looks the fact that mining is a business which is controlled by economic changes. In respect to the Gilpin-Clear Creek region, we have a large amount of contemporary testimony, some of which is of sound character. This testimony establishes that some mines were abandoned because they became poor; others ceased working for other reasons. Generally mines were successively abandoned and re-worked many times, rich ore being found below where previous workers had left off. In Gilpin County, at all events, no important mine was worked continuously, without intermission, from its outcrop to the deepest point reached. We may fairly expect that, in this particular, history will repeat itself. Gilpin County veins do not, characteristically, contain single ore shoots, followed from surface and terminating in depth, where the veins cease to be ore-bearing. Rather, there are zones in the veins, some with a definite general pitch. In such zones ore shoots occur, of irregular outline. In most of the veins, the proportion of the ore shoots to the total area of vein, as shown by the stope maps, was relatively small; and there was no general tendency for the longer axis of the ore shoots to be vertical rather than horizontal; if anything, the latter perhaps predominated. Mines did not, of course, stop working when they were in bonanza. Therefore, it is reasonable to expect that the bottom workings were usually poor. It is, however, inadmissible to argue that the vein, at these depths, had necessarily changed in character, or that it had ceased to contain commercial ore.

So far as I am aware, there is no valid evidence, in the Gilpin-Clear Creek region, of anything approaching general impoverishment of the veins in depth; nor has any competent authority heretofore suggested it. The Georgetown silver veins, where the rich silver ores are probably secondary, but where lead-zinc ore, with low silver, continues downwards, were exceptions. However, in the deepest and probably the richest of the silver veins, the Colorado Central, the testimony of Ernest Le Neve Foster was that there was no perceptible lessening in richness down to the lowest level[2]. In comment-

[2]Foster, E. Le Neve, Proc. Colo. Sci. Soc., vol. 7, p. 8, 1901-04.

ing upon this statement, Spurr and Garrey (who, of course, had not seen the lower levels of this mine), state the following:[3]

"It is true that rich ore has persisted in this mine to a depth unequaled in the Silver Plume mines, but it is to be doubted whether some indications of falling-off in depth are not present. It is stated by miners that ruby silver was more abundant in the upper than the lower workings. According to information received, the richest ore shoot in the mine was worked downwards more or less continuously from the surface to the 500-foot level. Between the 400-foot and 500-foot levels, this shoot contained the Carnahan stopes, the richest in the mine. It is reported not to have extended below the 500-foot level, though it split into rich spurs which were followed downward."

I personally was familiar with the upper levels of the Colorado Central mine, but never saw the bottom levels, and cannot add to this testimony. I did not find any continuous ore shoot, including the Carnahan stopes, extending from surface down to the 500-foot level. The ore shoots were rich bunches, often continuous to a greater extent horizontally than vertically.

Mr. Lovering suggests that in the Gilpin County area the bottom limit for commercial ore is 7,300 feet above sea level, or the bottom of the California and Gem shafts. The lowest level on the Gregory-Bobtail-Fisk group was the 1400 level of the Cook shaft. So far as I know, the Gregory 900 and 1000-foot levels developed little commercial ore; and the 1400-foot level of the Cook intersected the Gregory vein in a cross-cut, but did not develop it by drifts. According to a report by W. A. Farish, quoted by Bastin and Hill[4] "the Fisk-Mammoth vein still contained fair values on the lower levels;" and I can vouch that there was good ore on the bottom level of the Bobtail, about 7100 feet above sea-level.

As to the California, I never saw the workings below the 1700-foot level (Hidden Treasure 1500). But there is a consensus of statement from those familiar with the mine that the important ore shoot worked west of the shaft between the 1700 and 2000 levels had not been reached by drifts from the 2100 and 2200, the lowest, levels. Possibly, it may

[3]Spurr, J. E., Garrey, G. H., and Ball, S. H., Economic geology of the Georgetown quadrangle. U. S. Geol. Survey, Prof. Paper 63, p. 248, 1908.
[4]Op. cit. p. 226.

not extend below the 2000 level. On the other hand, there were also persistent statements from eye-witnesses, most of whom are no longer living, that rich ore was coming in again in the sump of the shaft below the 2200 level, which may be the commencement of another ore body.

The account of Forbes Rickard may be quoted here:[5]

"In the deepest mining, that of the California mine just instanced, the lode shows no essential change of character in its deepest developments; and although sinking on that vein has been abandoned for some years, my familiarity with its lowest levels prompts me to say that had it not been that the main working-shaft of this mine was several hundred feet away from the main ore chute [shoot] of its workings, this mine would have been working today at good profit in still lower depths. Work on this vein is now almost wholly confined to its western extension, where it has been in *bonanza* for the last three years, at a depth ranging from 600 to 1000 feet. . . . It is safe to say that the 'measurable distance' [where ore will eventually terminate G. E. C.] in the main veins of Gilpin County has yet to be sounded at some point deeper than hitherto reached by its deepest explorations."

That Mr. Rickard's conclusion was based upon fact cannot reasonably be questioned, for he was in personal charge of the mine for some time, when the bottom levels were being driven.

The California mine, at the time when the lower levels were abandoned, was the deepest gold mine in the world, and one of the deepest mines of any kind. It was considerably deeper than the length of ground on the main vein owned by the company. The economic and mechanical difficulties resulting from its depth were, in view of the limited technical knowledge and facilities available at that time, quite serious. The temperature of the lower workings reduced the efficiency of mining labor, and all mining was hand-work. The raising to surface of considerable quantities of very acid water by buckets required a large percentage of the hoisting capacity of the shaft, and the resulting splash and drip interfered materially with its use for other purposes. There was only one shaft available for use, because the Hidden Treasure shaft, which if continued would have been in the center of the important deep ore body above mentioned, had—unfortunately as it turned out—not been extended below the 1400 level.

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[5]Rickard, Forbes, Trans. Am. Inst. Min. Engs., vol. 28, p. 122, 1898.

The lower workings were comparatively dry; but there was no provision for holding back the water in the upper (and wet) levels, and all the water went to the bottom, and was hoisted from there. It is evident that by drainage into the Kansas lateral of the Argo adit most of these difficulties are now obviated. The mine could be operated today under much the same conditions as if it were starting again as a shallow mine 500 feet deep. As to rock temperature, I was greatly struck recently, when revisiting my old stamping-ground in the Argo adit, by the great change for the better that had taken place, after 20 years of cold-air current from adit to surface. This difficulty of high temperature has been considerably reduced, if not entirely removed.

Since writing the above, the accidental finding of an old notebook, kept in 1901 by R. Gould Simonds, then bookkeeper for various properties operated by the late Arthur L. Collins and myself, enables me to add a piece of direct testimony. This note-book records particulars and yield in retorted gold (but unfortunately not the weight or assay of concentrates) of all custom-ores then treated at the Hidden Treasure stamp-mill.

In that year Mr. Richard Sykes, the chief owner of the Kansas-Burroughs group, leased the California mine. He unwatered it from the 1700-foot level to the bottom, and drove the 2200 level, which had been started many years before, both east and west; but not far enough for the latter to come under where, on the 2000 level, the deepest bonanza ore body had been worked. Sykes also did some stoping on the Hidden Treasure 1600 level. At the end of 1901 financial reverses overtook Mr. Sykes, and shortly thereafter operations on all these properties ceased, and they filled with water and so remained until recently, when drained by diamond drill connections with the Argo adit.

It was the practice of Mr. Sykes (as of most other operators in the district then) to save all material from drifting, unless completely unmineralized, and ship it to a custom-mill, where it was separately treated and cleaned up in small lots, thereby affording more specific information of yield than could be obtained by assaying. The Hidden Treasure mill was then run solely as a custom mill, each lot, large or small, being cleaned up separately, the gold retorted, the concentrates weighed and sampled, and all delivered to the owner or loaded into cars for his account. It is interesting to observe, as bearing on the economics of that time, that the uniform charge made to Sykes for milling was $8.50 per "cord," equivalent to $1.06 per ton. If a "section" of 25 stamps was rented, the expense per "cord" was materially reduced.

The note-book shows that during the period of three or four months, when the mine was unwatered and drifting (by hand) in progress, 328 tons from the 2200 level E. were thus milled, yielding an average of $2.25 per ton in retorted gold. From the 2200 W., 224 tons were milled, yielding an average of $3.20 per ton. Of lots marked "2200," but without the E. or W. drift symbol, there were 112 tons, averaging $4.97 per ton. This last may have come from trial stopes; the material broken in drifting being always impoverished by admixture with waste. If the length of the 2200 E. level, shown on the working map of the mine, is correct, practically all the material broken in driving the 2200 E. is accounted for as having been milled.

From the Hidden Treasure 1600 level, 1272 tons were milled, yielding in retorted gold an average of $5.04 per ton. [In each case, the value of the concentrates may be assumed, as a rough approximation, to have been about two-thirds of that of the retorted gold.] The total yield therefore would be about as follows: California 2200 E. drift, $3.75 per ton; California 2200 W. drift, $6.33 per ton; California 2200 (not further described), $8.28 per ton; Hidden Treasure 1600 W. stope, $8.40 per ton. I saw the Hidden Treasure 1600 level shortly before or after this time, when the water was just below this level; the ore then exposed was considered rather better than the average grade then profitably worked in the district. It therefore appears that the California 2200 level, apart from the important ore body, if it continues to that depth, shows no material falling-off as compared with the

1600. Indeed, these figures of actual yield, from parts of the vein which were not considered pay ground, indicate a rather surprisingly high value.

That the argument which seeks to prove that the existence of ore necessarily ends in depth where existing mines ceased working is not always valid, was clearly shown by my brother, the late Henry F. Collins[6], in the discussion on T. A. Rickard's paper on "Persistence of ore in depth."[7]

> "Individual ore shoots, sooner or later, do invariably become impoverished in depth, but cases are extremely common . . . in which the shoot which was the mainstay of the output from a particular mine has pinched, and either at the same horizon or a little deeper another shoot which did not outcrop has come to take its place. What does very often happen in the history of a mine is that the principal shoot is worked down to a point, another which does not outcrop is also worked down to a point, and perhaps a third similarly; and then some day or other, just about the time when a shoot has been worked out, there is an increase in the coming water; or the limits as regards depth of the existing pumping installation have been reached; or the price of metals is abnormally low; . . . or it turns out that development has been neglected by the management for some time previously in order to keep down costs or to increase production with limited hoisting facilities; . . . and no funds are available or obtainable to develop the property laterally by long drives along the lode from its short bottom levels, which for several lifts have been driven only the length of the shoot or shoots actually being worked.
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> In hundreds of such cases mines are stopped and abandoned because the working shoot has become impoverished, without any adequate attempt having been made to drive along the course of the lode in the deeper levels to look for other shoots. . . . Although it is quite accurate to state that the ore shoots followed down have become impoverished, it is hardly fair to argue from the evidence available that the lode itself, as a whole, is less mineralized in depth."

The question under discussion is an economic, rather than a geological one. Mr. Lovering speaks of 7300 feet as the "bottom limit" for ore in this district, as having been proved by experience. That there will be an eventual bottom limit I agree; but I see no sufficient evidence that this limit has yet been reached. The bottom of an individual ore shoot, and the ultimate bottom of ore occurrence, are two radically different things.

A great increase in the cost of mining took place, in this district, between, say, 1900 and 1920; and, as a result of this,

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[6]Collins, H. F., Trans. Inst. Min. & Met., XXIV, p. 125, 1915.
[7]Rickard, T. A., Trans. Inst. Min. & Met., XXIII, 1914.

rather than of increasing depth (for the greatest depths had been reached ten years or more earlier, and in fact very few of the deep shafts were sunk deeper during this period), much material which in 1900 would have been commercial ore had ceased to be such by 1920. Increasing depth had little or nothing to do with it, for no such increase in general took place. There is, I think, a tendency to assume that the average grade of ore mined and treated in Gilpin County prior to 1900 was much richer than it really was. Profits were realized, not so much because the ore was rich, as because costs were low, and methods were, on the whole, good. Under favorable conditions very low-grade ore was sometimes mined with profit. At the Perigo, for instance, we made a little money, besides paying royalty to the owners, from ore upon which it would be difficult to make both ends meet today. I find the following incomplete figures in my records:

For the year 1899, the average total yield per ton was $3.58; in 1900, $4.65; and in 1901, $3.06.

This ore was mined above the adit level, but in veins of no great width; and the total tonnage was only 2000 to 3000 monthly.

I think it is correct to say that some economic factors have tended to increase mining costs in this district, while others will in future tend to reduce them. During the last generation, the technique of mining relatively narrow fissure-veins has not made the striking progress that has been achieved in mining large ore bodies where operations are more readily mechanized; but he would be a rash man who would say that the last step in progress has been taken. It is at least possible that ten years hence the cost of mining such deposits may be much lower than it was thirty years ago. Furthermore, there is considerable reason to hope for improved metallurgy which may offset any increase in other costs.

Pumping charges, in many cases, will be eliminated in future, by use of the Argo adit. Where pumping is still necessary, application of electric power, which is specially adapted for this work, and which was formerly not available, will enable it to be done more economically. But it is strikingly, and almost universally, true of these veins, that they make very little water below a depth of 1000 or 1200 feet from surface.

Bastin and Hill[8] remark on the fact that many veins, which at surface are of their 'composite' galena-sphalerite type, change to the pyritic type at the depth of the Argo adit. I had previously noted[9] that many veins in the vicinity of Nevadaville, which at their easterly ends were characterized by pyrite and chalcopyrite, became towards the west predominantly lead-zinc veins.

Mr. Lovering suggests, as an explanation of these facts, that:

> "the early iron-rich solutions took the most direct route to the surface and formed pyritic deposits which largely clogged the more centrally located fissures. Solutions of the latter stages, therefore, had to find their way around the central pyritic area, except where renewed faulting had opened the pyritic veins."

However, some veins of the pyritic type in the central part of the district contain very rich ore streaks; and there is often clear evidence that the original pyritic veins had been reopened and shattered, and quartz, chalcopyrite, and free gold introduced. I incline to think that the zoning to which I called attention in 1903,[10] referred to by Mr. Lovering, was domical, proceeding outwards in all directions from a more or less definite center. If this supposition is correct, the central veins were channels, but, in the part now remaining after erosion has removed their original upper part, not depositories for the "composite" lead-zinc mineralization. The veins as we now see them in deeper workings indicate what we may expect to find, with increasing depth, in the developed "composite" veins; and the ultimate limit of mineralization will be much lower than present deep levels.

I referred above to the fact that the ore-bearing zone of some veins has a definite pitch. In the area around Nevadaville, this trends to the west. The westerly pitch of localized

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[8]Op. cit. p. 16.

[9]Collins, G. E., Proc. Colo. Sci. Soc., vol. 10, pp. 226, 1912.

[10]Trans. Inst. Min. & Met., vol. XII, pp. 480-499, 1902-03.

ore shoots in this area is clearly due to the westerly dip of the strata; ore occurs mainly in the gneissic bands, and is limited by the schistose bands. But considering the pitch of the ore zones as a whole and apart from individual ore shoots, there still seems to be a westerly pitch, which may be influenced by domical zoning.

Furthermore, when I stated (above) that there is no satisfactory evidence of general impoverishment in depth in Gilpin County, I might qualify the statement by adding that there are certainly fewer mineralized veins in depth[10a]; and it should also be understood that I do not include the first hundred feet, which was very notably enriched by removal of iron and mechanical concentration due to long-continued erosion in which much of the gold remained behind. Nor do I include the next few hundred feet in which there was marked secondary enrichment of copper, with some accompanying secondary enrichment of silver and, in less degree, of gold.

The generalization that most of the veins become narrow, or even disappear, when traversing schist, especially when the strike and dip of the vein nearly coincide with the laminations of the schist, was observed by most of the intelligent miners in the district. To this may be added the further generalization that veins often become narrow and "tight" in extensive areas of hard, rigid rocks. That firm rocks are more favorable for ore was always, and is in the tungsten district today, almost too well-established for discussion. But there has been no previous attempt to work out the structure of the schists and gneisses; and no recognition that it was possible to do so. The mine operator of the past was usually too intensely occupied with his immediate problems to visualize the broad structural facts of his district, even if he had the training necessary to enable him to realize the help that he might obtain from more accurate maps and sections. He failed to see the wood, for the trees. No geologist, so far as I know, has ever suggested heretofore that the interbedding of the gneiss and schist, and the folding of both, are uniform in this area to a degree that admits of predicting far in advance where one or the other rock will

[10a]Not because the veins ended in depth, but because many veins coalesced. My experience included no instance of a vein, followed down from surface, playing out in depth. [G. E. C.]

be encountered. If Mr. Lovering can give us maps that will tell us, with reasonable certainty, where we shall find gneiss, schist, or pegmatite, several hundred feet beyond present workings, he will have made a substantial contribution to the fund of data with which the miner of today can work.

Nevertheless, I think it would be a grave error to go further than this, and to assume that, where schist comes in, mine exploration must necessarily cease. So many other factors enter into the localization of workable ore bodies that, even if the interstratification of gneiss with mica-schist is as clearly marked as shown in Mr. Lovering's figure 3, I believe that the schist has been changed to gneiss and is interrupted by pegmatite and porphyry, to such an extent as to vitiate Mr. Lovering's conclusion that prospecting should be confined to the gneiss bands. To my mind, the statement, as applied to figure 3, that "the marked influence of gneiss on the localization of ore is apparent" is over-emphasized.

While it is certain that schist is generally an unfavorable wall-rock, it seems equally certain that the fractures where they passed through schist were nevertheless able to serve as channels which admitted the passage of ore solutions from greater depths; and these solutions may have deposited ore wherever suitable spaces or fractured rocks were encountered, although not in the schists themselves. I have in mind that there is some evidence to suggest that uniformity of enclosing rock was unfavorable to formation of bonanzas; and that a change from schist to gneiss was more favorable for ore than a long stretch of gneiss or granite without any intermission of barren stretches. The total load of mineral, capable of deposition under given conditions of temperature and pressure, may have been limited.

The particular illustration which Mr. Lovering uses, the California vein, seems to me unfortunate for his contention; for this vein everywhere follows a wide dike of porphyry, sometimes on one wall of it, sometimes on the other, and sometimes crossing it. It is, therefore, always associated with a very compact and brittle rock, and to that extent is independent of the enclosing rocks. Old miners, familiar with this mine, used to tell me that where the vein crossed the dike was a specially favorable place for ore bodies. Possibly this was because the dike was there usually shattered, and therefore replaceable by ore. The only contemporaneous written reference that I have found, by any well known writer, is that of T. A. Rickard[11]. Writing of veins in this region which follow the contact between igneous rocks and the metamorphic or sedimentary formations which they have penetrated, he says:

> "In such cases, the mineralization may often be found to have spent itself on the more soluble porphyritic igneous rock, rather than upon the less soluble metamorphic. The walls of such veins will vary, as the ore-deposition has followed either fractures along the immediate contact, or those which ramify into the body of the dike, or again those which cut across the latter, where its irregular outline has been an obstacle to the main line of fissuring."

On page 206, he describes the west breast of the California 2000-foot level, where he speaks of the porphyry dike as being 17 feet thick, and says the vein has mica schist on the foot-wall and porphyry on the hanging. In the lower (2100-foot) level, "the lode has crossed the dike, and the porphyry forms the foot-wall."

On page 232, it is stated: "In the Indiana 800 level [the Indiana is the westerly continuation of the California vein], the mineralization is mostly zinc-blende. The country-rock is quartz-feldspar rock, best described as granulite. . . . The lode has departed from the dike, with which it is so closely associated in the neighboring mine, but the workings show that it meets this dike at intervals, and is benefited by the intersection."

Here again, we need not accept Mr. Rickard's opinion that the reason why the vein had better ore when in the porphyry, is the greater solubility of this rock; his observation as to the fact is the significant thing.

I believe that studies of the influence of structure on localization of ore bodies are centering on a dual conception; first, open spaces, created by fracturing, by solution, or by

[11]Rickard, T. A., Vein-Walls. Trans. Am. Inst. Min. Engs., vol. 26, pp. 193-241, 1896.

movement contemporaneous with passage of mineralizing fluids; and second, confining limits, which prevent or delay passage of the fluids. If this is true, the alternation of schistose and gneissic rocks may be more favorable than long uninterrupted stretches of either rock. The fractures, made by a zone of fissuring in schist, intercalated with successive resistant beds of hard gneiss, enlarged by bed-faulting along the contacts, seem likely to result in irregular open spaces between the laminated and massive rocks, of just such forms as I have observed in some of the old bonanza stopes of the Gunnell mine.

Conversely—in a case like that of the Druid, mentioned below, where a vein system passes downwards from schist into granite gneiss, at a depth of about 350 feet from surface, and becomes poorer—the question suggests itself whether the blanketing effect of the relatively impervious schist may not have been a principal factor in the localization of ore; especially in view of the fact that the richer ore occurs in, and as a replacement of, the fractured schist itself, overlying and at considerable distances from the comparatively flat Searle vein, which was the main channel connecting with the ultimate source of mineralization.

It seems to me that these ore bodies in the Druid mine, enclosed in schist, first described in 1912[12] have received insufficient attention, as indicating the significance of the confining or damming effect of schist in localization of ore bodies Similar replacements in schist, adjoining weak, slightly mineralized fissures, were found and worked a few years earlier, when driving the Argo adit through the Trentina claim; and about the same time, in the Wellington or King Bee, at the Argo adit level. Replacements of this type also occurred in pegmatite and gneiss[13], but at that time were more prominent and of higher grade, when in schist.

In 1917 Bastin and Hill[14] described replacement ore bodies, which I consider to have been of the same general

[12]Collins, G. E., Proc. Colo. Sci. Soc., vol. 10, p. 226, 1912.
[13]Loc. cit. p. 230.
[14]Op. cit., Field work in 1911-12.

type, in many mines (Frontenac, War Dance, etc.) as occurring both in granite gneiss and schist.

I do not think that ore-replacements of this kind had been observed in Gilpin County prior to my work in the Druid about 1909. They were completely unfamiliar to the miners in this district, with the exception of an Italian at the Druid, who told me that he had seen similar occurrences in shallow workings, in the area north of the Searle-Frontenac lode. I have, moreover, an indistinct recollection of having been told, about 1897, of what may have been a similar occurrence in an old shaft on what was later patented as the Clifton Bell claim of the Wellington group.

Such ore bodies will, I imagine, always be hard to find, and rather expensive to mine, but they are characteristically of higher grade than most of the Gilpin County ores. The Druid, for instance, judged by average grade of ore shipped, was one of the richest mines ever worked in the district. The recognition of such ore bodies took place late in the history of this region, after increasing costs had curtailed its activity, and shortly before war and post-war conditions practically ended it, so that there was little opportunity to ascertain their extent or distribution, apart from the Druid mine itself. My opinion, however, is that such ore bodies may prove to be of widespread occurrence; that this type of replacement ores may shade into and be correlated with telluride ore bodies such as those of the Treasure Vault and "West Gold" mine near Idaho Springs; that the preconceptions of miners, and the trend of metallurgical method in the district, have hampered the intelligent search for such ore bodies; and that they should be taken into account in any estimate of the future of mining in this district.

I have not yet ascertained whether occurrence of tellurides in uniformly characteristic of the replacement ore bodies. It is certainly not confined to them; but as the telluride mineralization followed the same channels, this should not be expected. The facts remain to be proved, by field observations and by examination of numerous polished sections, the technique of which was unknown when the mines were accessible. My own impression is that the telluride ores, both in Gilpin, Clear Creek, and Boulder counties, are later than the sulphide ore of either stage; and that their occurrence in Gilpin and Clear Creek is far more general and of greater economic importance than had been supposed. That telluride minerals occurred in Gilpin and Clear Creek ores was early established by Richard Pearce[15], who mentioned specially the Frontenac (the westerly extension of the Druid), Gem, and Sleepy Hollow mines. However, the significance of this discovery was not recognized, partly, I think, because early Gilpin County practice was guided almost entirely by the pan and mill-run. Assaying was at first little used, except on high-grade ore (hand-sorted, or selectively mined by the eye in the first place), and on mill-products.

Most Gilpin County ores were fairly amenable to simple milling methods; but after assaying became more general it was observed that occasionally lots of ore were received at the custom-mills, even from mines the ore from which was ordinarily docile, on which the saving either by amalgamation or gravity concentration was small. Somewhat later I observed that this was particularly true of what I have termed the replacement ores. Does not this fact support the possibility that these ores belong to a different stage of mineralization? And that owing to their different appearance (which was often such that the ordinary miner would consider them waste-rock) they were generally overlooked?

I therefore think it possible that such ores were frequently encountered, but not followed; the conditions, both of mining and milling, being such that there was little chance of their being detected, in preference to the sulphide ores of normal type, especially as they contained the same sulphide minerals, in less amount.

Mr. Lovering refers to "the lean and unprofitable nature of the ore found in most of the veins cut by the Argo adit" (Elev. 7600 to 7650 ft.) as having discouraged deeper exploration. The fact has often been brought forward in sup-

[15] Pearce, Richard, The Association of Gold with other Metals in the West, Trans. Am. Inst. Min. Engs., vol. 18, pp. 451-2, 1889-90. Also Ibid, Further Notes on Cripple Creek Ores, Proc. Colo. Sci. Soc., vol. 5, pp. 11-16, 1894.

port of the hypothesis of impoverishment with depth. It is, however, doubtful whether a similar crosscut opening, made over the same line for the first two-thirds of the distance, at an average depth of two hundred feet, would have made a better showing. The fault lies not with depth, but with the poor judgment exercised in the original lay-out of the tunnel. After I changed its course, it traversed more promising territory; but the failure to find ore in the tunnel where it passed directly under the best part of the "Patch" was a great disappointment. However, had the westerly lateral under Quartz Hill, been carried out as I urged, the results achieved would probably have been more satisfactory.

Mr. Lovering says:

"Garnet, magnetite, hematite, and fine-grained quartz, have formed early in the period of mineralization near some of the large quartz-monzonite porphyry stocks which are closely related to centers of mineralization."[16]

In the Nederland area, these minerals are often developed along lines of fissuring which do not appear to be related to the tungsten-bearing veins, or to the porphyries. I therefore concluded them to be the product of mineralization long antecedent, perhaps even pre-Cambrian; possibly originating when the calcareous sediments were altered to lime silicate by the early granite gneiss and granite pegmatite.

Additional Discussion by T. S. Lovering: I have read Mr. Collins' discussion with considerable interest. His chief quarrel is with my limiting the depth of the ores at Central City and Idaho Springs to approximately 7,300 feet altitude. He does, however, say that there are fewer veins in depth than there are near the surface. In other words, many of the veins found in higher altitudes have played out[17] by the time they reach the level of the Argo Tunnel. Of course, the persistent fissures should carry ores to greater depths than the smaller fissures, and I do not doubt that some veins have ore as much as 1,000 feet below the deepest workings in the district.

[16]Lovering, T. S., Proc. Colo. Sci. Soc., vol. 12, p. 247.
[17][Not necessarily so—many veins came together. G. E. Collins, Sept. 20, 1930.]

The zone of worthwhile exploration is rather different from the zone of sulphide deposition. I believe that in the majority of veins ore will give out before an elevation of 7,300 feet is reached. In some of the largest veins it would be distinctly worthwhile to go below this depth. I indicated this when I said that deep exploration should be confined to the veins in the stronger rocks. I may have overemphasized the relation of ore shoots to gneiss in my cross-section of the Argo Tunnel. This section is clearly diagrammatic, but the geologic map of the Central City special area certainly shows a striking concentration of the veins in the granite gneiss. Replacement ores which Mr. Collins discusses are interesting, but the data at hand do not warrant any statement as to the probability of finding them excepting where they outcrop or are cut by chance in some mine opening.

The development of garnet, hematite, fine-grained quartz, epidote, magnetite, and tremolite near stocks is the clearest kind of evidence of contact metamorphism. There are many places, such as the Montezuma stocks and quartz monzonite stocks at Tiger and near Breckenridge where these deposits are formed. Such minerals are not found in fissure veins excepting under unusual deep-seated conditions, although many of them were developed in the schists during regional metamorphism. It is possible that the "lines of fissuring" that Mr. Collins found near Nederland are zones of regional metamorphism in pre-Cambrian rocks and as he surmises, these minerals then date back to the pre-Cambrian.

Of course, the dike along the California vein is largely responsible for the persistence of the fissure that follows it. I should think that it would be obvious, however, that one strong wall and one weak wall would be less favorable for ore than two strong walls. In other words, the alternation of schist and gneiss would still control ore deposition. In general I think Mr. Collins and I are agreed as to the data and the general interpretation of them, but disagree as to the emphasis.

April 22, 1930.