ON THE ORIGIN OF FISSURE VEINS.

BY S. F. EMMONS.

At the first autumn meeting of the Society last year I presented the results of recent observations upon some ore deposits in Colorado, and pointed out certain lines of investigation which these observations suggested in regard to the mode of formation of what are commonly known as fissure veins.

During the past summer I have had opportunities of examining a great number of fissure deposits in various parts of the Rocky Mountains, so many indeed, that in consideration of the remarkable uniformity in the mode of formation of the fissures in which these deposits occur, I think I am justified in making certain preliminary generalizations, which I propose to present to you to-night.

As these generalizations were already outlined in my former paper, I cannot promise that what I may have to say will seem either novel or striking, but it has the merit of being founded on actual and personal observation, and further the practical value of explaining away certain popular misapprehensions or prejudices among the mining community.

There are certain elementary geological considerations to be borne in mind when studying an individual ore deposit, or a class of ore deposits, which, though so simple in their nature as to be almost axiomatic to the geologist who has made a practical study of this subject, I think it well to repeat here since many persons who may be familiar enough with them from a theoretical point of view are apt to neglect or temporarily lose sight of some of them in practical work.

These are, as applied to the majority of deposits:

1. That they have been formed from solutions, not by fusion or sublimation.

2. That deposition has in consequence taken place in channels which would admit a relatively free access to, and consequently a concentration of the solutions circulating through the rock masses of the earth's crust, but in which nevertheless the circulation would be still extremely slow.

3. Further, that most ore deposits have been formed at considerable depths below the surface of the earth, consequently under different conditions from those which we find at the present day; that they have been brought into their present relative proximity to the surface by upheaval, or by erosion, or by both combined; and that the influence of water circulating through them from the present surface is to change their original character, and frequently to remove rather than to deposit.

It will be evident that all these considerations do not apply to superficial or detrital deposits of minerals, such as bog-iron or placer deposits, nor to deposits formed contemporaneously with the enclosing rocks, such as beds of coal, gypsum and rock salt, but only to those which have been formed later than, and of materials foreign to the mass of the enclosing rocks.

It seems hardly necessary to insist on the fact that the contents of our present ore deposits have been precipitated from solutions. The only support of the other theories mentioned would be derived from the fact that igneous rocks contain metallic minerals, presumably original, which must therefore, like their other constituents, have formed from a fused mass; and that in the vicinity of active volcanoes they are found under such conditions as make it possible that they are sublimation products. In neither case, however, do they occur concentrated in sufficient masses to constitute bodies of economic value, and actual investigations of ore deposits show that deposition from solution is the only method consistent with the conditions under which they and the enclosing rocks are now found; although the original material of which these deposits are the concentration, may have been formed by sublimation or fusion, since it seems probable that, in many cases at any rate, they have been leached out of eruptive or igneous rocks.

It being admitted, then, that the mineral contents of ore deposits have been gathered up in minute quantities by underground waters or solutions percolating slowly through the various rock masses which constitute the earth's crust, the next point to consider is, what are the conditions which would produce a precipitation from those solutions in the concentrated masses in which we find them to-day in the various ore bodies of our mines.

There are two points of view from which to regard this process: the chemical, and the physical or structural. It is mainly from the latter point of view that I propose to consider the subject this evening.

The chemical processes of original ore deposition are necessarily difficult of experimental demonstration, owing to the fact mentioned above that they must have taken place at considerable depths and consequently under conditions of pressure and heat of which we can at best have but a hypothetical knowledge.

The generally received idea is that the metals are taken up by waters containing alkaline sulphides, and deposited again either as a result of dilution, or of diminished heat and pressure, it being well known that the latter forces generally increase the dissolving power of chemical agents. This idea is founded on the observation that deep-seated waters contain sulphides; the alkalies would be furnished by the decomposition of felspathic constituents of the rocks. These alkaline waters would also dissolve silica.

Further evidence pointing in this direction is furnished by the fact that all the metals, except tin and manganese, occur in unaltered deposits in the form of sulphides or some sulpho-salt. Still much remains for practical investigation in this line, to remove it from the region of hypothesis into that of practical demonstration.

An important step has recently been taken by Mr. G.

F. Becker of the U. S. Geological Survey, who, by a series of laboratory experiments, has practically demonstrated the solubility of gold, mercury, arsenic, antimony, copper, zinc and iron in solutions containing monosulphides of the alkalies, either alone or mixed with sulphydrates.

Let us turn, then, to the physical or structural conditions which would favor the precipitation of vein materials from percolating solutions and their concentration in workable masses. My observations show that these resolve themselves into the simple conditions of the existence, at the time of deposition, of a water channel through the rocks which would permit of a freer passage for solutions than is afforded by the capillary circulation of a comparatively homogeneous rock mass.

Whether the precipitation along such channels is induced by a dilution of solutions entering from the sides by waters already flowing through them, or, in the case of solutions ascending from greater to less depths, by reduction of heat and pressure, or again by the reaction of the material held in solution by the circulating waters upon that of the adjoining rock, is a problem of terrestrial chemistry, upon which I do not here propose to enter. It is possible that in a study of different deposits, now one, now the other, and again more than one of these conditions might be found to be the more probable cause.

I myself consider that in most cases there must have been in the composition of the rock itself some peculiar affinity for the materials held in solution by the percolating waters, which induced, or at least precipitated, a chemical interchange between the two.

Another condition which would seem to favor precipitation in certain cases would be a partial stagnation of the current along such a channel.

The various forms of water channels affording a more ready passage for percolating waters than the average mass of the surrounding rocks, which we find in nature, may be classed under the following heads:

1. Stratification planes.

2. Planes of contact of eruptive masses, whether in the form of dikes or of intrusive sheets, with the rocks, whether sedimentary or eruptive, through which they have been forced.

3. Contraction joints.

4. Faults or slip planes and cross-fractures produced by dynamic movements of the earth's crust.

The circulation of deep-seated underground waters must necessarily have had a great deal of analogy with those more superficial currents which produce the springs we see appearing at the surface at the present day, and the study of the structural conditions which produce the latter will naturally throw much light on the probable course of the former. At the same time there is much danger in carrying this analogy too far, and the doing so has undoubtedly led to many misconceptions in the study of ore deposits. It is important to bear in mind that the springs we observe flow out upon the surface and have a comparatively rapid current, whereas the waters which produced deep-seated ore-deposits, so far as this precipitation was concerned, had no relation to surface agents, and their flow was probably extremely slow as compared to that of most springs.

The action of spring waters is essentially a dissolving one, and their main precipitation is produced by free access of atmospheric agents. On the other hand, in the ore-bearing currents we are considering, solution and precipitation must have been nearly equally balanced, and atmospheric agents cannot be supposed to have had access to them.

The distinctive characters of the first two of the above enumerated natural channels for underground waters are easily recognized in nature; those of the last two are, however, less evident, and, as I propose to show later, it is not always possible to determine to which a given plane of division in rock masses may belong.

Class 1. *Stratification planes.* Where alternating sedimentary beds, laid down one upon the other, are of different composition and texture, especially where one is more porous or permeable than the other, it is easy to see that either the dividing planes themselves, or the more porous zones adjoining these planes will form the normal, and, where none of the planes mentioned above have been produced by a later geologic action to interrupt their course, the only water channels. Experience shows that, even where the adjoining beds are nearly identical in character, the tendency of ore solutions has been to follow these planes until interrupted by those of one of the other classes which may afford a more ready passage to waters. A large portion of our common springs, and almost all artesian flows come from waters circulating along such planes which have been interrupted in the former case by natural, in the latter by artificial causes, and their waters brought to the surface under the influence of hydrostatic pressure.

Class 2. *Contact planes.* Where eruptive bodies cross the strata, either in the form of dikes or of cross-cutting sheets, they cut off the previously existing channels along stratification planes and force the waters circulating through them to follow the newly formed channels along the contact with these bodies. To such causes are due most of the springs, especially thermal springs, appearing at the surface near the outcrops of eruptive bodies.

Where these bodies are in the form of intrusive sheets following, or parallel with, stratification planes, they serve to accentuate or render still more easy the flow of waters along such planes, and, when later formed, may interrupt the flow along planes of the last two classes.

Class 3. *Contraction joints.* How far the various joints or cleavage planes in a given body of rock are to be attributed to contraction alone is a matter in regard to which I feel very uncertain.

It is natural to suppose that the volume of an eruptive mass must contract in passing from a fused or liquid to a solid condition; on the other hand it seems likely that in the passage from an amorphous to a crystalline condition some expansion of the mass may ensue. Again, sedimentary beds when deposited at the bottom of the sea must have been far less compact than the resulting hard limestones, sandstones and shales which we find in mountain masses; their volume is undoubtedly much less than that which they originally occupied, whence it must be assumed that they have contracted.

If we examine the mud deposits left by the drying up of any body of water, we will find a net-work of cracks, often of considerable size, which undoubtedly result from the contraction of the mud as it dries. So we find cracks and fissures in lava masses which have cooled on the surface, but when these rocks have consolidated away from the contact of atmospheric agents, and under the pressure of a considerable volume of superincumbent beds, as is the case with the greater portion of the rocks which form our mountain masses, it is by no means certain that actual cracks or fissures would have formed. To determine the probabilities under such conditions we need to know by experimental demonstration more in regard to the effect of changes of temperature and of pressure on the internal structure of rock masses than we now do.

In my own experience I cannot recall any important crevices or fissures which I could feel assured were the result of contraction alone. I can conceive that within the mass both of sedimentary and of eruptive rocks, planes of weakness or joints, of relatively small extent, might be formed under the influence of contraction which would be in the nature of cleavage planes; such planes or joints, like the cleavage planes of crystalline masses, would require some exterior force to bring them prominently into evidence, such as dynamic movements or the action of atmospheric agents or "weathering." Their form would vary with the differing constitution of the various rock masses in which they were developed, and this peculiar form would constitute what is generally known as the characteristic fracture of a given rock mass.

If actual cross-joints are developed by contraction alone, they must necessarily be confined, as such, each to the bed or rock mass in which it is developed, since the coefficient of contraction of rock masses of differing composition must vary with that composition. Hence, giving the widest scope to contraction as a producer of ore-bearing channels, it could only result in the production of what is known as gash veins, and not to more extended planes which pass through different rock masses, and which, when mineralized, produce what are generally termed fissure veins.

CLASS 4. *Planes produced by dynamic movements.* Generally cross-fractures and fault or slip planes.

The term "dynamic" (from the Greek "δύναμις"-force, power), is generally applied to that branch of geology which treats of the forces which have produced the various changes in the earth's crust from its original formation to the present day. In my idea it should be applied rather to the mechanical and physical than to the chemical changes, though the latter may often be so intimately connected with the former as to make an entire separation difficult.

The dynamic movements, of which I speak above, are certainly mechanical, the modern earthquake being the only manifestation of them which we can observe at the present day. It is these dynamic movements that have produced the unconformities which serve as datum points in the history of the formation of the earth's crust. This history, for a given region, represents a succession of periods of comparative rest during which sedimentary formations were accumulated at the bottom of the ocean, alternating with periods of disturbance during which these beds were compressed and folded, gradually forced above the sea-level and made into dry land; during the succeeding quiescent epoch these would themselves be abraded and worn down by erosion to furnish material for the formation of a new series of sedimentary beds in the seas or oceans adjoining this newly made land; these new beds would in many places be deposited at unconformable angles along the flanks, or even overlapping the eroded edges of the upturned strata of earlier epochs, thus producing the unconformities which enable us to determine the geologic age of the movement.

It will be observed that each series of beds that have been consolidated must partake of all of the dynamic movements that succeeded its formation, and thus the older rocks will have experienced several series of dynamic movements.

As modern earthquakes are often accompanied by the eruption of igneous rocks, so these earlier dynamic movements were often accompanied by eruptions, which in some cases reached the surface like modern volcanoes, but in others consolidated, before reaching the surface, in the form of intrusive masses or sheets.

The mechanical working of these dynamic movements can best be conceived as an enormous tangential pressure acting mainly at right angles to certain already determined orographic lines, assumed to be lines of weakness or least resistance, and in part also in the direction of these lines; in other words according to the so-called "contraction theory," as a tangential contraction of the outer layers of the earth's crust, due to the general shrinkage of its mass resulting from its secular cooling.

The most readily apparent result of this contraction or compression is seen in the anticlinal and synclinal folds in which the beds forming our mountain ranges are involved. Next to them are the great fault movements by which a whole succession of beds are broken across and moved past each other, a displacement in some cases measured by thousands of feet. Such faults can often be found to pass at one or both ends into folds, hence it may be assumed that they are the result of an extreme tension or compression along the given line which, after the limit of plasticity, or capability of compression into folds, had been reached, produced an actual fracture and slipping past each other of the rock masses, before the strain upon them could be relieved.

In masses as rigid as are the rocks forming our mountains (which have, it is true, a certain degree of plasticity but only under the enormous forces exercised by such contraction) it is readily conceivable that, besides these larger manifestations of the relief of strain, minor folds and fractures will be produced within smaller areas of these rock masses, analogous to them but more frequent and numerous within a given area, and of lesser dimensions; the folds becoming mere undulations in the strata, the faults degenerating into slip-planes or even simple cross-fractures in which little or no movement of displacement can be observed.

As the relative readiness to fold or to fracture must be dependent on the comparative plasticity of the rock masses involved, it will readily be conceived that in regions where crystalline and eruptive rocks form a considerable portion of the crust, as these have much less plasticity than sedimentary beds, the tendency to the formation of faults or cross fractures will be relatively greater; and this conception is borne out by actual observation.

It is a well known fact in geology that the effect of pressure on the internal structure of sedimentary beds is to produce a foliation or arrangement in parallel layers or sheets lying at right angles to the direction of pressure. By analogy, therefore, we might expect that a similar tendency would be observed in faulting, though on a far larger scale, commensurate with the enormous force and larger areas of rock mass involved. Such is found to be the case in nature.

In the case of the larger faults involving movements of many thousands of feet there is in most cases either a system of nearly parallel faults, or the movement of the fault is distributed partially on adjoining planes decreasing in amount from the main fault-plane outwards, thus producing what are called step faults.

In the faults of minor displacement the result will be similar, only on a correspondingly smaller scale, and the parallel sheets, when such are formed, will be proportionately thinner. The relative thickness of these sheets will, however, be necessarily somewhat dependent upon the composition and structure of the rock masses involved. Thus as regards its tendency under great pressure to separate into more or less parallel sheets, or in other words to be broken by a series of more or less parallel planes, the behavior of an unyielding crystalline rock like granite would differ from that of a series of relatively plastic beds of shale. The former would be more likely to be divided into zones of comparatively unaltered rock separated by somewhat widely distanced fracture planes; the latter into thin sheets which would show the effect of pressure by a certain amount of alteration in the structure of the rock composing these sheets.

In the movement of faulting under such conditions of pressure it is further evident that not only will the adjoining rock masses involved in the movement be polished and striated, or "slickensided," to an extent varying in different cases with the physical character of the rocks themselves, but that certain portions of these rock masses will be actually broken or ground off, and carried along to greater or less distances on the fault fissure; when recemented together, such fragments may form a breccia, or, if they have previously been acted upon by solutions so as to round off their edges, they may appear more like a water-worn conglomerate.

It is along such cross-fractures and faults that the so-called fissure veins, that I have thus far had the opportunity of examining, have been deposited. I have gone somewhat at length into the structural conditions which have produced them, because I have found that those who are exploiting these deposits are often led into error through the want of proper conception of these conditions. They still cling to the old idea that a fissure vein was necessarily once a large open cavity with practically parallel walls, which has been filled in by vein material entirely foreign to the wall rocks. They have a superstitious reverence for a wall with a clay gouge or selvage, and in some cases are unhappy if they cannot trace such a wall continuously along both sides of their deposit. In other cases I have found them religiously following a given wall, which consisted simply in the filling, by a seam of quartz or spar, of the narrow opening between two of these parallel sheets of rock formed by the faulting action, while their vein material was merely the alteration of the sheet or zone of country rock on one side of this seam; happy in the possession of this well-defined wall, they had never cut through it to see if the corresponding zone or sheet on the other side was not mineralized and replaced by rich ore as well as the one they were working.

In none of these veins have I found any evidence that there existed previous to the deposition of the vein materials any considerable open cavity. Seams of spar or quartz about a half inch in thickness represented to my eye the average space left between the parallel sheets; sometimes associations of minerals entirely free from the constituents of the country rock were found in thicknesses of a foot or more for short distances, and may have been the filling of cavities left by irregularities in the opposite walls as they moved past each other in the original movement of faulting. The bulk of the material was, however, a more or less complete replacement of the country rock by vein materials. Much of it, of course, showed nothing that could be distinctly recognized as having been originally part of the bounding rock, but by close observation of the bounding planes one could trace its continuance along the strike into material where such evidence could readily be found.

It must not be assumed that all the deposits examined presented uniform and similar conditions; on the contrary, no two were exactly alike, but in all cases was there evidence, in a greater or less degree, of a certain amount of displacement along certain planes, shown either by striated faces or by brecciated material, recemented in mostc ases by vein materials, or by more or less sheeting of the country rock, wherever cross-cuts had been run sufficiently far into the hanging or footwall to reach a subordinate parallel plane. Such planes were often barren of pay ore, but generally showed a certain amount of mineralizing action along them.

Again, in some cases mineral deposition followed pretty regularly one central plane or set of planes for long distances, but sooner or later there would be a tendency for it to accumulate on one of the adjoining planes; in other cases the deposition of rich ore would change from one plane to another with great frequency. In this respect I could formulate no rule except that of an entire absence of any system that could be counted on, and the practical necessity of frequent cross-cutting to determine whether or no the adjoining planes were mineralized. In other words, that the well-defined wall upon which the honest miner so prides himself is likely to prove a deception and a snare if he persists in the belief that it constitutes necessarily what he calls the "true" hanging or foot wall, as the case may be, for any great distance, without actual proof by cross-cutting of the barrenness of the ground beyond.

Not all water passages produced by faulting, however, necessarily produce fissure veins, that is, sheet-like deposits whose length is far greater than their width. There may be cases where by the crossing of three or more faults a considerable zone of the country rock may be shattered and broken up into fragments, thus admitting the free passage of waters through this zone. In such a case the ore-bearing solutions would fill the interstices between

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these fragments, and, if the rock material were readily attackable, gradually eat into these fragments, round off their edges, and surround them with more or less concentric deposits of vein materials, as in the Bull-Domingo mine at Silver Cliff, which is such a deposit in an easily attackable Archean gneiss, or in the case of a still more readily soluble country rock, like limestone, replace the whole shattered zone by vein material, as at Eureka, Nevada.

On the theory that the majority of our ore-deposits are formed by the more or less complete replacement of the country rock by ore-bearing solutions acting upon these country rocks along one or more of the above enumerated natural channels, and not by the filling-up of already existing open cavities whose size limited that of the ore-body to be placed in them, it will be seen that the relative attackability of that country rock is a potent factor in determining the size of the deposit. The form of the ore-body in any given rock mass is, however, mainly dependent upon the structural conditions that have produced the water passages along which the solutions may circulate, and it is evident that definitions or classifications of ore deposits founded on form alone, or even in great degree, such as are found in most writings on ored-eposits, is pernicious and misleading, especially when important questions of ownership are to be settled on the basis of such definitions, as is constantly occurring in our courts; for one and the same ore-bearing solution, that is, one that has probably been a constant and continuous current, may, if the structural conditions are such as to admit it, produce in one part of its course a bedded deposit or blanket vein, in another a contact vein, and in still another a fissure vein.

In Leadville for instance, we have the two latter in the immediately adjoining claims of the Iron mine and the Silver Cord; the former being a typical contact deposit between intrusive porphyry and limestone; the latter a series of deposits in vertical fissures, which have broken across not only the Blue or Lower Carboniferous limestone, but also the underlying Silurian formations, the Parting Quartzite and White limestone.

These fissures, although, as far as I am informed, not accompanied by any considerable displacement or faulting, are probably the result of the same strain or compression which has produced certain minor folds or corrugations in the beds, whose axes follow the prevailing direction of the rich ore-bodies.

In Aspen on the other hand, which has become famous for the mining litigation which has seriously retarded the development of an entire mining district, a somewhat hasty examination would lead me to the opinion that one and the same ore current has produced in closely adjoining claims what under the old definitions might in the one case be called a bedded deposit, in the other a fissure or gash vein, since the ore currents have in the one apparently followed stratification planes exclusively, in the other in part also cross-fractures or fault planes.

Leaving aside the question of definitions, it is evident that, not only in the same mining district, but even in the same claim, a combination of two or more of the above enumerated classes of water channels may have been instrumental in producing the ore deposits that are found there. In the complicated forms that may result in what is practically the same deposit, since it must have been formed by the same or similar ore-solutions, it may be very difficult for the eye not trained by a long study of earth movements and the resulting geological phenomena, to trace out the different water channels and their causes. There are, however, many cases in which the conditions are comparatively simple, and in which, provided one divests himself of preconceived theories which run counter to this simple explanation of the phenomena, an examination of the deposits and enclosing rocks, especially the transition zones between pay ore and barren country, will readily show the applicability of some of the above mentioned conditions of ore-deposition.

I will briefly mention certain deposits which have recently come under my observation, where the character of the ore-bearing channels can readily be distinguished.

Of deposits formed exclusively along stratification planes good examples may be found in the Ten-Mile and Red Cliff districts. In the former, the dividing planes between different limestone beds of the upper Carboniferous formation and overlying shaly sandstones have been favorite channels for ore-bearing solutions, which have eaten downwards from this plane into the underlying limestone body. The deposits of the White Quail, Aftermath, Milo, Badger, Wintergreen and many other mines are typical instances of this form of deposit. The Wintergreen deposit is also of especial interest as giving such unmistakable evidence that the manner of deposition has been a replacement or substitution, particle by particle, of limestone by metallic sulphides. In the incline the blackened and dust-stained walls retain every semblance of a limestone; the bedding planes of distinct beds, from three inches to a foot or more in thickness, and even cross-joints, are still perfect, but on breaking off a fragment, the rock is found to be a solid mass of fine grained pyrite. For 150 feet down the incline, which follows the dip of the bed, it replaces the entire thickness of the limestone (16 to 22 feet). For the remaining 150 feet which have been opened, the ore-body is only a foot or two in thickness, but continuous along the roof, while the foot wall, or under side of the deposit, forms an irregular transition from solid pyrite to unreplaced limestone.

At Red Cliff the Iron Mask, Black Iron and a multitude of other mines have deposits between the Lower Carboniferous or Blue limestone and an overlying bed of shale. There are also deposits in the underlying Cambrian quartzites, whose ore-bearing solutions have generally followed stratification planes in the quartzite itself, but some of these are complicated by cross-joints and possibly by eruptive contacts.

Of deposits along contact planes of eruptive bodies those in the Blue limestone at Leadville are striking examples. In most instances these contacts accord more or less closely with the stratification planes, in others they cross these at varying angles. As mentioned above, these are sometimes associated with deposits along cross-fractures or slip-planes. The deposits in other rocks than limestone often present other types, but are not always so easily recognizable.

Of contacts of eruptive bodies with crystalline rocks frequent instances are to be found in the deposits in the Archæan rocks of Clear Creek, Gilpin and Boulder Counties. As they generally lie in a nearly vertical position there is a disposition on the part of the owners to insist on calling them "fissure veins," because of the old popular prejudice that a true fissure vein is more valuable than any other form of deposit. That this predilection for fissure veins *is* a popular prejudice I think must be admitted, if the general truth of the propositions laid down in this paper be agreed to, for, according to them, the particular form of the deposit is merely the result of structural conditions prevailing in a given region; the richness and abundance of the ore-bearing solutions, and the relative readiness of the country rock to induce a precipitation from those solutions, are far more important factors in producing a valuable and extensive ore-deposit than the mere form that the channels, through which they must pass, lead it to take.

Of deposits formed along contraction planes I can cite no typical instances, since, as I have said before, I know of no large fractures which I could be sure were produced by contraction alone; while I have certain deposits in mind which might in part have been induced by water passages resulting from contraction, I feel as yet too uncertain in regard to this point to be willing to commit myself to any written statement in regard to them.

Of deposits along water channels evidently produced by dynamic or earth movements, on the other hand, and to which the common term, *fissure vein*, is, in my understanding of it, properly applicable, I will cite a few of what occur to me at the moment as proper exponents.

In that portion of Gunnison County lying on the west slope of the Elk Mountains which is tributary to the town of Crested Butte, may be found a great number of veins which show the typical fault-fissure structure. The greater part of the mountains here are formed of Cretaceous strata, consisting in large proportion of argillaceous members, broken through in every direction by eruptive bodies belonging to several distinct periods of eruption, which correspond probably with as many different series of dynamic movements. In consequence the country rocks are broken by innumerable cross-fractures, most of which are actual fault planes, but in which the movement of displacement is generally of limited extent. Most of these planes are found to be more or less mineralized. The vein material of the principal deposits shows in large measure a banded or sheeted structure, and a considerable proportion may be a breccia composed of small fragments of the country rock cemented by metallic minerals and spar or quartz. The sheeting or lamination of the country rock is very finely divided when the fault runs through the more plastic rocks, less so as a rule in the eruptive bodies. Hence what might be called *blind walls*, that is, seams of mineral filling the narrow fissure between the adjoining sheets of what were once country rock, but which may or may not be replaced by vein material, are very frequent, and those miners who blindly follow the old fashioned ideas without doing sufficient cross cutting may readily be led into error. Thus in the Forest Queen mine a drift may be seen following a comparatively barren seam for three or four hundred feet in hard porphyry, and all the time within four feet of a fine ore body lying parallel to it, which was only discovered when those driving the drift had become quite discouraged.

In my former paper I mentioned the Sheridan-Smuggler vein in the San Juan region as an instance of a deposit upon a fault-fissure which can be traced on the surface for a long distance, and hence may be assumed to extend to a correspondingly great depth. The Yankee Girl mine in the same region appears to be an instance, like the Bull-Domingo of Silver Cliff, already mentioned, where a series of three or more fracture planes crossing each other produce a shattered zone between their intersections. Ore-bearing solutions percolating through such zones produce what are commonly called "chimneys" whose horizontal outlines are generally represented as more or less rounded. This might at first sight seem inconsistent with areas formed by the intersections of three or more vertical planes with a horizontal plane, which must necessarily be polygons. It must be borne in mind, however, first: that what is taken out for ore is not necessarily the whole of the mineralized body, but only such part as constitutes pay ore for the time being, and the outline given on the map may not exactly represent that of the mineralized zone. Second: that the greater the number of sides to the polygon, or the greater the number of intersecting planes which produce it, the nearer it will approach a circle; and finally: that the tendency of solutions acting on a rock mass is to round off all angles.

The Queen of the West mine in the Ten-Mile District presents an instance of fault-fissure which seems at first very complicated, for the reason that the fault-planes cross a series of sandstones and intrusive or interbedded sheets of porphyry so that the vein material is the replacement, now of porphyry, now of sandstone or shale. Under the wise management of the present owners of the mine, cross-cutting has been carried on very freely, and frequent opportunities are consequently had of observing the parallel fissuring of the country on either side of the central zone or principal planes where ore-deposition has been most active. The fact that the fault-planes are not at right angles to the bedding-planes, and that the dip of the latter apparently varies from one part of the mine to another renders the reading of the structural history of this deposit rather difficult.

The famous Ontario mine in Utah affords an instance of deposits along fault-planes in which the conditions differ somewhat from any thus far described, but they are so complicated I do not feel justified in taking enough more of your time to describe them.