

ART. LIV.—*Peculiar Modes of Occurrence of Gold in Brazil;*
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1. NATURAL DEPOSITION OF GOLD FROM SOLUTION.

THE following facts are believed to justify the heading of this paragraph. A specimen (Mus. No. 84) in the National Museum at Rio de Janeiro shows films of gold which are difficult to account for on any other hypothesis. The specimen was received some thirty years ago from the Danish Collector Claussen, with the indication "gold on limonite, Ponte Grande, Sabará, province of Minas Geraes." The formation at this

place consists of hydromica schists with granular quartzites (itacolumite) and itabirite. The region abounds in old alluvial washings and rock mines in quartz, itabirite and pyrite, those in the latter material being the most important. The geological formation at the Sabará bridge is identical with that of the country rock of the great pyrite vein at the celebrated mine of Morro Velho some fifteen miles away.

The specimen in question is about six centimeters square and two centimeters thick, and consists of white vein quartz. A bit of adhering country rock on one margin shows this to have been a very quartzose micaceous schist. Judging from the appearance, the fragment came from one of the ill-defined and irregular lines of quartz which traverse the rocks of this region generally coincident with the bedding. The lower side, which is almost perfectly flat and seems to have rested on a bed of the country rock, is coated with a thin crust of rusty brown limonite and presents nothing of interest. The other side though flattened is more irregular and had evidently formed one of the walls of a narrow open fissure which had become lined with a crust of black botryoidal limonite less than a millimeter in thickness. The greater portion of the polished surface of this crust is covered with an excessively thin varnish-like film of an iridescent bronzy color. Similar crusts, some of them presenting the bronzy film, line the numerous small cavities of the quartz which appear to have been left by the decomposition of pyrites. Still a third crust or film of reddish brown earthy limonite forms a V-shaped streak about five millimeters broad, at one side of the specimen. This film, though very thin, is of appreciable thickness and rests on the polished surface of the black limonite, from which it may be detached in minute flakes by a very slight pressure with a metal point. On various parts of the specimen, but particularly along the whole length of the V-shaped streak, are minute detached films of gold, the largest of which cover a surface equal to about a square millimeter. These gold films adapt themselves perfectly to all the irregularities of the botryoidal surface of the limonite, and under the microscope are seen to be uniform (not composed of distinct grains joined together) and to present a surface like frosted metal work. The character of the surface is precisely like that of the limonite crust of the V-shaped streak, which, unlike that of the black limonite and of the iridescent film, is not polished. Similar films (as regards adaptation to the irregularities of the limonite and character of surface) were obtained by allowing a drop of mercurial ointment to dry on the surface of the specimen.

We have here, therefore, gold resting on the surface of a secondary mineral (limonite), and in such conditions that it

may be compared to films of limonite deposited from an aqueous solution, or of mercury deposited from suspension in fatty matter. It seems impossible to regard these gold films as transported granules simply lodged against the surface. Their perfect adaptation to the surface on which they rest, their almost inappreciable thickness and their uniformity of structure and of surface, whether large or small, are against this view. In order to judge of the probability of this hypothesis I made the following experiment to determine the state in which fine gold occurs in the rocks of the region. A fragment of arsenopyrite assaying about five ounces to the ton, coming from about 500 meters below the surface in the Morro Velho mine, was dissolved in acid. The exceedingly minute specks of gold obtained in the residue are distinctly granular and crystalline. The smallest, an octahedral crystal, measures 0.075 millimeters, while the largest, an irregular group of crystals, is 0.375 millimeters long. The fine gold of São Gonçalo described in the following article, is of the same character. Such grains could not possibly be lodged against the surface so as to produce films of the appearance of those here described.

The V-shaped streak of earthy limonite shows some peculiarities that seem to throw light on the process of introduction of the gold. Its outer margin is distinctly thickened, showing that the iron-bearing solution stood for some time upon it with a tendency to flow onward, causing a piling up of the liquid at the margin and a consequent thickening of the matter deposited from it. As before remarked, the gold is more abundant on this streak than elsewhere on the specimen, and more abundant on the outer than on the inner half of it, as would naturally occur if it had been deposited from a solution which had been for some reason, dammed back, so as to remain for some time on the place of the streak while it slowly evaporated, as the iron deposit proves to have actually occurred. On removing a little of the iron crust similar films of gold are seen resting on the botryoidal surface underneath the streak. These had evidently been formed before the accumulation of liquid from which the streak was deposited. Some of the gold films outside of the limits of the streak were also most probably deposited at the same time and in the same manner. Of these the greater number occur in a considerable patch, slightly discolored with iron, just below the angle of the V, as if the liquid which deposited gold on the streak had flowed over at this point, that of greatest accumulation, on the adjoining surface, carrying a little iron with it.

The facts above noted appear to be susceptible of the following interpretation as regards the course of events in the history of this specimen. In a narrow open slit of a quartz vein con-

taining pyrites, a crust of botryoidal limonite was deposited lining the walls of the cavity. After its formation this crust became moistened with an iron and gold-bearing solution which deposited the extremely thin film of iridescent limonite (?) and scattered films of gold. Afterward a more abundant supply of liquid gathered and rested for some time, or until it evaporated, in a long, narrow V-shaped band, being prevented from flowing on and spreading evenly over the whole surface by projections of the opposite walls of the slit, or more probably by adhesion to the surface of the limonite; as the liquid slowly evaporated it deposited first its iron, thickest at the margin where adhesion would cause a piling up of the liquid, and afterward its gold, which, instead of spreading evenly over the surface, gathered in certain points by a concretionary action. During the deposition of the iron the upper portion of the liquid, becoming lighter than the lower, flowed over at the lowest point where the accumulation was greatest and, carrying with it gold and a relatively small proportion of iron, produced the thinner film of iron with gold below the angle of the V.

2. GOLD IN GNEISS.

Gold, almost universally worked from veins or from debris derived from them, is supposed to have come in some way from the adjoining rocks (Dana's Mineralogy, 5th ed., p. 6), but thus far no case of its occurrence in workable quantities throughout the mass of such rocks seems to have been recorded. Museum specimens of country rock charged with gold are comparatively common but in such cases the deposition of the precious metal in the rock is clearly connected with the filling of the adjacent vein. The gold-bearing itabirites of Brazil come nearer to a case of the distribution of gold throughout a rock independent of well-defined veins, but even here the irregular pockets of friable iron ore (*jacutinga*) and lithomarge, in which the gold is found so abundantly, partake somewhat of the nature of veins. The district of Campanha and São Gonçalo in southern Minas Geraes, however, afford an example of extensive mining operations in decomposed gneiss in which the almost complete absence of veins and of the other usual concomitants of gold is remarkable.

This district lies some fifty or sixty miles to the southwest of São João D'el Rei which may be taken as about the southern limit of the rich belt of auriferous slates, quartzites and itabirites which constitutes the best known and most famous mining region of Brazil. In approaching the region from the sea coast one crosses the high gneiss ridge of the Serra da Mantiqueira and then traverses for a distance of fifty

miles or more a high mountainous plateau composed, for the most part, of rounded hills and knobs of profoundly decomposed gneiss. Above these rise several hills and ridges of compact gneiss and at least one ridge of granular quartzite, the Serra de São Thomé das Letras, mentioned in the preceding article on itacolumite. The quartzite, however, constitutes only a subordinate feature in this region which may be described as almost wholly gneissic; and the accompanying auriferous schists, which characterize the typical gold-mining region of Minas, have not been noticed in this part of the province, though it is probable that they occur. The limits of this mining district have not been traced. Old workings may be seen over a very considerable area all the way from the Rio Verde to the Sapucahy, a distance of twenty-five to thirty miles. The most important centers of the mining operations were, however, the city of Campanha and the village of São Gonçalo, at and between which the following observations were made. Mining has been carried on in this district to a greater or less extent down to the present day, but the most extensive operations seem to have been at about the beginning of the present century. Spix and von Martius, who passed through Campanha in 1818, speak of it as, at that time, a prosperous mining town, the mines having been opened a few years before, while São Gonçalo was already on the decline.

The road from Campanha to São Gonçalo, twelve to fifteen miles long, passes through a region of rounded gneiss hills, so profoundly decomposed that rock is only seen in the beds of the streams and, in a few cases, in the bottom of the old mines. To the eastward there is a high rocky gneiss ridge, known as the Serra das Aguas Virtuosas, from mineral springs at its base, which rises some two or three hundred meters above the general level. To the westward a similar parallel ridge, called the Serra de São José, extends from São Gonçalo about half way to Campanha. These two ridges have a northeast-southwest trend corresponding with the general strike of the rocks of the region. Among the foot-hills of the latter ridge and along a line extending from its extremity to Campanha there is an almost continuous string of old washings often covering several acres and cutting deeply into the hillsides, as extensive as can be found any where in Minas. The feature that particularly strikes the observer accustomed to the deep and narrow open workings, suggestive of railroad cuttings, of central and northern Minas where decomposed vein stuff or thin intercalated beds have been followed, is the great superficial area and nearly uniform depth of the greater part of these old washings. They are suggestive of placers, but on entering them one is surprised not to find gravel heaps and only a comparatively

thin mantle of transported clays at the top, the greater part of the walls and all the bottom being of decomposed gneiss which is evidently *in situ*. The comparative rarity and insignificance of the quartz veins is equally surprising, and when they occur there is no evidence of their having been followed in preference to the enclosing rocks which have been worked away in mass. Indeed the veins are said to be generally barren, though that this is not always the case is proven by one of the mines at São Gonçalo where a little work has been recently carried on along a face twenty feet or more in width traversed by a small vein which affords a richer streak. Some of the hills, as that of the Cata Funda at São Gonçalo, have been worked in ledges or terraces, successive coats of a thickness of a few meters having been more or less completely stripped off as one would peel an onion. In this manner nearly the whole of one side of an elongated ridge a quarter of a mile or more in length had been stripped from base to summit over a width of a few hundred meters. This mode of working is of itself sufficient to prove that the gold was found in workable quantities very generally distributed throughout the mass of decomposed gneiss. This same conclusion is presented in an unpublished report to the Brazilian government by the late Prof. Hartt, who visited São Gonçalo in 1875. Tests made on the clays resulting from decomposition at numerous points selected at random, and on masses of half decomposed gneiss still retaining their form which had been thrown out of a pit, all showed traces of gold and thus confirmed this conclusion.

At São Gonçalo and Campanha the rock is completely decomposed, and it is only by an examination of the clay banks that its original character can be determined. At Santa Luzia, however, about midway between the two places, one of the old workings has uncovered a considerable surface of solid rock in which work was being carried on at the time of my visit. This mine, called Andaime (scaffold), is situated on the top of a hill in which, for some reason, decomposition does not seem to have been so profound as in the other hills of the neighborhood. The older workings show the same characters as those above described; but at present only richer streaks are being followed in the exposed gneiss which, though still retaining its form and stratification, has been sufficiently softened by decomposition to admit of its being easily reduced to a paste with water by the use of crowbars and hoes. The rock is a blackish highly micaceous schistose gneiss, with many thin seams of quartzites, which in places increase to beds of about a meter in thickness. The strata are much contorted, but the general strike seems to be about due east, with a dip of 30° to the south. A small vein of pegmatite traverses the beds. Mining

is at present confined to one of the thicker beds of quartzite which is considered the richest, but very good tests were obtained from the black gneiss and also from loose masses of reddish half-decomposed rock much more feldspathic than that in contact with the quartzite bed. Considerable iron sand was obtained in all these tests.

The washings at São Gonçalo lie on both sides of a small stream that flows near the base of the Serra de São José and parallel with it. On the town side a broad belt over a mile long has been almost continuously washed, and it is said that other washings make with these an almost uninterrupted belt of washed ground as far as the mouth of the stream in the Sapucahy, a distance of about three miles. The washings on the other side of the stream are less extensive, but there is the same tendency to a linear arrangement parallel to the stream and to the Serra, and in the direction of the strike of the rocks. It thus appears that a heavy bed or set of beds is auriferous throughout a thickness of some hundreds of meters and for a distance of several miles along the strike. Although the decomposed material has been very generally washed, traditions speak of richer streaks, and there is some reason for supposing, from the few experiments made, that the more quartzose and ferriferous portions are richer than the generality of the mass. The proportion of gold shown by a single panfull of dirt is very small and the average richness must be very low. I was informed that some recent tests on a measured quantity of dirt gave about fifteen cents of gold per cubic meter.

Owing to the extensive decomposition, there is considerable difficulty in obtaining unaltered specimens of the rock in contact with the auriferous dirt. The only good exposure seen was in the bed of a small stream just below São Gonçalo and near one of the old mines. A panfull of dirt taken a couple of feet above the undecomposed rock gave a color of gold, so that the specimens obtained may fairly be assumed to be auriferous. The rock is here a massive, fine-grained, black and white gneiss, approaching granite in aspect but with a slight tendency to a stratified arrangement in the flakes of mica. The mica is abundant in fair-sized black flakes; the quartz is in small well-formed crystals and is the least conspicuous ingredient, while the feldspar, which is the most abundant of all, is white, a large proportion of it being plagioclase. In the microscopic sections examined, no magnetite or pyrite was detected, but magnetic sand was always found in the tests made of the soft material, and one or two very small crystals of pyrite were found on examining a hand specimen. In view of the almost constant association of pyrite with the gold of the central and northern parts of the province in the auriferous schists,

quartzites and itabirite series, its rarity here is very noticeable. The quartz sand obtained by washing the decomposed gneiss, as well as that from the quartzite bed at Santa Luzia, was in well formed doubly terminated crystals.

The gold of this region is excessively fine. A number of specimens from São Gonçalo and Santa Luzia examined microscopically showed distinct crystalline grains, with sharp, well defined angles. Nothing of a leafy character or resembling the flakes on limonite described in the preceding article were noticed. The grains range in size from 0.05 millimeters for single crystals up to 0.4 millimeters for agglomerations of several crystals, and present the same characters as those obtained by dissolving the arsenopyrite of the Morro Velho vein.

As a company has been recently organized to reopen the São Gonçalo mines by the hydraulic method it is to be hoped that further details regarding this interesting region may soon be obtainable. As already mentioned, a few small gold-bearing quartz veins occur, and in future examinations under more favorable circumstances it may be possible to determine something bearing on the question as to whether or not these veins have been enriched from the adjacent rock.