lutions that leaked through from the footwall side of the London fault. The leakage perhaps occurred where brittle Paleozoic sedimentary rocks constitute the hanging wall and, presumably, formed less gouge than the underlying pre-Cambrian rocks. The deposit in the Sacramento mine, which is farther east on the hanging-wall side, may have had a similar origin. It seems reasonable to expect that at depth, in the "Blue limestone" or in the "porphyry zone" in the footwall of the London fault, there are more extensive deposits than in the hanging wall, but there is no way of predicting whether the deposits are gold ores or silver-lead ores.

Lower Loveland Mountain Center

Limits of ore.—The group of ore deposits including the Hock Hocking, Brownlow, Orphan Boy, Shelby, Phillips, Paris, Excelsior, Great West, and other mines and possibly including the deposits at Mineral Park appear to constitute an elongated mineralized area whose center is under Loveland Mountain, west of Park City. The belt has a northerly trend. Its western boundary is the upper, easternmost branch of the Cooper Gulch fault. The silver-lead deposits of the Hock Hocking mine and of the numerous small workings south of the Brownlow mine are of a marginal type and therefore must be close to the southern limit of notable mineralization. The northern limit must be not far north of the Great West mine. The eastern limit is somewhat indefinite because the productive zones are covered by the Weber (?) formation or by glacial till; however, the mineralogy of the small silver-lead deposits on the Red Cross claims and at the Mosquito Gulch mine, both of which are of the marginal type, suggest that the boundary is not much farther east. In the central part of this belt the deposits are valuable chiefly for gold, but toward the north, east, and south gold decreases in relative amount and silver and lead increase.

Structural control.—The major structural feature of the belt is the Cooper Gulch fault, a reverse fault dipping at a low angle toward the east. The belt is associated with the

upper, easternmost branch of the fault and is located where the branch dies out. The distribution of the deposits, which extend several thousand feet away from the hanging wall of the fault, is in marked contrast to that of the deposits that are close to the footwall of the London fault. This difference is probably due to the small amount of gouge on the Cooper Gulch fault, which permitted the solutions to escape readily into fissures in the hanging wall.

Although the location of the belt as a whole has been determined by the Cooper Gulch fault, individual ore bodies within the belt are localized along minor faults, whose prevailing trend is northeast. Their displacement is small, the maximum throw being 50 feet, and many of them have a larger displacement at the base of the Sawatch quartzite than at higher horizons. All of them die out within short distances, both horizontally and vertically. The ore bodies occur at favorable horizons as replacement deposits in and outward from these fissures.

Stratigraphic control.—The Sawatch quartzite is present throughout most of the belt, and it has been the most productive zone. The ore, which is valuable at least in part for gold, occurs in certain beds in the middle and upper part of the quartzites, probably in those beds that have a calcareous cement. Even where, as in the Orphan Boy mine, the ore occurs beneath a porphyry sill, the composition of the rocks must have been the main factor in localizing it, for sills higher and lower in the formation have no ore shoots under them. Veins that are narrow and unproductive in unfavorable beds open out as replacement deposits where they cut the favorable beds, and form ore shoots that extend several feet from the fissure. As many of the deposits are highly oxidized, the exact mineral composition of the primary ore is not known. Pyrite was abundant, however, and dark sphalerite, galena, and chalcopyrite occurred in varying proportions, both in different veins and in different parts of the same vein. Dolomite containing small quantities of iron and manganese was the most abundant gangue constituent al-

though a considerable quantity of quartz was also present. All of the production has been obtained from ore that was at least partly oxidized and doubtless enriched, and it is questionable, therefore, whether much of the primary ore could have been mined profitably. The highly oxidized ore consists of a spongy mass of quartz and limonite with small quantities of the carbonates of copper, lead, and zinc. Gold in the oxidized ore is metallic gold and so could be simply and cheaply extracted.

The "Blue limestone" is eroded from most of the central portion of the belt. It crops out along the north, south, and east margins, but its most favorable part, close to the top, is uneroded only along the eastern margin. The ore at this horizon is valuable chiefly for silver and lead and has a mineral composition very similar to that of the ore of the Russia mine. The production has been small except from the Hock Hocking mine, where the ore occurs mainly as replacement veins extending from the middle part of the "White limestone" to the top of the "Blue limestone."

Thick porphyry sills occur in the basal part of the Weber (?) formation, but they have yielded no ore, probably because the structural conditions are different from those at London Mountain.

Possible undiscovered ore bodies.—Gold deposits comparable in size and value to those already discovered in the middle and upper part of the Sawatch quartzite are likely to be found within the limits of known gold production. The most favorable localities are the lower slopes of Loveland Mountain and the lower slopes of Mount Bross for a short distance north of Buckskin Gulch. Neither of these slopes has been glaciated, and any deposits under them are probably at least partly oxidized. Prospecting should be directed along minor faults at the proper stratigraphic position.

There is reasonable hope that silver-lead deposits may be found along the eastern margin of the belt at places where the "Blue limestone" is covered by the Weber (?) formation or by glacial till. For nearly a mile northeast of the Hock

Hocking mine the upper part of the "Blue limestone" is not exposed and has been almost untouched by prospecting. This area seems the most promising territory, but the area south and for a short distance west of the Hock Hocking mine and the area extending a short distance west of the outcrop of the contact between "Blue limestone" and Weber (?) formation are also worthy of consideration, although the size of the known silver-lead deposits in this belt does not encourage expensive prospecting to locate new ore bodies. The porphyry sills close to the base of the Weber (?) formation do not seem to be favorable zones in which to prospect within this belt.

North Star Mountain Center

At North Star Mountain some gold production has come from deposits in the Sawatch quartzite and from fissures in the pre-Cambrian schists. The fissures in the schist strike north, approximately with the schistosity, whereas those in the overlying quartzite strike east of north. The occurrence of ore in the quartzites is essentially the same as in the lower Loveland Mountain belt, except that at North Star Mountain the deposits contain some magnetite, specularite, and pyrrhotite, which indicate deposits formed at a somewhat higher temperature.

The Sawatch quartzite on North Star Mountain is confined to a narrow ridge. It is well exposed on the cliffs, but on part of the ridge it is covered by the "White limestone." The prominent veins have been prospected, but some undeveloped parts of them doubtless contain undiscovered ore, although there is no reason to expect the discovery of larger or richer deposits than those already found.

Mount Lincoln-Mount Bross Area

In value of past production the Mount Lincoln-Mount Bross area is of the same order of importance as the London Mountain area, but its output has been mainly silver-lead ore, whereas that from London Mountain has been mainly gold ore. Much of the ore was of high grade, that from the Russia and Moose mines probably averaging nearly 100 ounces in silver to the ton.

The relations of this area to a center of mineralization are less definite than those of the areas already described, but the center may be in the Buckskin Gulch stock, which, if its axis of elongation were prolonged to the northeast, would extend under the western slope of Mount Bross. Around the stock the zones favorable for mineralization have been eroded for a considerable distance except in the direction of Mount Bross and Mount Lincoln; but there are some unimportant magnetite deposits near the stock, and the silver-lead deposits of Mount Bross and Mount Lincoln are so located as to be referable to the stock as a center.

Structural control.—The major structural feature that seems to have localized most of the ore is the terrace described on page 106, which extends nearly northward from a point just east of the Dolly Varden mine. The eastern slope of the terrace is narrow at the Dolly Varden mine but widens toward the north. The largest mines are located where northwesterly structural features cross the terrace: the Russia and other mines on Mount Lincoln are on the north flank of a gentle anticline that extends approximately S. 35° E. from the saddle between Mount Lincoln and Mount Cameron, and the Moose mine is on the south flank of the same anticline; the Dolly Varden mine, on the other hand, is located where a relatively large minor fault crosses the terrace.

As elsewhere in the district, although these larger structural features have localized the mineralized area as a whole, individual ore bodies within the area were localized by minor faults. It is of interest that the prevailing trend of the minor faults and fissures in the vicinity of the Russia mine is northwesterly, nearly at right angles to their prevailing trend throughout most of the district.

Stratigraphic control.—On parts of both Mount Lincoln and Mount Bross, as shown in Figure 2, the sedimentary rocks from the Sawatch quartzite to the lower part of the Weber (?) formation occur, and all the favorable zones are present. Nearly all the production, however, has come from the upper part (Leadville) of the "Blue limestone," and no important

mines have been developed in either the Sawatch quartzite or the "White limestone," although these formations have been considerably prospected where they crop out on the cliffs around the mountains. The "Blue limestone," therefore, must be regarded as the most favorable zone, although some mineralization may have occurred at other horizons.

The only accessible mine in the area was the Russia, which was described in a previous paper.[17] Except for one vein, the Russia ore bodies were replacement deposits localized in shattered areas adjoining minor faults and fissures that strike northwest. The ore bodies along the larger faults extend up the dip from the faults. The ore zone as a whole, however, trends northeast, nearly at right angles to the individual shoots. An iron-bearing dolomite is the most abundant original gangue mineral, but it is accompanied by considerable amounts of barite and a little quartz. Galena and sphalerite that is moderately low in iron are abundant; pyrite is moderately abundant; and chalcopyrite, tetrahedrite, and freibergite occur in small amounts. The silver content is rather high, but the gold content is insignificant. Freibergite seems to account for most of the silver in the high-grade ore. The deposits have undergone considerable oxidation and have probably been enriched to some extent, both in the oxidized zone and in the upper part of the sulphide zone.

The map of the Moose mine workings[18] suggests the presence of an eastward-trending ore zone in which the local ore shoots formed along northeastward trending fissures. Specimens from the dump indicate that the mineralization was essentially the same as at the Russia mine.

Almost nothing is known regarding the other mines in the area. Those in the "Blue limestone" probably were similar to the Russia, although the ore in the Treweeck mine is reported to have had a higher gold content than the others. A little gold ore has been produced from the Sawatch quartz-

[17] Singewald, Q. D., and Butler, B. S., Preliminary report on the geology of Mount Lincoln and the Russia mine, Park County, Colo.: Colorado Sci. Soc. Proc., vol. 12, no. 12, pp. 389-406, 1931.

[18] Patton, H. B., Hoskin, A. J., and Butler, G. M., Geology and ore deposits of the Alma district, Colo.: Colorado Geol. Survey Bull. 3, pl. 21, 1912.

ite in the lower slope of Mount Lincoln, near the St. Louis dike.

Possible undiscovered ore bodies.—Experience indicates that the silver-lead replacement deposits in the "Blue limestone" are by far the most promising objectives of search in the Mount Lincoln-Mount Bross area. The most favorable part of Mount Bross, immediately west of the eastern boundary of the structural terrace, has been extensively prospected, but there is in that vicinity a considerable area covered by the Weber (?) formation and porphyry sills (see fig. 2), beneath which the "Blue limestone" has not been prospected. In this area, especially west of the Dolly Varden and Moose mines, there may be small ore bodies of the same grade as those already discovered, but still farther west, where the "Blue limestone" crops out on the west slope of Mount Bross, no important ore bodies have been discovered. On Mount Lincoln there is much less unexposed "Blue limestone" than on Mount Bross, but there is nevertheless a considerable area covered by the Weber (?) formation or porphyry (see fig. 2), beneath which the "Blue limestone" has not been prospected and is likely to contain ore bodies. A larger portion of the Mount Bross-Mount Lincoln area is underlain by the Sawatch quartzite than by the "Blue limestone," but the results of prospecting along the outcrop of the quartzites do not lend strong encouragement to expensive prospecting of that formation where it is covered.

Veins in the pre-Cambrian Rocks

Mineralized fissures are abundant in the pre-Cambrian rocks wherever they are exposed in the belt extending from Leadville to North Star Mountain, but extensive prospecting of them has resulted in only a few mines. Among those that have been productive are the Champaign and Coney mines, in Mosquito Gulch; the Kentucky Belle and Sweet Home mines, in Buckskin Gulch; and the Ling and Wheeler mines, in Platte Gulch. Of these, the Champaign was most productive. As exposures are good in most of the pre-Cambrian areas, it is pretty certain that the most promising veins have been dis-

covered, and although undiscovered deposits of value may still be present, the chances of finding and exploiting them profitably are less than for any of the other types of deposits.

Other Possible Centers of Mineralization

It is very unlikely that undiscovered centers of mineralization exist anywhere in the northern and western parts of the Alma district, but it is possible that undiscovered centers of mineralization may exist in the southeastern part, where the zones favorable to ore deposition are concealed beneath the Weber (?) formation and porphyry sills, which are not productive anywhere in the Mosquito Range. From Windy Ridge to Buckskin Gulch the largest body of porphyry in the eastern part of the district is exposed. West of this porphyry the sedimentary rocks have their regional dip to the east, but east of it the Weber (?) formation dips to the southwest. The projection of the beds across the porphyry indicates that a fault with downthrow to the east is within the area covered by the porphyry. It seems probable that the molten material that formed the porphyry rose along the fault, which now should be occupied by a dike; but there is no exposure to show either the fault or the dike. If such a structural relationship exists, it is possible that the fault zone was also a channel for ore solutions that formed deposits in the upper part of the "Blue limestone" or at the lower horizons and that the deposits are concealed by the Weber (?) formation. The only known deposits that may be associated with mineralization in this area are those of the galena-barite type at Mineral Park, but these may be marginal to any one of three mineralized areas. There is, therefore, no direct evidence of mineralization associated with the Windy Ridge fault, and any prospecting along it would be more speculative than at any other possible locality in the district.

Appendix

Sections of the London Mine

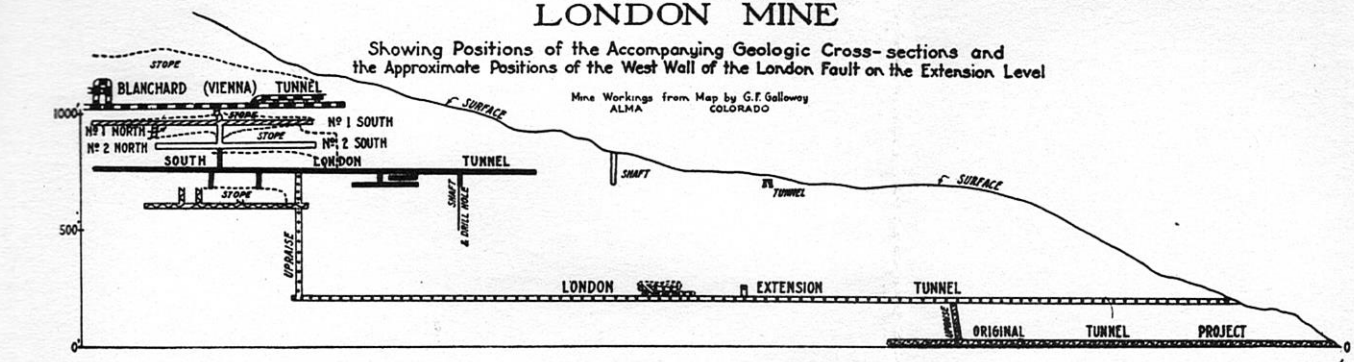
Appended to this paper are seven cross sections of the London mine and one longitudinal section with plan showing

their positions. These are presented so as to be available as early as possible for those interested in the structural details of the most productive mine in the Alma district. The text on pages 116-121 furnishes a general basis for their study.

MAP OF
PART OF THE
LONDON MINE

Showing Positions of the Accompanying Geologic Cross-sections and the Approximate Positions of the West Wall of the London Fault on the Extension Level

Mine Workings from Map by G.F. Galloway
ALMA COLORADO



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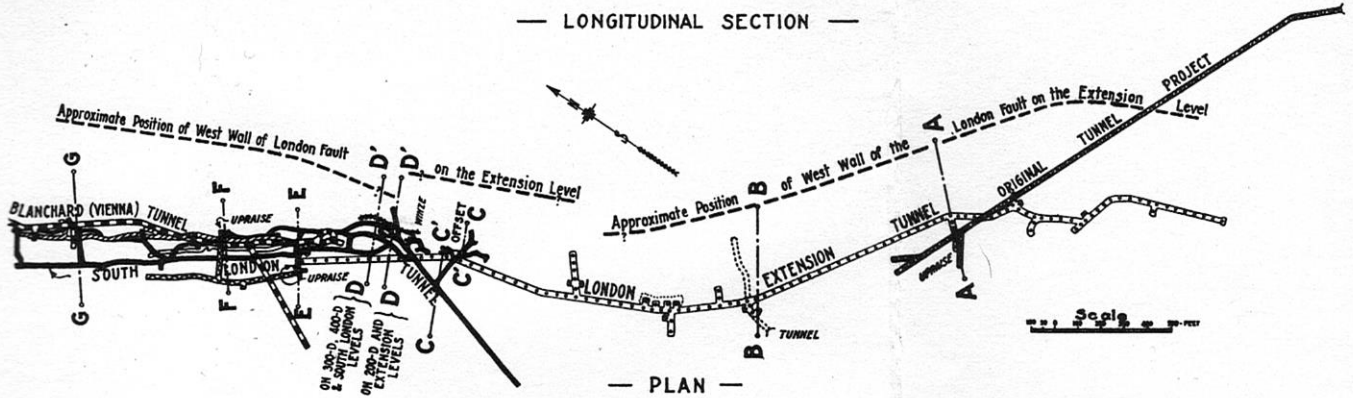
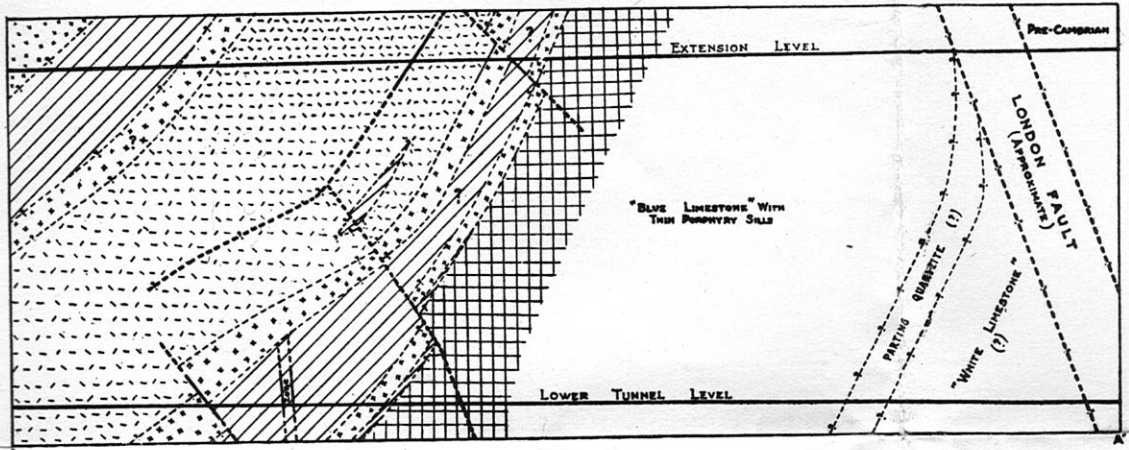
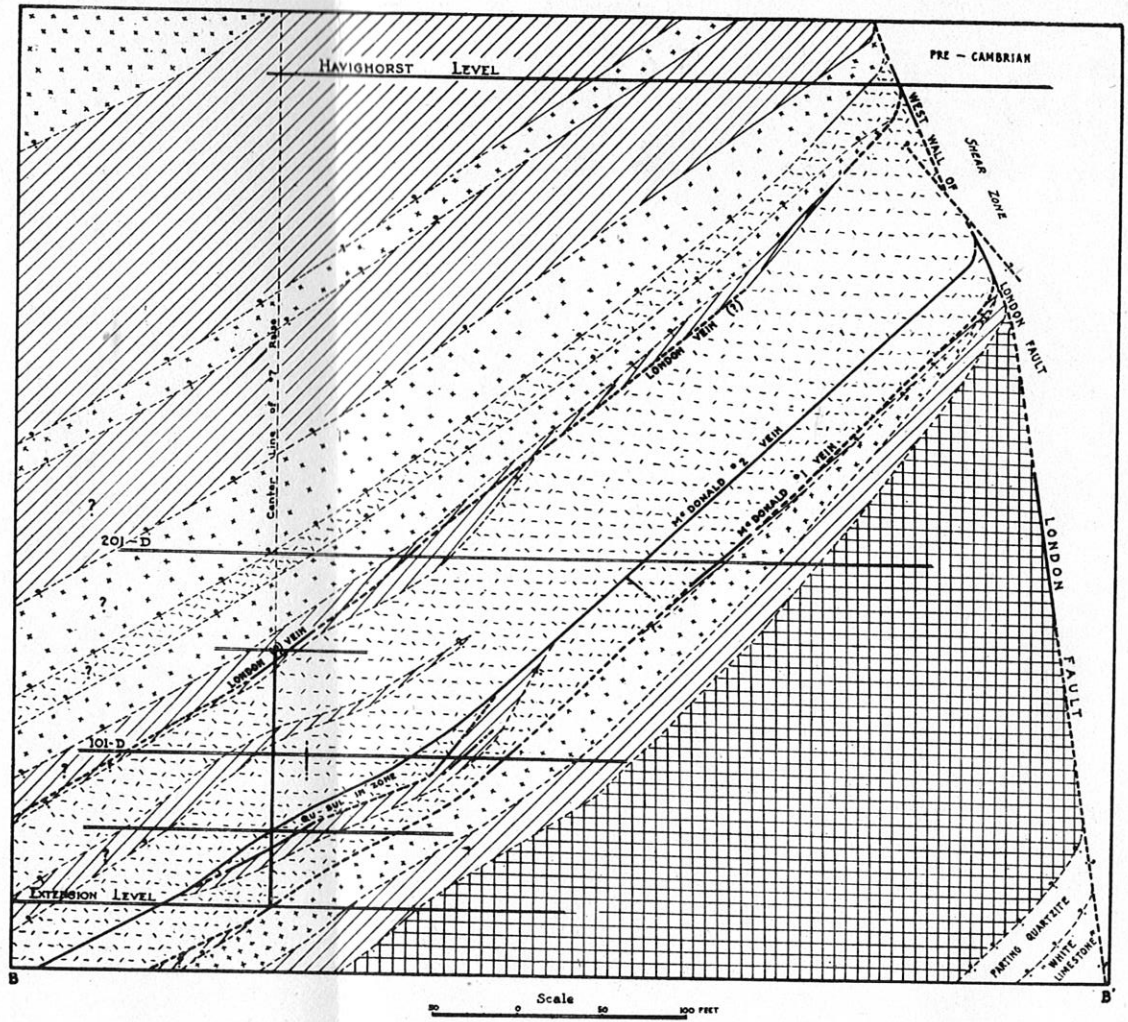


— PLAN —



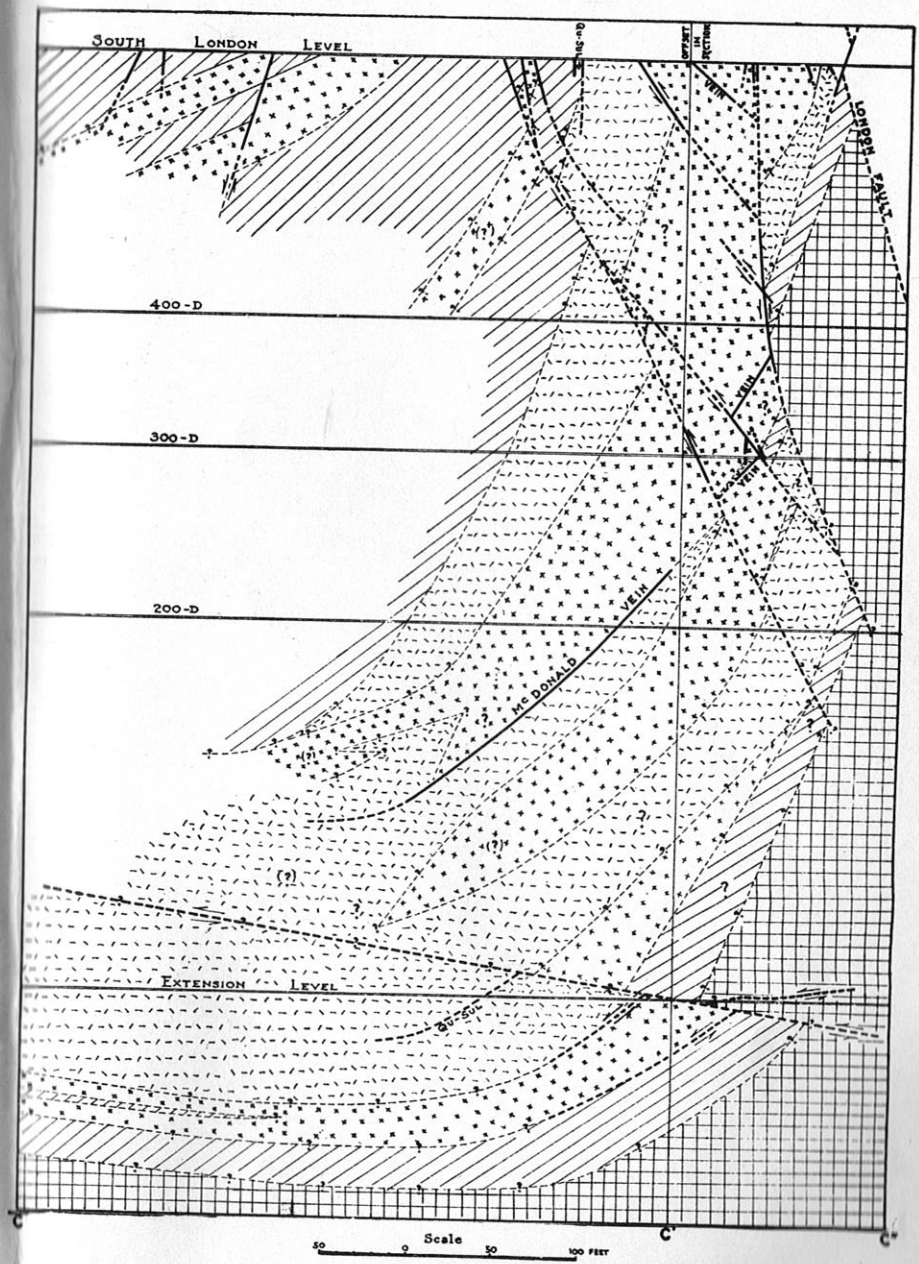
LONDON MINE

SECTION A–A'



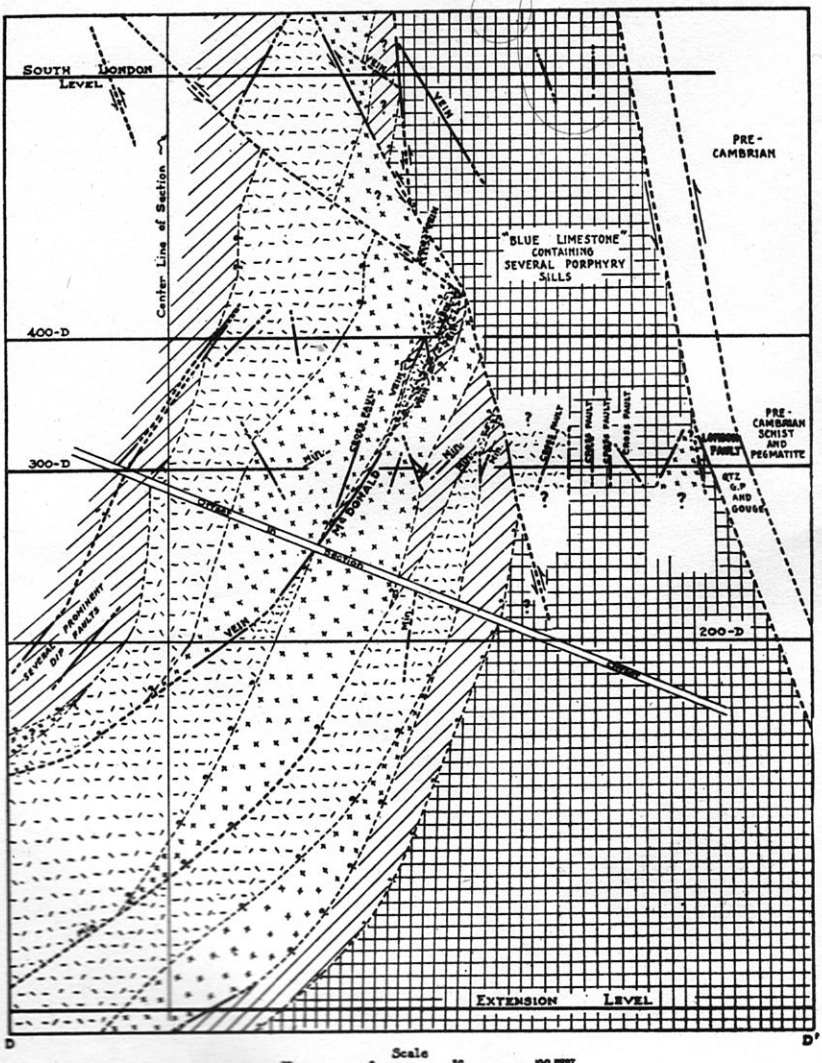
LONDON MINE

SECTION B-B'



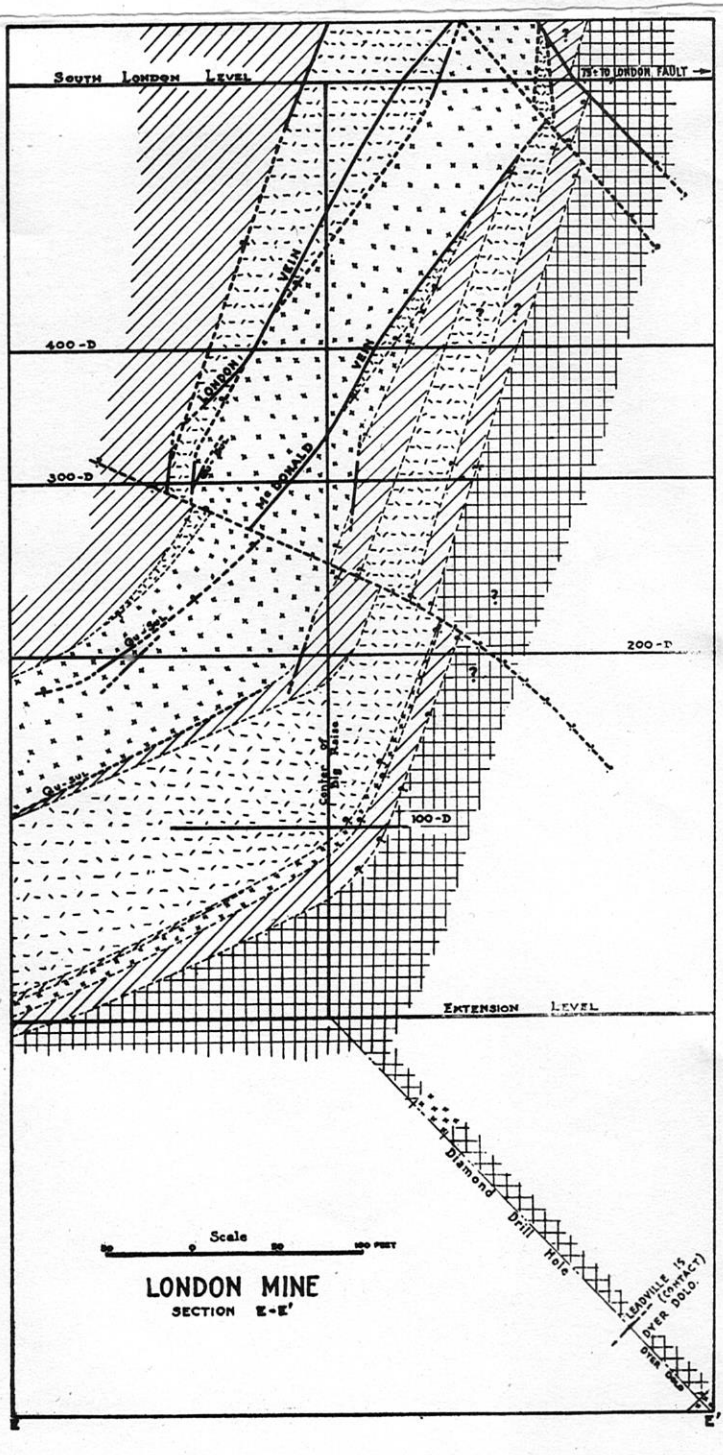
LONDON MINE

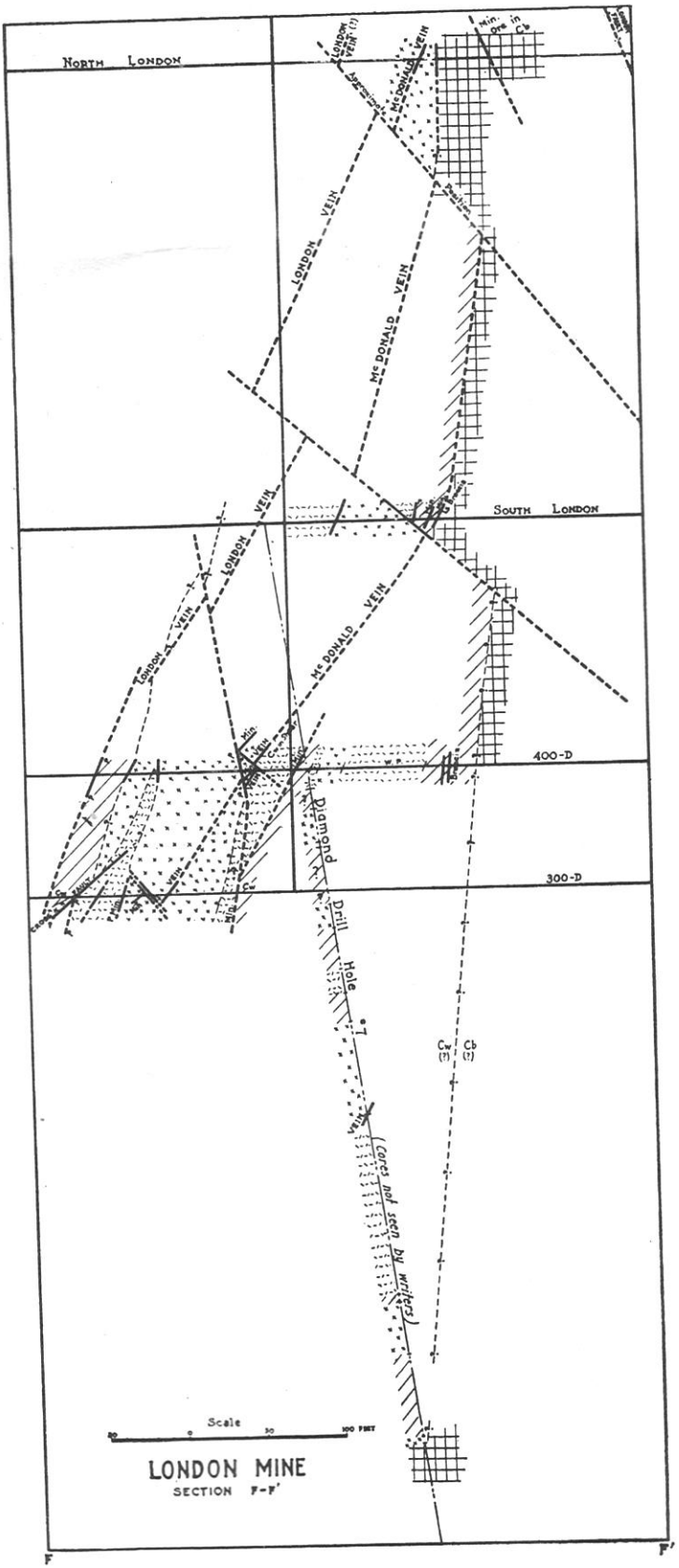
SECTION C-C'-C"

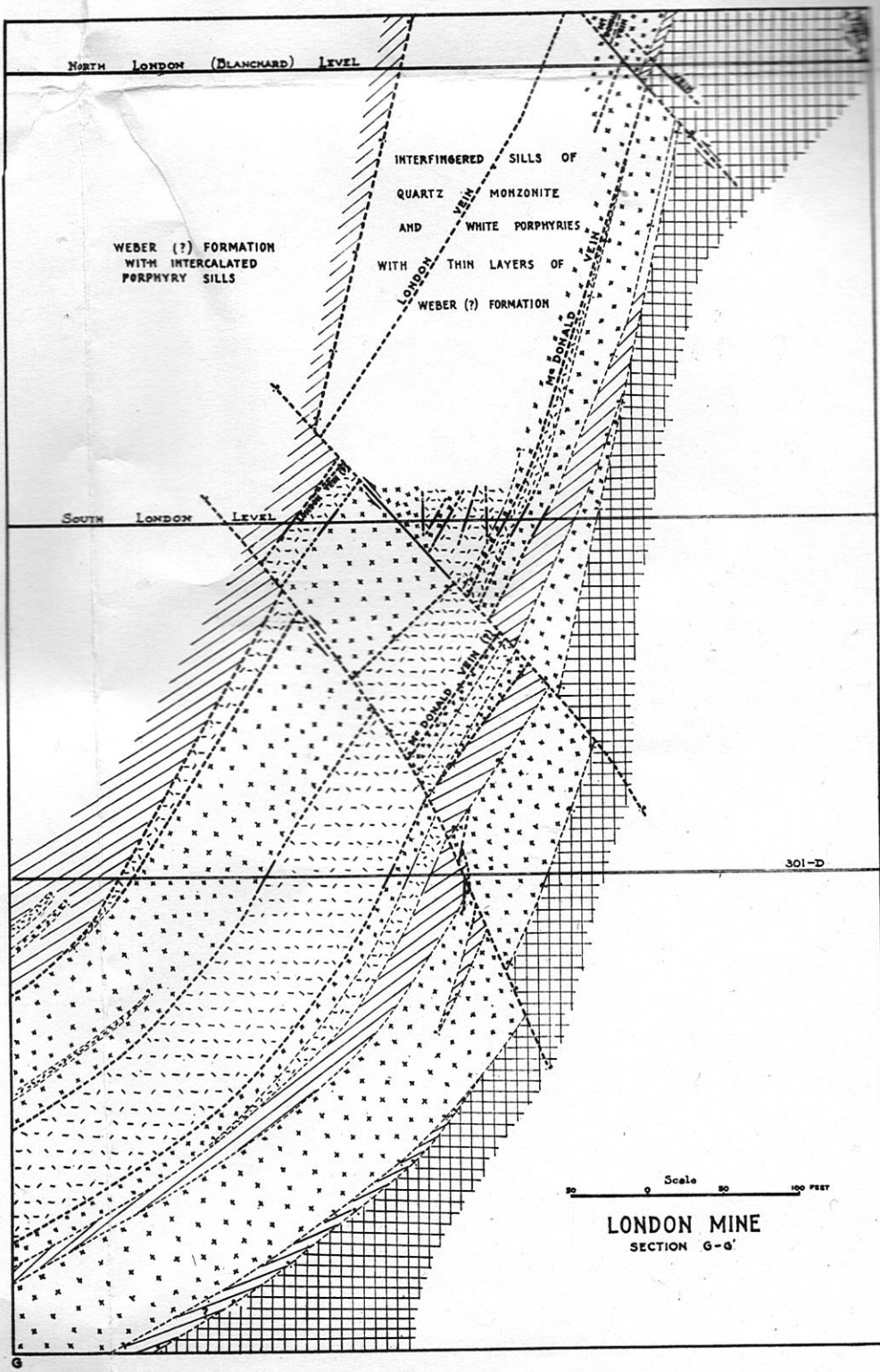


LONDON MINE

SECTION D-D'


SOUTH LONDON LEVEL
75-TO LONDON FAULT
LONDON VEIN
McDONALD VEIN
400-D
300-D
200-D
100-D
EXTENSION LEVEL
Diamond Drill Hole
LEADVILLE IS (CONTACT)
DYER DOLO.
Scale
50 0 50 100 FEET
LONDON MINE
SECTION E-E'
E
E'


NORTH LONDON
SOUTH LONDON
LONDON VEIN
McDONALD VEIN
400-D
300-D
Diamond Drill Hole
(Cores not seen by writer)
Scale
LONDON MINE
SECTION F-F'
F
F'


NORTH LONDON (BLANCHARD) LEVEL
INTERFINGERED SILLS OF QUARTZ MONZONITE AND WHITE PORPHYRIES WITH THIN LAYERS OF WEBER (?) FORMATION
WEBER (?) FORMATION WITH INTERCALATED PORPHYRY SILLS
LONDON VEIN
Mc DONALD VEIN
SOUTH LONDON LEVEL
301-D
Scale
50 0 50 100 FEET
LONDON MINE
SECTION G-G'
G