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CONTAINING THE PAPERS AND DISCUSSIONS OF 1901, EXCEPT
THOSE WHICH RELATE TO THE MINERAL RESOURCES
AND INDUSTRIES OF MEXICO, WHICH WILL BE
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6. Zeolitization is also produced by silicic acid, but under different conditions (probably, as a rule, by a solution containing silicates of sodium, potassium, calcium and aluminum).

7. Intense contact-metamorphism involves a recrystallization under high pressure, with penetration by heated aqueous vapor, and is, *per se*, accompanied by a comparatively subordinate change of material. Sometimes, however, it occurs in connection with ferrification, silicification, tourmalinization or axinitization, etc.

8. The formation of alum-stone or alunite is chiefly effected by the penetration into the rock of a solution of sulphuric or sulphurous acid.

Frequently several of the above agencies operate in combination, rendering the results more complicated.

IV. DIFFERENCES OF DEPTH IN THE ORIGINAL POSITIONS OF EPIGENETIC DEPOSITS; AND THE SECONDARY ALTERATIONS OF DEPOSITS.

The attention of both miners and geologists was long ago drawn to these theoretically interesting and economically important problems; yet only in recent years have they received thorough and comprehensive treatment. The valuable contributions made to the *Transactions* of this Institute by Don, Emmons, Rickard, Posepny, Van Hise, Weed and others, are familiar to its members, as well as the work of R. A. F. Penrose and his associates of the U. S. Geological Survey, and other American observers. Much may be learned from the recent treatise of our celebrated professional colleague, Prof. L. de Launay.*

These two phenomena—namely, the original differences of depth connected with the formation of ore-deposits, and the secondary alterations of such deposits, occurring often, perhaps even millions of years later—are in many cases, as genetic factors, very widely separated; yet it may often be difficult to decide what is to be referred to the primary and what to the secondary process. Partly for this reason, and partly because, as Van

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* "Les variations des filons métallifères en profondeur" (*Rev. Gén. des Sci. Pures et Appliquées*, xi., 1900; discussed by P. Krusch in *Zeitsch. f. prakt. Geol.*, Oct., 1900). See also De Launay's *Contribution à l' étude des gites métallifères* in *Ann. d. Mines*, 9 Série, vol. xii., p. 119 (1897).

Hise's last paper shows, the two factors go, in many localities, hand in hand, I think they may be, with advantage, discussed together.

Original Differences of Depth.

In considering the original differences of depth, it must be kept in mind, as De Launay has pointed out in the treatises just cited, that the present surface is, in general, very far below the surface existing at the time of the ore-formation. The geological investigations of recent decades have shown that the work of denudation (or abrasion or erosion) must be measured on a larger scale than was formerly suspected. In the Archean and Algonkian mountain chains (now often removed by this agency down to their base-level), and also in the Paleozoic ranges (showing, as a rule, the effects of extremely energetic denudation, as, for example, the Ural and the Norwegian mountains), the difference between original and present levels is to be generally reckoned, not in such units as 0.1, 0.25, 0.33 or 0.5 kilom., but rather on the scale of 2, 3, 4 or 5 kilom., or even more. Even in the Mesozoic and Tertiary, many denudations of astounding depth have been recognized.*

In many epigenetic ore-deposits of Archean-Algonkian or Paleozoic origin (*e.g.*, Kongsberg, Cornwall, Przibram, the Keweenaw peninsula at Lake Superior) mining has been carried

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* As instances of great denudation, the following may be named:

On the E. side of the Kristiania fiord, in Norway, this process has removed, (1) a series of Devonian conglomerates and porphyry overflows, with Silurian and Cambrian rocks, of an aggregate thickness (according to W. C. Brögger, *Nyt. Mag. f. Naturv.*, vol. xxxviii., for 1900) of 2500 meters; (2) also a large part of the Archean surface—first, during the long period preceding the Cambrian, and again after the removal of the Cambrian, Silurian and Devonian strata. This thickness must also be measured in thousands of meters; so that we have here at least 4000, perhaps 5000, 6000 or even more meters of thickness removed.

The fiords of the W. coast of Norway are often 1.5, sometimes 2 to 2.25 kilom. more deeply eroded than the adjoining high plateau; and the latter frequently consists of deep eruptives, without any remains of the extensive overflows—showing that on the plateau a very extensive denudation, probably to be measured in kilometers, has taken place.

In the Aspen silver-district, Colo., 5 kilom. of strata (according to Spurr) have been removed by erosion from a range of Tertiary origin. (I quote from Krusch's review of De Launay, *Zeitsch. f. prakt. Geol.*, 1900, p. 317.)

In California, according to Lindgren, denudation has extended to a depth of 500 to 1500 or more meters. So far as I know, this denudation has taken place since the beginning of the Cretaceous period.

Numerous other similar instances could be easily adduced.

to depths of 0.75, 1 to 1.25, and 1.25 to 1.5 kilometers. Taking the depth roughly as 1 kilom., and assuming that in some districts the present surface has been denuded 3, and in others 4, kilom. below the surface at the time of the ore-formation, we may say that mining has reached a depth of 3 to 4 or 4 to 5 kilom. below the original surface.

These figures are, of course, somewhat arbitrary; but modern investigations of the extent of denudation justify us in saying that they are not too high for some districts belonging to the ancient geological periods above named.

It may be observed, also, that in many deposits of deep and geologically old origin, the deepest portions of the mines have shown no change in the nature of the fissure-formation. Occasionally, as at Przibram, Bohemia, and Dolcoath, Cornwall, the richest ore-bodies have been encountered in the deepest mine-workings.

We conclude, then, that, under favorable circumstances, the ore-veins may continue at least to a depth, below the original surface, of 3, 4, 5 or more kilometers.

In opposition to this view, Prof. Beck declares* that he has come to the opinion

> "That ore-veins, and mineral veins generally, can by no means extend to great depths, geologically speaking. . . . Even if we could assume the existence, at a depth between 4000 and 6000 meters, of fissures filled with water, it would be inconceivable that, at that depth, mineral deposits could be made from solutions."

I believe, notwithstanding, that future determinations of the extent of denudation, together with the mining of many deposits to the depth of 1.25, 1.5, or even, perhaps, 2 kilom. below the *present* surface, will prove that Prof. Beck's conclusion is not correct.

It may also be remarked, in passing, that mineral deposits may be made from solutions at above the critical temperature (364° C.) of water—for instance, the deposits of cassiterite, wolframite, apatite, topaz, tourmaline, and even pyrites, in many granite-pegmatite veins.

In his latest treatise, which is rich in new conceptions, De

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* *Lehre von den Erzlagerstätten*, 1901, p. 139.

Launay compares ore-deposits occurring relatively near the surface, in less denuded regions, with those deep below the surface in strongly denuded regions. As instances of the former, he takes the quicksilver-deposits, which occur chiefly in recent rocks, near volcanic eruptives, while from older ranges, partly destroyed by erosion, they have disappeared, with other débris. As instances of the latter class, he takes the pyritic deposits (Röros, Huelva, Schmöllnitz, etc.), which have been found in old mountain-chains or in districts of regional metamorphism, and are to be explained as of deep-seated origin. He also mentions very briefly the lead-silver veins.

Induced by his description, I have already suggested in this paper the hypothesis that the differences between the later gold-silver-lead veins (Nagyág, Comstock, Potosi, etc.) and the old gold and silver-lead veins (Kongsberg, *Erzgebirge*, Harz, Przibram, etc.) may be explained by their formation at different depths. The relative or total absence from the older veins of the propylitization which is so characteristic of the later ones may, perhaps, be due to the fact that hydrogen sulphide (or sodium sulphide), which was a very important factor in this process, could not, under the great pressure due to great depth, make its way from the solutions in the fissures into the country-rock.

The later silver-lead veins are, on the whole, richer in silver than the older ones. This may be connected with the fact, inferred on physico-chemical grounds by Van Hise, that at great depth lead sulphide separates in larger proportion than silver-sulphide or sulpho-salts. According to this view, the precious silver-veins (carrying relatively little galena and zinc-blende) of recent eruptive ranges become, at a very great depth, richer in galena and zinc-blende. This seems to be sometimes the case. (Instances are given further on.)

This hypothetical view is not contradicted by the fact that many of the older silver-lead veins, as at Andreasberg and Kongsberg, are highly "precious"—*i.e.*, relatively poor in galena and zinc-blende; for this character may be due to the small proportion of lead and zinc in the original vein-solutions.

In view of the range *below the original surface* through which mining is carried on, beginning, not at that surface, but already thousands of meters below it, we may easily see that, in many districts, the directly observable differences in original depth have little significance. For instance, at Kongsberg there is no difference in the character of the veins from the present surface to 0.5–0.75 kilom. below it.

In other districts, however, very important differences of original depth have been established. For instance, these differences were very distinct in many Cornish mines, where the veins carried: (1) at the uppermost level (in the tin-bearing gossan) tin-stone and a little copper-ore (the latter as the result of a secondary process, the original sulphides having been mostly leached out of the gossan); (2) their copper-ore, with some tin-stone (in the Dolcoath mine, to the depth of 0.3 to 0.33 kilom. below the present surface); (3) still deeper, first, a zone of mixed tin-stone and copper-ore, and under that almost exclusively tin-stone. The veins traverse, in depth, chiefly granite; at higher levels, slates. But zones 2 and 3 are not confined to either rock. In this case, then, the tin-stone was originally deposited at a greater depth than the copper-ore.

In many silver-lead-zinc veins there is an increase in the proportion of zinc-blende with depth. The Clausthal veins, and many in Mexico (Pachuca, Zacatecas, etc.) are instances. In the latter, very important differences in the depths of original deposition are often observed. (1) Near the surface are very rich silver-ores (the so-called *colorados*, containing cerussite with chloride, bromide and iodide of silver, and native silver), the richness of which is the result of secondary processes.* (2) Below these, after an intermediate zone of transition, appear for the first time the so-called *negros* ores—galena, silver-glance, silver sulpho-salts, etc.; and (3) in the deep workings, say 0.5 kilom. below the present surface, the so-called *fuego*-ores,† carrying much zinc-blende and galena, with a scanty admixture of true silver-ores. It is possible that the Tertiary Mexican veins have in depth a character resembling that of the older rather than that of the younger group described in a previous part of this paper.

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* According to the Mexican geologists and miners at the Paris Exposition of 1900, these ores extend, as a rule, very little below the ground-water level.

† That is, "fire"-ores, or, in other words, smelting-ores. The surface-ores are treated by amalgamation.

With regard to the increase of zinc-blende in depth, which has been observed in many places, I have already observed that Van Hise, in his last paper, concludes upon theoretical grounds that from an ascending solution containing zinc and lead, the zinc sulphide would be deposited lower down than the lead sulphide. In many veins carrying copper and iron sulphides, the richest copper-ores are found at the higher levels. As Emmons and Weed have shown for the Butte district, this is in numerous cases the result of a secondary process. In sundry localities, however, the influence of original differences of depth may be recognized. This is the case, for instance, at Vigsnäs in Norway, where the ore, a fine-grained mixture of chalcopyrite with pyrite, occurs in several (about seven) nearly vertical "stocks." In the upper levels the pyritic mixture carried easily 3 to 4 per cent. of copper; at the depth of 735 meters the thickness of the mass was, on the whole, tolerably well maintained; but the copper-content had sunk to about 1 per cent., or a trifle more.

A corresponding phenomenon is not presented, however, by the flat-lying pyritic masses or "lineals" at Röros, which dip respectively 9°, 9° and 15°, and have been worked in these dips to distances of 1080, 1350 and about 2000 meters.

In the pyritic deposit at Huelva (at Rio Tinto, Tharsis, etc.) the secondary concentration in the "zone of enrichment," immediately below the "iron hat," plays a very important part; but there appears to be, besides, a primary distribution according to which the copper diminishes as depth increases.*

According to many American reports, there are also in the United States and in Chile many known instances of the deposition, from an ascending ore-solution, of pyrite and chalcopyrite, in which the former was, to a considerable extent, deposited deeper than the latter.

Not only in the sulphide-ore deposits, but also in those of iron and manganese oxides, primary differences of depth are recognized. Thus at Romanêche in the Department of Saône et Loire, France, the ore-deposits, occurring in granite, consist of psilomelane (named romanechite by Lacroix, on account of its constant considerable percentage of baryta) and specular

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* See *Zeitschr. f. prakt. Geol.*, No. 7, 1899.

hematite, with quartz and heavy spar, a very little fluor-spar, and traces of calcite. The mine is, with one exception, the largest producer of manganese-ore in France. For our present purpose, the interesting feature is the change of proportion, at different levels, between psilomelane and hematite. Above, the psilomelane predominates; going down, the proportion of hematite increases with considerable regularity. During a visit which I made in the summer of 1900, together with my friend and colleague, Prof. L. de Launay, Mr. L. Chamussy, the director of the mine, called our attention to the fact that this relative increase of iron-ore in depth is found in many manganese-deposits. His explanation was, that the solution containing manganese and iron compounds came from below, and the ores were precipitated mainly through oxidation by the oxygen of the air contained in surface-waters; that iron thus oxidizes more easily (*i.e.*, sooner) than manganese,* and therefore, on the whole, the larger proportion of iron-ore would be deposited lower than the manganese. This seems to me quite plausible.†

Secondary Alterations of Ore-Deposits.

Concerning the secondary alterations more or less directly connected with surface agencies, I would observe, first, that such phenomena have very little importance in the Norwegian and Swedish deposits, which are generally found in very solid rocks, such as gabbro, gneiss, granulite, mica-slate, phyllite, etc. The occurrrences of magnetite, specular hematite and ilmenite show, as a rule, no trace whatever of a zone of weathering—except that here and there apatite has been, to a slight extent, leached out. The dense, massive magnetite resists

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* That from a solution containing protoxides of iron and manganese (*e.g.*, in carbonic-acid water) iron is precipitated by oxidation before manganese has long been known. The literature of the subject is given in my work "*Salten og Ranen*" (1890–91), in which a geological application of this order of precipitation was attempted. See also *Zeitschr. f. prakt. Geol.*, 1894, p. 33, and 1895, p. 39; also "The Chemical Relation of Iron and Manganese in Sedimentary Rocks," by R. A. F. Penrose, *Jour. of Geol.*, 1893, vol. i., p. 356.

† I regret that this contribution must be prepared for publication in such haste that I have not time to obtain by correspondence further details concerning this primary difference of distribution in the manganese-deposits. Nevertheless, I venture to give here the above theoretical explanation.

even denudation, so that, for instance, the extraordinarily large deposit at Kirunawara-Luossawara, in northern Sweden, forms a real "iron mountain," rising about 100 meters above the surrounding rocks. The same is true of the Taberg, a mountain of titanomagnetite-olivinite, in southern Sweden. Even the pyritic deposits, like Röros, Sulitelma, Vigsnäs, etc., and the nickel-pyrrhotite deposits, like Erteli, 5 to 10 meters in thickness, show a zone of weathering seldom more than one or two meters deep. At Fahlun, where the pyritic mass was very wide, the "iron hat" was probably deeper.

This insignificance of the secondary alterations, even in the pyritic deposits, is probably due to two chief causes: (1) that the surface was polished clean by the Quaternary ice-sheet; and (2) that the solidity of the country-rocks has permitted very little circulation of water.*

In sharp contrast stand the thick pyritic deposits of Rio Tinto, etc., in the Huelva district, where the "iron hat" extends to 35–50 meters. Here the Quaternary ice-period was lacking, and the country-rocks were much more porous than in the corresponding Scandinavian formations. Concerning these secondary alterations, I would refer to an earlier work of my own, which is mentioned, among others, in the papers of Messrs. Emmons and Weed. Especially noteworthy here is the re-formation of rich sulphides in the "zone of enrichment," and the very characteristic re-formation in Mass II., at Rio Tinto, of a narrow zone, rich in gold and silver, on the boundary between the "iron hat" and the underlying pyritic mass.

Concerning the chemistry of the secondary alteration of ore-deposits I can add little, in this hasty review of the subject, to the excellent discussions of Don, Emmons, De Launay, Penrose, Van Hise, Weed and others.† Especially interesting are

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* I know several deep mines in Norway, in which the lowest pump-station is only about 250 meters from the surface. In one of them, water for use in drilling below that level has to be carried down.

† I will only introduce some observations upon the solvent effect of the ferric salts, $Fe_2(SO_4)_3$ and $FeCl_3$, upon sulphide ores. To test this point, I made in November, 1896, the following experiment:

Samples of 6 grammes each of pulverized chalcocite, bornite, chalcopyrite, pyrrhotite and pyrite were separately treated in Erlenmeyer jars, 100 cub. cm. of neutral aqueous solution containing 30 grammes of $FeCl_3$ being poured upon each sample, after which they were allowed to stand quietly at the ordinary the proofs furnished of late years from North America that secondary alteration often extends far below the ground-water level and the re-formation of sulphides in the zone of enrichment, investigated especially by Emmons and Weed.

I would here refer to the collection of specimens from the gold-district of West Australia which was exhibited last year at Paris under the direction of Mr. A. G. Holroyd. That the gold of many localities had been first dissolved, most probably in $Fe_2(SO_4)_3$, and afterwards precipitated, could be clearly seen in a whole series of specimens.

1. From the zone of weathering in many veins were shown small and exquisitely beautiful crystals of gold, sitting upon

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house-temperature of about 14° C. After a few weeks the chalcocite was almost entirely dissolved, and the bornite had been very strongly attacked. On the other hand, at the end of nine months the chalcopyrite was affected but slightly, the pyrrhotite a little more, and the pyrite not at all.

At the present time, after the lapse of 4 years and 1 month, the chalcocite and bornite have long been completely dissolved; the pyrrhotite is almost all dissolved; the chalcopyrite has been somewhat further affected (by far not so much as the pyrrhotite), and the pyrite has been attacked, though very slightly. From the first four, and probably also to a small extent from the pyrite, sulphur has separated. The filtrates from the chalcocite and bornite showed with $BaCl_2$ a weak trace of H_2SO_4; that of the chalcopyrite a somewhat stronger trace; and that of the pyrite a trace stronger still, yet, after all, amounting to little. The formula is:

$Cu_2S + 4FeCl_3 = 2CuCl_2 + 4FeCl_2 + S$, or $Cu_2S + 2Fe_2(SO_4)_3 = 2CuSO_4 + 4FeSO_4 + S$.

Weed gives the formula thus:

$Cu_2S + 5Fe_2(SO_4)_3 + 4H_2O = 2CuSO_4 + 10FeSO_4 + 4H_2SO_4$.

In the reactions with Cu_2S and CuS, however, the sulphur does not appear to be oxidized to sulphuric acid, though this occurs in subordinate degree in the reactions with FeS and FeS_2.

The above experiments were made, as stated, at ordinary house-temperatures. At higher temperatures the process is very much more rapid. I was present in 1893 at an experiment in the Siemens-Halske metallurgical testing-laboratory at Berlin, when pulverized unroasted pyrites from Rio Tinto, containing 3 per cent. of copper and nearly 50 per cent. of sulphur, was stirred in a weakly-acid solution of ferric sulphate (50 grammes of iron to the liter), at 80°–90° C. After 6 hours, the percentage of copper had been reduced to 0.4. Zinc-blende is also attacked, though not as strongly as chalcopyrite. These reactions are metallurgically utilized in the Siemens-Halske electrolysis of copper-ores, and in the present leaching of pyrites at San Domingo, Tharsis, etc., in the Huelva district.

Metallic silver also is very rapidly attacked by $Fe_2(SO_4)_3$. Gold will be considered below.

Pyrite is one of the commonest minerals in sulphide-deposits; its weathering yields $Fe_2(SO_4)_3$, which plays an exceedingly important part in the secondary alteration of ore-deposits, as I have shown in earlier publications.

cobalt-manganese-ore (asbolite), which is unquestionably a secondary mineral, yet older than the gold which has been precipitated upon it.

2. In many samples from gravels or placers, gold could be seen in small breaks in iron-ocher, limonite, etc.

3. Gold appeared also in stalactites, or "drip-stones," consisting chiefly of iron-ocher and calcite. In this case the gold was unquestionably in a ferric solution.

4. Again, gold from various localities was seen as a very thin tarnish, "breathed," as it were, upon the pebbles of the placer-conglomerates.

5. Several tree-roots were exhibited, upon which gold was sitting.* Here the gold had been reduced or precipitated from solution by organic substances.

6. Finally, gold was to be seen, in several cases, in fine cracks in the dried clay of the placers, into which it had percolated while dissolved, to be precipitated as a thin coating upon the clay.

I am aware that series of similar instances have been described already from America, Australia and South Africa; but I have dwelt upon these new exhibits from West Australia because they plainly show that the solubility of gold may play a *quantitatively* important part.†

The same collection showed beautifully the weathering of the telluric gold-veins of Kalgoorlie. The mines, as is well known, carry in depth (down to 1150 feet, in the year 1900) very rich gold-tellurides (calaverite, sylvanite, kalgoorlite, petzite), sometimes in masses of extraordinary weight (50–100 kilog).‡ In the neighborhood of these, the ordinary phenomena of flake-, sheet- and wire-gold are often found, the native gold being sometimes, intergrown with the telluride mass, and sometimes independent of it. In the highly oxi-

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* The label read: "Great Boulder Main Reef. Root of tree, found at 70-ft. level. Two pieces of wood, with gold-deposition. (Very rare.) W. A."

† The platinum metals, on the contrary, are to be regarded as practically insoluble by the chemical reagents encountered in nature. See note on p. 131.

‡ I will not enter here upon the discussion of so many years' standing concerning the "mechanical" *vs.* the "chemical" origin of gold-nuggets in placers. (Notwithstanding the solubility of gold, I adhere to the "mechanical" explanation.) But I may say, in passing, that in West Australia the masses of gold-tellurium found in the veins are as large as the placer-nuggets of other regions.

dized upper vein-zones, the gold-tellurides have been entirely decomposed, metallic gold and derivative compounds of tellurium being formed,* and this metallic gold, appropriately called "sponge-gold," "mustard-gold," etc., could be easily distinguished by its peculiar structure from the native gold occurring in depth. This is an indication that the deep native gold is not a secondary formation from gold-telluride, but a primary metallic precipitate. Secondary alteration thus helps us to decide a question which has been discussed for many years, especially in Austria-Hungary, where each of the views just stated has been held by many observers.†

It is well known that in numerous ore-deposits, all over the world, unusually rich ore-bodies have been formed by secondary processes more or less directly connected with the surface. We need mention only Pachuca and Zacatecas, in Mexico; Pasco, in Peru; Potosí and Oruro, in Bolivia; Chañarcillo,‡ in Chile; Broken Hill, in Australia; Mednorudjansk, in the Ural, etc. Our knowledge of the secondary formation of very rich bonanzas is now specially enlarged by the investigations of Emmons and Weed on secondary sulphide-enrichments below the ground-water level, as at Butte, Montana.

Since in the development of science it has been so often seen that new ideas or impulses are liable to be overestimated, I will here add that there are innumerable rich "shoots," "chimneys," "*edle Säulen*," "*Adelsvorschübe*," "bonanzas," etc., which have nothing to do with secondary processes, being of exclusively primary character, and dependent upon the laws which governed the original ore-deposition. I may cite as examples Kongsberg, Andreasberg, Schemnitz, the rich shoots in the Transylvanian gold-veins, etc. And my study of the literature

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* The same is known to be true of Cripple Creek.

† On other grounds, I have formerly expressed my adherence to the latter view—namely, the primary character of the ordinary native gold of the deep zones. *See Zeitschr. f. prakt. Geol.*, 1898, p. 418; 1899, pp. 179–180.

‡ See F. A. Moesta, *Ueber das Vorkommen der Chlor-, Brom- und Jodverbindungen, u. s. w., besonders in Chili* (1870). He points out that at the outcrop of the silver-veins of Chañarcillo, etc., the relative proportions of chlorine, bromine and iodine to one another are about the same as in sea-water, to the percolation of which he attributes the formation of these haloids. The explanation given by R. A. F. Penrose (*Jour. of Geol.*, vol. ii. (1894), p. 34, for the presence of silver-haloids in the arid regions, which connect them with neighboring salt lakes and marshes, seems to me more acceptable.

of the Comstock lode has given me the impression that its famous bonanzas were of primary, not secondary, origin.

The question, What is of primary and what of secondary nature? will doubtless long remain an interesting and often difficult problem for discussion.

POSTSCRIPT.

The foregoing contribution is in many respects much less complete and more fragmentary than I would have it. If, with some hesitation on that account, I have decided notwithstanding to send it to the Institute, it is in the hope that its defects of form will be judged in the light of the fact stated in the introduction, that the manuscript was begun on the 3d and finished on the 31st of December.

I close this work of mine on the last day of the nineteenth century, with a miner's hail, "*Glück Auf!*" to my numerous American colleagues, unknown to me personally, yet well known through their scientific labors, and held in high esteem. Undoubtedly the new century will fill up many defects and solve innumerable riddles and doubts in the science of ore-deposits.

The Rôle of the Igneous Rocks in the Formation of Veins.

BY J. F. KEMP, NEW YORK CITY.

(Richmond Meeting, February, 1901.)

CONTENTS.