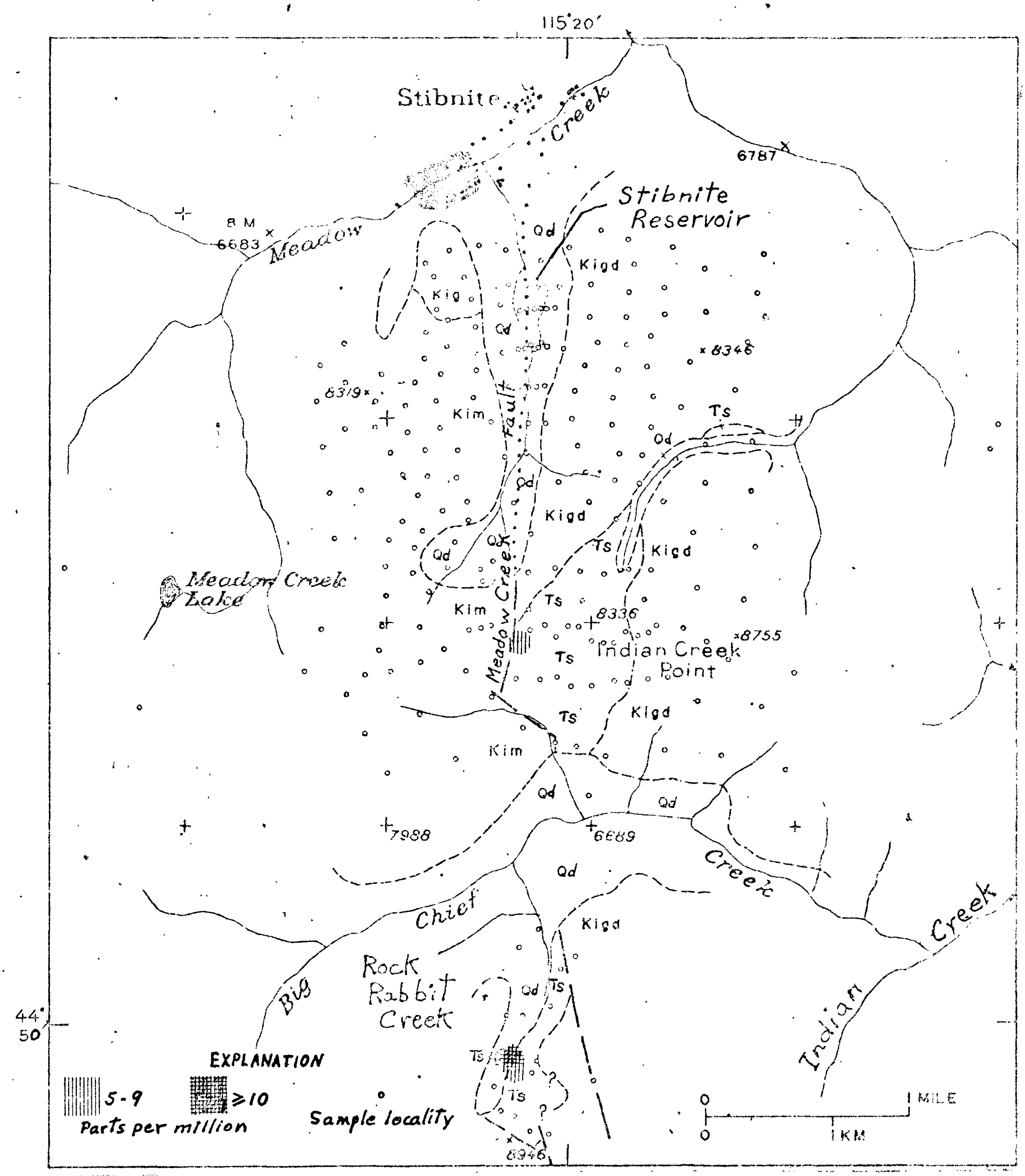

Figure 25. Geochemical map of Mo distribution in A horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

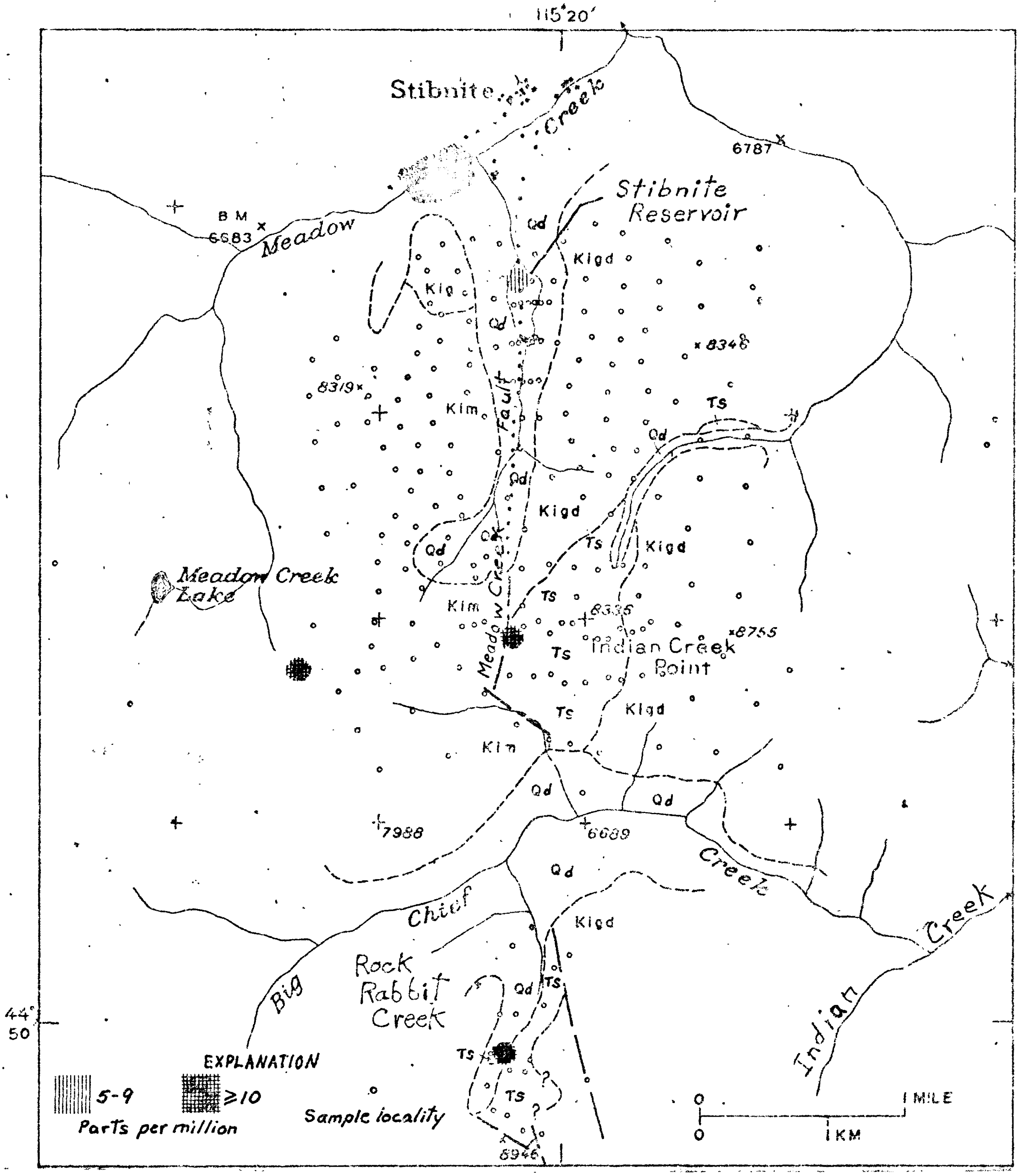

Figure 26. Geochemical map of Mo distribution in B horizon soil. Geology shown: Qd = Quaternary deposits, Ts = silicified zone, Kim = mixed alaskite and Precambrian metasedimentary and metavolcanic rocks, Kig = garnet-bearing biotite granodiorite, Kigd = biotite granodiorite. Heavy dashed and dotted lines are faults.

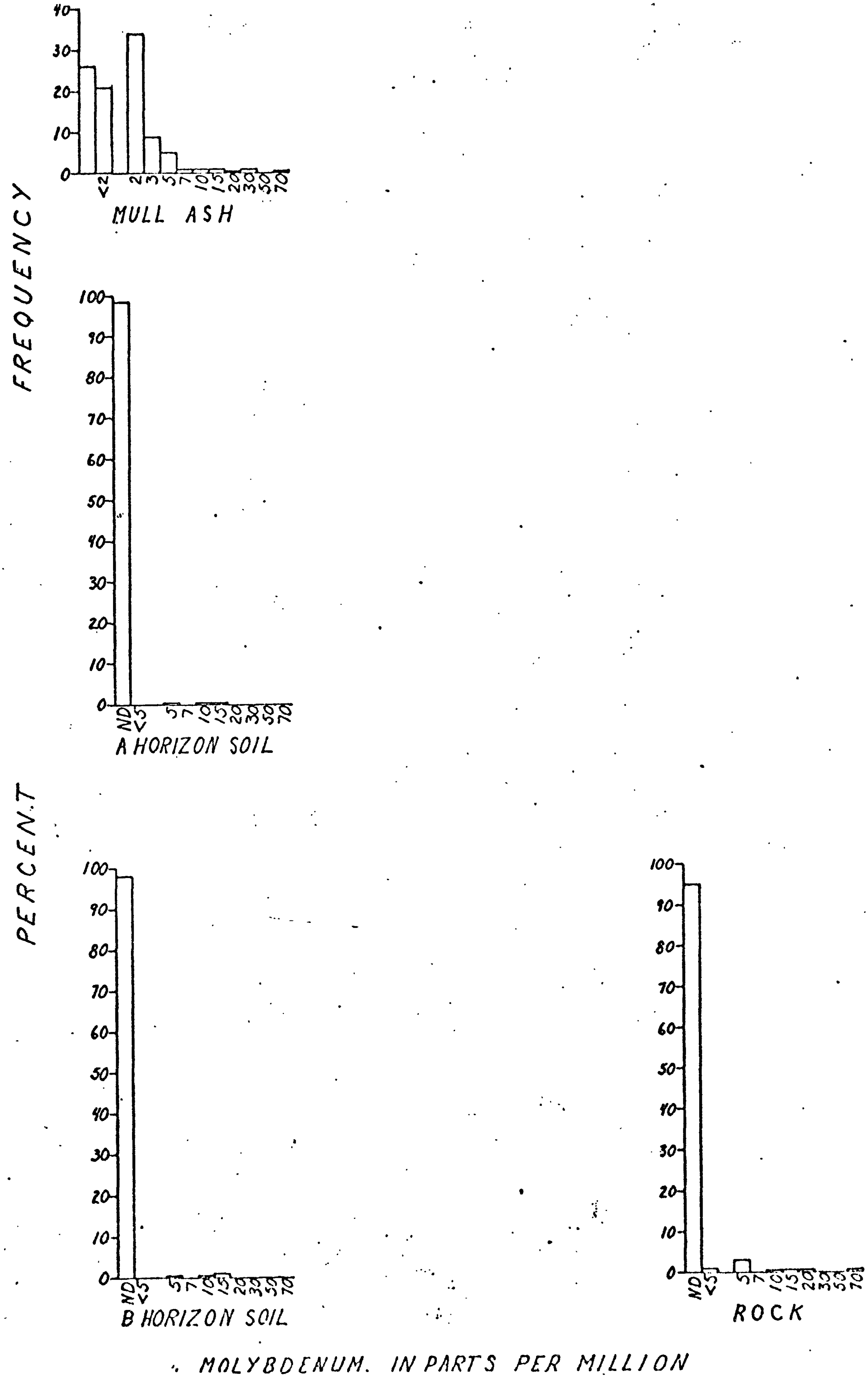

Figure 27. Histograms of Mo distribution in mull ash, soil, and rock. ND: Not detected at lower limit of determination for analytical method used.