ART. II.—*On the Manganese Ore Deposits of the Queluz (Lafayette) District, Minas Geraes, Brazil;* by ORVILLE A. DERBY.

IN a communication entitled "The Manganese Ores of Brazil," published in the Journal of the Iron and Steel Institute for the current year (1900), Mr. Herbert K. Scott gives a very interesting account of two ore districts in the state of Minas Geraes that within the last few years have sprung into considerable prominence on account of the abundance and high quality of their ores. These two districts, though adjacent, differ widely in geological characters and in the mode of origin of their ores. The Miguel Burnier-Ouro Preto district, which is more particularly described by Mr. Scott, is constituted by a series of quartzites and schists in which hematitic quartz-schists (itabirites) are a prominent feature, the manganese ore occurring in intimate association with these iron schists and with limestone. The geological conditions are therefore similar to those described by Vogt in his work *Salten og Ranen* for certain Norwegian deposits of associated iron and manganese ores that have almost certainly been derived through leaching from iron- and manganese-bearing carbonates. The details given by Mr. Scott are very conclusive in support of this view of the mode of origin, which I have briefly discussed in a note appended to his paper.

In the closely adjacent Queluz* district, on the contrary, the ore bodies occur in association with granitic and gneissic rocks and there is a complete absence of the calcareous and ferruginous beds that accompany the ore in the other district. The mining and prospecting operations thus far effected have, on account of questions of transportation, been limited to a zone 10 to 20 kilometers wide on each side of the railroad. In the zone thus defined the outcrops of ore are so numerous and large as to indicate an extremely extensive and widespread mineralization of an area that is doubtless much larger than has thus far been recognized. The existing maps of the region are so defective that no positive correlation of the different outcrops can be made, but there are strong indications of the existence of at least three distinct ore belts. These are:

1st. A western belt, marked by the two active mines of

* The name Lafayette given in Mr. Scott's paper was given to the railway station in the border of the town of Queluz in order to avoid confusion with another place of the same name in the same railway system. In common parlance the name Lafayette has come into general use for the whole district, but in the administrative division of the state Queluz is still retained as the name of the town and of the municipal district of which it is the center.

Piquiry and São Gonçalo, situated some 3 or 4 kilometers apart on the same ridge, with a number of known intermediate outcrops and probably prolonged southward by others that have been prospected but not worked,

2d. An eastern belt, marked at the extremes, so far as known, by the Morro da Mina (Mine Hill) and Agua Limpa (Clear Water) deposits; and

3d. A central belt, represented by the abandoned Barroso workings close to the railroad a few kilometers south of the town.

At all of the localities above mentioned perfectly sound granite occurs within a few hundred meters of the ore bodies and at Piquiry the wall or walls are constituted by a residual clay resulting from the complete decomposition *in situ* of a typical granitic rock that gives an abundant and characteristic residue of sharp-edged zircons. At São Gonçalo, where only the foot wall is exposed to view, this and some intercallated layers near it are of completely decomposed schists whose original character will be discussed farther on. At Barroso both foot and hanging wall are of decomposed schists that are suspected to have been originally amphibolic, while at Agua Limpa a sound amphibolic schist of peculiar character occurs within a few meters of the ore body. At Morro da Mina, aside from dubious decomposed schists apparently similar to those at São Gonçalo, a peculiar residual clay occurs that will be discussed below. A peculiar feature is the occurrence of well-defined layers of graphitic schist in the ore of Agua Limpa, Morro da Mina and São Gonçalo, while at all of the localities parts of the ore body are more or less graphitic.

The Piquiry ore body presents the appearance of a mass of secondary material, or gossan, resulting from the alteration of a vertical dike or vein, some ten or dozen meters wide. The margins are sharply cut against a tough clay which is undoubtedly decomposed granite, presumably identical with the sound granite occurring a few hundred meters distant from the mine. In appearance both foot and hanging wall are presented, but Mr. Scott thinks that the opening is on an elbow of the ore body, so that in reality only one wall is seen. The ore is a hard spongy black oxide apparently consisting for the most part of psilomelane but with an admixture of other oxides that frequently occur in beautiful crystallizations in the spongy cavities. No cargo analyses are at hand, but Mr. Scott gives for a sample of ore prepared for shipment: manganese (metallic) 51·40 per cent, iron 2·00 per cent, siliceous residue 5·02 per cent, phosphorus 0·13 per cent.

In the midst of the merchantable ore occur inconstant bands and patches of hard siliceous material with the appearance of a

quartzite, but which on examination proves to be composed almost exclusively of a finely granular mass of ashy white manganese garnet. A complete series of alteration phases between perfectly typical garnet rock and merchantable ore can be readily selected, and there can be no doubt that the latter results from the decay and leaching of the former.

In part from the ore body itself, in part from the dump heap of rejected material, the following phases of the garnet rock were obtained.

1st. A very fine-grained, compact and finely jointed rock of bluish gray color with partings lined with asbestus. Under the microscope the rock is seen to be composed almost exclusively of closely appressed idiomorphic grains of white garnet showing a clear border but with the center highly charged with a fine black opaque powder that appears to be graphite. In the somewhat rare interspaces between the garnet grains and molded upon them is a glassy white anisotropic mineral generally altered to a mass of asbestiform fibers which, so far as its form, optical properties and cleavages can be made out, is a member of the amphibole group. A qualitative test on a small amount of material, largely asbestiform, separated with heavy liquids shows the presence of silica, lime, magnesia, iron, manganese and alumina, the latter in scarcely more than traces, thus confirming the identification of the mineral as an alumina-free amphibole. The only accessories that could be detected in the section are apatite in rare grains and the above mentioned inclusions in the garnet, the reference of which to graphite is apparently confirmed by a distinct reaction for carbonic acid after fusion with nitre and by the presence of free graphite in other similar rocks from the same ore body. An analysis of this rock kindly made by Dr. G. Florence gave:

SiO_2	38·47
Al_2O_3	21·07
Fe_2O_3	7·38
MnO	27·90
CaO	4·70
	99·52

A second specimen of the same general type but not jointed is largely oxidized and stained at the margins and in patches with manganese oxide and has the amphibolic mineral stained brown while the apatite is much more abundant.

2d. A dark brown rock heavily charged with manganese oxide and too friable to permit the preparation of microscopic sections is evidently of the same type as the second specimen above mentioned but more completely decomposed and much

more heavily charged with graphite. The very abundant residue obtained by washing, or by treatment with acid, is in great part of a dirty white color, the garnet grains being discolored by a closely adherent graphitic powder. The amphibolic mineral, apparently more abundant than in No. I, appears in the residues in rudely prismatic forms but is too heavily stained with manganese oxide to permit of a satisfactory determination. No apatite could be detected in the residue, but the acid solution from the rock gave a distinct reaction for phosphoric acid.

3d. A milky white rock which under the microscope is seen to be composed of about equal parts of garnet and quartz, the latter being abundantly threaded with delicate transparent needles of a white asbestiform mineral. The garnet is for the most part larger and better crystallized than in the specimen above described and has a decided yellow tinge. The quartz in a fine mosaic about the garnet grains and in minute refilled joints is almost certainly secondary, filling the place of some mineral that has disappeared. The asbestus (?) needles, in part free, in part included in the quartz, are undoubtedly secondary but not, as in the case above described, formed without migration by the transformation in place of some preëxisting mineral. The only accessory, embedded in the garnet as well as in the quartz and thus probably of primary origin, is a transparent red mineral in minute grains and hexagonal flakes that give strong reactions for both titanium and manganese. The crystallographical, optical and chemical characters of this mineral, so far as they can be made out, agree with those of pyrophanite.

The above observations indicate that the original rock from which this ore body was derived was essentially a manganese garnet rock containing sporadically (and perhaps in segregated masses) an amphibole mineral, apatite, a titanium mineral and presumably an easily decomposable silicate that has entirely disappeared. Graphite is also distributed capriciously throughout the mass, but, as will be shown below, this is perhaps not an original or essential element. The predominant quantity of merchantable ore of high grade shows that by far the greater part of the mass must have been an almost absolutely pure manganese garnet rock from which silica and alumina have been leached out. Since in the process of oxidation iron oxide would almost certainly have remained and have been concentrated with that of manganese, the original rock (and especially the garnet) must have been notably free from this element, which in the ore analyses is in smaller proportions than in the rock sample above analyzed. It is worthy of note that no free iron

oxide, in the form of magnetite, ilmenite or hematite, could be detected as an original element in the sections or residues.

At São Gonçalo the main ore body, composed exclusively of hard secondary material similar in appearance and composition to that of Piquiry, has the appearance of a heavy intercallated bed with an inclination of 30–40° in a decomposed schistose rock. Sound granite occurs a few hundred meters away, but none was seen in immediate contact with the ore. The principal working near the top of a high hill exposes about three meters of the foot wall, consisting of banded clay of predominant red color with white streaks, which on a carefully scraped surface shows a characteristic gneissic structure with indications of small included fragments, or segregations, differing somewhat in texture and color from the body of the rock. On washing, this clay gives a very abundant argillaceous slime, leaving a residue of tolerably abundant white mica (bleached biotite?) with a very moderate amount of quartz and in the heavy portion rare grains of transparent red (secondary?) hematite and tourmaline. Next to the ore body the clay for the space of about 20 centimeters is lighter colored with white and yellow streaks, and this shows very distinctly an augen-gneiss structure. Its residue does not differ materially from that of the underlying reddish clay except that the micaceous portion has more the appearance of secondary sericite.

From the above observations it is tolerably evident that the foot wall at São Gonçalo was a somewhat micaceous gneiss poor in quartz and without characteristic clastic or granitic accessories, that is to say, it was most probably a sheared basic eruptive presumably of dioritic or gabbroitic type.

At the base of the ore body comes a layer about 30 centimeters thick of quartz rock charged with manganese oxide and with the appearance of shattered vein quartz. This give a moderate residue of garnet without other recognizable accessories.

Above the quartzose layer and separating it from the heavy mass of secondary oxide that constitutes the ore body proper, comes a layer about 40 centimeters thick of a banded yellowish clay with tolerably distinct traces of original feldspathic and micaceous elements giving a well-defined gneissic structure. This gives on sliming a residue of secondary (?) mica and earthy grains of manganese oxide.

Higher up in the ore body is another clay layer from 2 to 3 meters thick which on a scraped surface shows a granitoid aspect, with small scattered patches of earthy manganese and iron oxides that appear to occupy the place of some original manganese-bearing bisilicate element. This also gives a very abundant argillaceous slime with a residue of granular kaolin,

secondary (?) mica and, aside from the earthy oxides, a few rare grains of tolerably large and well-formed zircons. This clay body apparently represents an unsheared eruptive rock, possibly of gabbroitic type.

Still another clay horse some 2 meters thick is gneissic in structure with white kaolinitic and greenish and yellowish micaceous (?) elements and nodular masses of clay charged with manganese and iron oxides. The residue after sliming consists of secondary (?) mica without quartz, and heavy dirty white earthy grains with occasional inclusions of rutile that are almost certainly alteration products of ilmenite. Associated with this layer is a thin one, a few centimeters thick, of a pulverulent clay heavily charged with graphite.

With the exception of the above mentioned quartzose layer (or sahlband), which apparently must be considered as an integral part of the ore body and which by its quartz and garnet contents establishes a relation with the original type of the Piquiry ore mass, the mineral at São Gonçalo is so completely altered by secondary processes as to give no clue regarding its original character and origin. The included horses of clayey matter may, *a priori*, be either inclusions of country rock, segregated masses of the original rock of the ore body itself, or intrusive dikes. The hypothesis may be ventured that the gneissoid layer without manganese and with traces of original ilmenite is of the first character, that the gneissoid layer above the quartzose one and with traces of manganese oxide is of the second, while the granitoid body with traces of manganese oxide and with zircon may be a mass of the same character that has escaped shearing, though it is more probably an intrusive dike.

The ore of the main opening is almost exclusively a hard stony, spongy psilomelane like that of Piquiry but presenting more distinct evidences of shear structure. A prospecting analysis by Mr. Scott gave metallic manganese 49·10 per cent, siliceous residue 6·34 per cent, and phosphorus 0·126 per cent. Lower down on the hillside another opening has been made which affords in part a hard secondary ore of the same character as the above, in part an ore of earthy aspect that was at first considered to be of doubtful character but which on analysis proves to be good merchantable stuff. This evidently represents an altered schistose (sheared) manganese-bearing rock in which the resulting oxide has not, to any considerable extent, migrated or been recrystallized but has apparently become somewhat hydrated, since a rough test gives about 6 per cent of water. Its appearance is that of a decomposed argillaceous or calcareous schist profusely pitted with minute rounded cavities that are frequently lined with a fine white crust of secondary silica that, on dissolving the oxide, present the appearance

of pseudomorphs of microscopic garnets. Another locality, to be discussed below, proves that this interpretation is correct and that the pitting of the rock is due to the disappearance of included garnets. Other specimens from the same opening, in which the structure above described is obscured by secondary manganese oxide, give a residue with some sound garnet, with a minute quantity of ilmenite and, on ignition with nitre, a tolerably abundant reaction for graphite.

The Morro da Mina, situated some 6 to 8 kilometers to the northeastward of the town, is a high hill covered quite uniformly with outcropping, or loose, ore and thus presenting the most extensive ore deposit yet known in the district. As, however, this ore is more siliceous than the present high requirements of the market admits, very little has been done in the way of development except in the loose superficial material that gives little insight into the structure of the ore body, but fortunately an old abandoned mining tunnel, apparently driven by some deluded gold prospector, gives a good section of a considerable portion of the mass and below the zone of surface action. As at Piquiry and São Gonçalo, granite occurs in the immediate vicinity of the hill but none was seen in close contact with the ore body. Prospecting operations in the neighborhood show that the ore continues for a considerable distance both northward and southward from the hill, and there are strong indications that in the latter direction a more or less continuous line of outcrops connect this locality with that of Agua Limpa, some ten or dozen kilometers distant.

The above mentioned mining tunnel, which unfortunately could only be examined by the insufficient lighting of matches, extends for about 25 meters in very hard somewhat sheared manganese ore and terminates in soft unsheared clay that evidently represents some massive rock decomposed *in situ*. An assay sample taken by an experienced prospector at every two meters shows that the mass is tolerably uniform in structure and composition and that, except in comparatively insignificant patches, the rock is perfectly fresh. This sample is understood to have given on analysis about 40 per cent of metallic manganese, thus corresponding very closely with the analysis given below of a picked specimen, if, as is presumable, the metallic contents was only determined in the soluble portion, the abundant residue being set down as quartz without further examination. This ore body has the appearance of a vertically sheared dike, or intercalated bed of which one side is free, forming the steep slope of the hill, while on the other side comes the above mentioned clay mass that separates it from another smaller and parallel ore body that outcrops on the top of the hill at a distance of some dozens of meters.

In the specimens obtained from this tunnel the altered patches present the earthy pitted appearance of the above described ore from São Gonçalo and like that give, on treatment with acid, a residue of microscopic garnet, skeletons of secondary silica in the form of garnet and a moderate amount of exceedingly fine black sand giving a strong titanium reaction and that is apparently ilmenite with a slight admixture of transparent red grains without defined form that appear to be rutile. The perfectly sound rock has a hardness between 6 and 7 and a steely luster, but under the lens is seen to be minutely mottled with white points corresponding to the pitting of the decomposed portions. Occasional patches of oriented sheen appear to be cleavage surfaces of large prismatic crystals. Treated with hydrochloric acid, even in considerable lumps, the black portion of the rock is readily and completely dissolved, leaving a considerable residue of white garnet with a slight amount of flocculent silica, ilmenite and rutile (?). Under the microscope the rock is seen to consist of minute isolated grains of garnet embedded in a much more abundant groundmass of manganese oxide of uniform steely luster, except in a narrow zone around each garnet grain where it is coal black and apparently softer. This black zone apparently comes from a beginning of alteration in the garnet, though it may also be due to an incipient hydratation of the manganese oxide of the groundmass. In any case, the rock is essentially a mixture of a hard prismatic, cleavable manganese oxide with a manganese garnet, both being primary elements. An analysis kindly made by Dr. Florence gave:

Residue insoluble in hydrochloric acid	20·78
SiO_2	0·77
Fe_2O_3	5·79
$NiO + CoO$	0·30
MnO	8·54
MnO_2	57·38
P_2O_5	0·08
CaO	0·49
MgO	0·20
H_2O	3·91
	98·24

The deficiency in this analysis is perhaps due in part to the presence of alkalies that were not determined. The manganese oxides calculated as metal and oxygen and reduced to 100 give: Mn. 65·06 per cent, O 34·94 per cent, which corresponds quite closely with the composition of polianite (Mn. 61·1 per cent, O 36·9 per cent), and in view of the physical properties,

so far as they can be made out, it is probable that the rock consists essentially of polianite and spessartine with small amounts of some lime and magnesia silicates, apatite and possibly ilmenite, though a portion of the water is doubtless combined with the manganese, which is in part visibly altered, and the iron may also be, in part, combined with the manganese oxide. The presence of a small proportion of nickel and cobalt is an interesting feature.

The clay in which the tunnel terminates shows no structural features except scattered patches of soft earthy manganese and iron oxides suggestive of segregations of original bisilicates in an essentially feldspathic rock. The slime obtained by washing consists largely of minute micaceous flakes, and the residue of a small amount of minute quartz grains with heavier dirty white earthy grains that give a titanium reaction and are probably leucoxene representing original ilmenite. A specimen taken close to the contact with the ore gives also a small amount of well-formed brown tourmalines, but this does not appear to be generally distributed throughout the clay mass. From the above characteristics it seems almost certain that this clay represents the decomposition product of an original massive eruptive rock that was predominantly feldspathic but with segregations of a manganese-bearing bisilicate element and with ilmenite as the only accessory. If, as seems most plausible, the small residue of quartz be regarded as secondary, the original rock was probably a gabbro or some closely related type.

At the point of the hill and apparently in prolongation of the smaller dike-like outcrop above mentioned as occurring at the top, mining operations had been commenced, in part in loose secondary ore, in part in ore *in situ*. The latter has an impure earthy appearance like that above described from São Gonçalo and such as might be expected to result from the alteration of the hard garnetiferous ore of the tunnel and of the said dike-like ore body. The siliceous residue is understood to run from 16 to 20 per cent and the contents in metallic manganese from 37 per cent to 45 per cent. A small pit showed two ore bodies of this type *in situ*, each being about three meters thick, and separated by a foliated layer of granular quartz rock about one meter thick. This quartzose layer resembles closely the itacolumite of the Ouro Preto region, but, unlike it, is without mica and gives no clastic residue, the only heavy element being transparent hematite that evidently comes from altered pyrite. Underneath the lower ore body comes laminated clays, in part graphitic, that are evidently derived from decomposed schists but are too incoherent to show distinctly the original structure. These give on sliming a residue of coarse quartz with nodules of earthy iron and manganese oxides

and a small amount of ilmenite, tourmaline and rutile, all of which have the appearance of antigenetic elements.

In the dump a few blocks of harder rock of various types were found which from their rarity and evident sporadic mode of occurrence may be presumed to represent segregated masses in the midst of the predominant type of earthy ore. One of these is a quartz-garnet rock like that already described from Piquiry but without traces of a bisilicate element and with the quartz mosaic in comparatively large grains that suggest a doubt as to whether this mineral is a secondary or primary element. Another highly quartzose type has as a bisilicate element an altered mica and has, as an accessory, yellowish isotropic grains that could not be determined but that give a decided titanium reaction. Still another type is a garnet-amphibole rock with rare grains of secondary (?) quartz and with the garnet full of delicate rod-like inclusions that appear to be acicular amphibole. With the exception of the mica-bearing rock all of these types are identical with those found at Piquiry, though no case of the formation of the secondary asbestus was observed.

At the Agua Limpa locality prospecting operations have revealed an extensive ore body which at the surface is composed mainly of secondary oxide but with a sufficient admixture of garnet to show that this body is also essentially a mass of garnet-bearing rock. A small pit shows underneath the ore a layer of about 20 centimeters thickness of graphitic earth with patches and streaks of white clay and resting on a mass of yellow clay enclosing graphitic patches. The graphitic earth gives much ilmenite but no other recognizable heavy residue, while the white streaks and patches in it give much quartz with a heavy residue of magnetite and malacolized zircon indicating that they probably represent apophyses of the neighboring granite. The yellow clay is massive with small patches of earthy iron and manganese oxides, thus resembling closely, except in color, the clay of the tunnel at Morro da Mina and like that giving a residue of fine quartz with ilmenite partially altered to leucoxene.

In the bed of a small stream a few meters from this pit is an outcrop of perfectly sound amphibole schist consisting principally of two types of amphibole (actinolite and cummingtonnite ?) in a fine mosaic of quartz and feldspar with sphene and a garnet giving a manganese reaction as tolerably abundant accessories. The heavy residue shows a small amount of ilmenite and amongst the smaller garnets yellowish crystals of ideal perfection of form. This rock has every appearance of a recrystallized sheared eruptive, and if so was probably originally of dioritic or gabbroitic type but containing manganese garnet

or, perhaps more probably, a manganese-bearing silicate that has given rise to the garnet in the process of metamorphism. Such a type, if unsheared and decomposed, would give rise to a clay very like that found in the immediate vicinity in the above mentioned pit, and the hypothesis may be ventured that the two represent sheared and unsheared portions of the same rock mass.

On the opposite side of the hill and a few scores of meters to one side of the ore belt pits had been opened in partially decomposed granite with stringers from a few millimeters up to about a meter in width of graphite, which though somewhat mixed with clayey matter appears to be of good quality.

At the Barroso locality, which, as already remarked, appears to mark a third ore belt intermediate between that of Piquiry-São Gonçalo on one side and that of Morro da Mina-Agua Limpa on the other, two openings have been made several hundred meters apart and apparently on independent ore bodies. One exposes a layer about two meters thick and with an inclination of about 45° between walls of decomposed schist threaded with stringers of granite. The ore presents for the most part the aspect of the earthy material at São Gonçalo and like that gives a residue of microscopic garnet but with a greater amount of quartz and of clayey matter. In places it passes to a granular quartz rock thickly sprinkled with macroscopic garnets. The enclosing schist presents an appearance suggestive of an original amphibolite and gives a residue of ilmenite only, and apparently represents a sheared eruptive of non-granitic character. In the other and more important opening the ore body is 4 to 6 meters thick, inclined at an angle of about 80° between walls of decomposed schist without granite. The ore, which is of the same general character as that of the first opening, though of better appearance is quite impure, giving, according to Mr. Scott's analysis of an average sample, 28·10 per cent of metallic manganese, 6·00 per cent of iron, 15·80 per cent of siliceous residue and 7·20 per cent of graphite. Much of the ore has the aspect of a decomposed graphitic clay slate charged with secondary manganese oxide, but one of my samples, too friable for a microscopic preparation, resembles, both in aspect and in its residue, the garnet-quartz rock with mica from Morro da Mina and like that has no graphite. Another specimen showing considerable well-crystallized graphite with ilmenite has the garnet enclosed in an earthy siliceous matrix apparently of secondary quartz stained with iron but not with manganese (except in the portions where the garnet is also decomposed), and this appears to represent an original rock composed of garnet with some iron-bearing silicate. The decomposed schist of the walls of this ore body is still quite

resistant and differs somewhat in aspect from that of the first opening but like that gives only a residue of ilmenite and appears to have been an amphibole schist.

Some 50 to 60 kilometers to the southward of Queluz and in the municipal district of Barbacena is another ore district which I have not had an opportunity of visiting but from which specimens from various points have come to hand. These represent an extension of about 30 kilometers as measured by the railroad line between the stations of Ressaquinha on the north and Sitio on the south. The region, like that about Queluz, is characterized by gneissic rocks abundantly injected with granite. The ores are of two types, of which one, corresponding to that of the Queluz district, consists of a garnetiferous rock impregnated with secondary manganese oxide evidently derived from the garnet. One specimen is heavily charged with well-crystallized graphite and gives in the residue a white amphibole, neither of which minerals have been noticed in the other specimens. The second type is a manganiferous magnetite of which a specimen from near the station of Ressaquina was analyzed by Mr. Scott, who found 11·60 per cent of metallic manganese with 40·08 per cent of metallic iron. The other specimen at hand seems to be somewhat richer in manganese but is still essentially an iron-manganese ore. The appearance of this ores is that of an ordinary finely granular magnetite charged with pulverulent secondary manganese oxide. The origin of this oxide is readily found by dissolving the metallic oxide with hydrochloric acid, which leaves a more or less abundant residue of rather coarse and highly corroded spessartine often reduced by superficial etching to irregular hook-shaped fragments. The original type was therefore a magnetite-spessartine rock from which the silica and alumina of the garnet has been almost completely removed by leaching, leaving a residue of manganese oxide. From another ore district near Paranaguá in the state of Paraná a specimen of identical appearance giving about 12 per cent of metallic manganese is at hand, which appears to represent the same type from which the original garnet has entirely disappeared. This conclusion is confirmed by a specimen received later from the state of Santa Catherina, but in the prolongation of the Paraná ore district, in which, as in the Barbacena ore, a remnant of corroded spessartine is still preserved. In this costal ore district, extending from southern São Paulo to Santa Catherina and embracing the Jacupiranga deposits described by me some years ago in this Journal (April 1891), titaniferous magnetites are very abundant and characteristic, but their relations to these rarer manganese-magnetite ores are not known.

It results from the above observations that the ore bodies of the Queluz district are residual deposits derived through decomposition and leaching from an original type, or types, of rock in which manganese garnet was the most constant and characteristic silicate element. With this, which often constituted almost the entire bulk of the rock, were associated minerals of the amphibole (and perhaps pyroxene) or mica series, and in some phases free manganese oxide that when in predominant proportions gave a type corresponding to that of the free iron oxide (magnetite) and manganese garnet rock of the Barbacena district, or, in more general terms, to the well known types of magnetic or titaniferous iron oxides with various silicates. The occurrence of garnetiferous quartzites appears to indicate that in some cases quartz may also have been a primary constituent, though for the most part it seems to have been of secondary origin. As accessory elements, ilmenite and rutile are of frequent though not of constant occurrence, while apatite, though positively recognized in two specimens only, appears to have been constant since a small proportion of phosphorus has been found in all analyses in which it was looked for. A remarkable feature, considering the highly basic character above deduced for this type, is the absence, except sporadically as ilmenite, of free iron oxide and the low proportion of combined iron as shown by the analyses of the residual ores in which a concentration of this element is presumable. The Barbacena ore, however, shows that, exceptionally, free iron oxide may occur and even rise to a predominant proportion. Another remarkable feature is the tolerably constant, though sporadic, appearance of graphite, though as will be shown below this is probably an introduced element.

This type, which may appropriately be denominated *queluzite*, is more or less intimately associated at São Gonçalo, Morro da Mina and Barroso with decomposed schistose rocks that evidently contained an original manganese-bearing silicate and which from the absence of recognizable clastic elements and from other characteristics, so far as they can be made out, is presumed to have been an amphibolic schist representing a sheared basic eruptive. At Agua Limpa a confirmation of this deduction is afforded through the presence in almost immediate contact with the ore body of a feldspathic amphibole schist containing manganese garnet, which is almost certainly a sheared eruptive and, although its original character cannot be positively determined, probably of dioritic, gabbroitic or noritic character. At Morro da Mina, São Gonçalo and Agua Limpa there is also in close connection with the ore an unsheared eruptive (represented by manganese-bearing clays) which in its original condition must have been of very similar

if not identical type. In the Agua Limpa schist, moreover, the manganese-bearing element is spessartine as in the ore bodies, thus giving greater plausibility to the hypothesis that the relation between these last and the above mentioned rocks may be a genetic one. If thus related, the ore bodies present strong analogies with those of magnetic, titaniferous and chromic iron ores that are now generally considered as magmatic segregations in various types of eruptive, and, all things considered, this hypothesis seems the most plausible one for the manganese ores here discussed. The fact that though carefully looked for, no rock types that could be positively, or even presumably, identified as clastic could be found near the ore bodies, makes the alternative hypothesis of a clastic origin a difficult one to apply. The occurrence of distinct traces of nickel and cobalt in the unaltered ore of the Morro da Mina tunnel may perhaps be also an argument for an eruptive origin, though too much stress cannot, without farther study, be laid upon it, since Mr. Scott reports these elements under totally different conditions near Miguel Burnier in a small patch of secondary manganese oxide that is undoubtedly a secretionary deposit in a decomposed clastic schist.

Through the kindness of Dr. Francisco da Paula Oliveira, director of the geological section in the National Museum of Rio de Janeiro, I have had the opportunity of examining a specimen from a manganese ore body enclosed in granite near Queimados, in the interior of the state of Bahia, that represents another interesting phase of this rock type. The rock is perfectly fresh, showing about equal proportions of large-sized garnets and of pyroxene with a diallage-like cleavage. The garnets, which attain a size of five millimeters or more, are of a light yellow color, becoming perfectly white in thin sections, and give a strong manganese reaction. The pyroxene, when free from staining by manganese oxide, is colorless and glassy and gives an extremely abundant reaction for manganese, which is evidently much more abundant than iron. Aside from a colorless glassy amphibole intergrown with the pyroxene, no other constituents could be recognized and the rock is essentially composed of manganese-garnet and manganese-pyroxene. From such a rock through the replacement of the easily decomposable pyroxene by secondary quartz the type of quartz-garnet rock of Piquiry and Morro da Mina might be produced.* With

* This type might, however, be expected to leave some trace of its lime and magnesia in the form of secondary asbestus, and in this case the most probable representative is the quartz-garnet rock with asbestus, while the similar rock without the latter mineral may be suspected to have come from an original type in which the bisilicate element was perhaps rhodonite, a mineral that has been looked for in vain although it seems natural that it should occur in such an association of manganese-bearing rocks.

it is associated a quartz rock with large well-formed garnets but this has the aspect of vein material.

From an unknown locality in the state of Espirito Santo a specimen is also at hand showing secondary manganese oxide with garnet and well crystallized graphite. The ore that is being exported from Nazareth in the state of Bahia is, judging from a specimen received from the gentleman above mentioned, of the same type as that described from the tunnel at the Morro da Mina. The polianite (?) is coarsely crystalline and strongly predominant in quantity over the garnet, which is in great part replaced by pseudomorphic skeletons of secondary silica. This specimen contains no graphite, but I am informed that a considerable proportion of the Nazareth ore is graphitic.

The almost constant occurrence of graphite with these manganese-bearing rocks is very suggestive of a genetic relation, as is also the converse association noted by Weinschenk in the graphite deposits of Bavaria and Bohemia. It is not, however, uniformly distributed throughout the ore bodies, as might be expected if the relation was a necessary one, and, moreover it occurs also quite independent of the manganese-bearing rocks as in the granite at Agua Limpa and in a decomposed schist a kilometer or more distant from São Gonçalo. In the former case the graphite appears in both the granite and manganese-bearing rock but in greater force and purity in the former. In the latter the graphite-bearing rock has no manganese ores in the immediate vicinity and the garnets with which it is abundantly charged give no trace of that metal. This schist is also heavily charged with iron in the form of a fine hematite dust and it may be presumed to have been originally a garnet-amphibole schist, or perhaps an eclogite. This is not the place to discuss the probable origin of the graphite, but it may be remarked that the hypothesis of a gaseous introduction propounded by Weinschenk for the Bavarian and Bohemian occurrences seems to me to best meet the conditions observed in this district. Whatever may be its mode of origin and admitting a doubt as to a necessary connection between graphite and manganese-bearing rocks, it is worthy of note that the two elements carbon and manganese certainly show a predilection for each other's society.

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