ART. II.—*On the Mode of Occurrence of Topaz near Ouro Preto, Brazil*; by ORVILLE A. DERBY.

THE current treatises on mineralogy, in the brief reference to the association of the yellow Brazilian topaz of the Ouro Preto district with talcose or chlorite schist, give an idea of a mode of occurrence quite different from that of any of the other known localities of the mineral. This statement is made on the authority of Eschwege, who in the early part of the century (1811–1822) spent a number of years at Ouro Preto and was very familiar with the mines during a period of active working. A fuller statement of Eschwege's observations, given in various writings, but most fully in his *Pluto Brasiliensis* published in 1833, is as follows. The topaz occurs in a narrow belt of country only a few hundred meters wide, extending for several kilometers from Saramenha, a suburb of Ouro Preto westward, in a nearly straight line for a distance of about 20 kilometers, by the mines of Boa Vista and José Correia to Capão de Lana,* with indications of a second less important belt a few kilometers to the northward. The topaz here occurs *in situ* and exclusively of a yellowish or rose color in contradistinction to the northern region near Minas Novas on the Jequitinhonha, where only white and blue stones occur exclusively in the state of rolled pebbles. The mineral, associated with quartz, specular iron, rutile and enclase, occurs in layers and nests of a fine scaly friable lithomarge, white or colored by iron oxide, all of these minerals being well crystallized but invariably broken at the base and irregularly mingled, as if kneaded into the lithomarge. The topaz-bearing nests and layers are enclosed in a decomposed unctuous schist which provisionally was called talc or chlorite schist, and which in turn are intercalated in the decomposed argillaceous schists of the region that were referred to the primary formation.

Mawe,† and Spix and Martius,‡ who visited the region about the same time gave descriptions of the mines in substantial accord with that of Eschwege, except that they refer the topaz to veins and the latter authors contest the classification of the enclosing schist as talcose, calling its characteristic mineral a modified mica.

No additional information of value regarding the topaz was given until 1882, when Gorceix§ described the principal mines

* Not Ulana nor Lane, as frequently given. Capão is the Indian name for an isolated group of trees or grove and Lana is probably the name of a former proprietor.

† *Travels in the Interior of Brazil*. London, 1812.

‡ *Reise in Brasilien*, Munich, 1831.

§ *Annaes da Escola de Minas de Ouro Preto*, No. 1.

and made analyses (reproduced in full in No. 57 of this Journal) proving that a great part at least of the unctuous schists of the region called talcose or chloritic by Eschwege and others are relatively poor in magnesia and rich in alkalies and are therefore essentially micaceous. Three of the schists analyzed were from the topaz mine of Boa Vista or its immediate vicinity, but it is almost certain that they represent what Eschwege called argillaceous schist (fibrous schist of Gorceix) rather than the topaz-bearing layers themselves, which are nowhere found in a sufficiently sound state to give satisfactory analyses. The lithomarge accompanying the topaz was also analyzed, giving: SiO_2 46.6 per cent, Al_2O_3 38 per cent, MgO 1 per cent, and loss on ignition 14.1 per cent—which is the composition of a true kaolin with a slight percentage of magnesia. The lithomarge is spoken of in one place as occurring in a vein occupying a line of fracture but in another as resulting from an alteration of the schist. The alignment of the principal mines noted by Eschwege was confirmed and somewhat extended by Gorceix and the existence of a second parallel line marked by the smaller workings of Caxambú and Fundão was affirmed.

In recent brief visits to the Ouro Preto region an attempt was made to resolve the doubts suggested by the above studies and to determine the original character and mode of origin of the topaz-bearing material. For this purpose the small mine of Caxambú was selected, as here the topaz bed was tolerably well exposed by recent workings, whereas in the larger mines it is now for the most part concealed and everywhere greatly obscured by landslides. A preliminary examination of these mines fully confirmed the opinion of Gorceix of their substantial identity with that of Caxambú, which may therefore be taken as typical of the topaz mines of the region. On account of the extreme decomposition of most of the material to be examined the problem presented was one of "mud geology"—the attempt to reconstruct from earthy materials the original rock types from which they were derived—and the solution here presented is necessarily largely hypothetical.

The mine is situated on the slope of a low col between the base of the high-rounded campo-covered knob called the Morro de Caxambú, and a lower knob a few score of meters to the southward. In both of these knobs on each side of the col sound rock is exposed in low bluffs. This is a sericitic phyllite heavily charged with fine hematite dust and on the southern side with a considerable amount of rather coarse quartz in scattered grains, which gives the rock the appearance of an iron-bearing quartzite (itabirite), though on examination it is seen to be more micaceous than quartzose. The rock from both of

these bluffs gives a small residue of rolled zircons, most abundant in the more quartzose one, and there can be no doubt that it is a metamorphosed clastic although from its essentially micaceous and ferruginous character, indicating a high percentage in alkalis and iron oxide, it may be suspected that it was not originally a perfectly normal sedimentary clay. On the slope of the col itself and only a few meters away from the mine on the line of strike there is a small exposure of a soft bluish black slate-pencil phyllite, which, in appearance, only differs from the rock of the bluffs on either side in its finer grain, and which is in all respects identical with the one of which an analysis was given in the September number of this Journal from a smaller topaz working in the immediate vicinity. This is a sericite schist free from quartz but heavily charged with iron, and in the paper above cited its low silica and high alkali contents were given as an argument for considering it as, possibly, a sheared eruptive. The absence of rolled zircons in its heavy residue (both the rock at Caxambú and the one analyzed) may be cited as a confirmation, though not an absolutely conclusive one, of this argument.

The mine itself, which is simply a small excavation in earthy material which when soaked with water has much the appearance and consistence of soft soap, exposes a zone some ten or dozen meters wide of bluish and yellowish clays which still distinctly show the nearly vertical lamination of the rocks from which they are derived. The predominant color is bluish but with streaks and patches of yellow which in part represent a more advanced stage of decay of the bluish material, in part, as will be seen farther on, a material of somewhat different structure and composition. The blue clay could be very satisfactorily traced into the slate-pencil phyllite above mentioned and on the other hand into a light yellow micaceous clay, or rather earth, that shows a change of color owing to the more complete hydration of the iron oxide. In the midst of this earthy material that, while still retaining its original form and structure, falls to pieces on the slightest movement, are bands from a few centimeters up to a meter or more in width of a different colored and more plastic earth, carrying oxide of manganese as well as of iron that gives it a darker yellow color passing to brown or black. The contacts between these two kinds of earth are perfectly sharp, like an eruptive contact, and are sometimes accentuated by a concentration of iron and manganese oxides, forming a black sahlband of about a centimeter's width that merges gradually into the general mass of the brownish or yellowish earth. In one case a band was observed having such a black sahlband on one side and on the other a

zone full of angular fragments of the blue phyllite, giving a brecciated appearance.

So far as could be observed, the topazes only occur in this darker-colored earth, and this is in accord with the descriptions given by Eschwege and Gorceix. This earth is evidently the decomposition product of an eruptive rock which though sheared is less perfectly laminated than the blue phyllite in which it is inclosed and which was evidently much more irregular in its composition and structure. This last difference is shown by a considerable variation, in streaks and patches, of the coloration and by the occurrence of nodular masses from the

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size of a pea up to that of the fist, or larger, of white kaolin, of a dark chocolate-colored earth, or of granular quartz, or of a mixture of these various elements. It is in these nodules that the topaz occurs though in a somewhat irregular manner, since a number of the smaller ones were washed without finding a trace of the mineral.

Of these nodular inclusions the most significant are those of kaolin. The small group exposed on a carefully-scraped face and shown of natural size in fig. 1 is very suggestive of an original porphyritic structure somewhat modified by shearing. The larger and more sheared group shown in fig. 2 exhibits a gneissoid aspect suggestive of the shearing of a granitic or syenitic nodule in a fine-grained rock as, for example in the phonolitic types of the Serras of Tinguá and of Caldas. The larger nodules of white or chocolate-colored earth and of quartz, in some but apparently not all of which the topaz occurs, are too friable to permit of satisfactory sections, but there can be little doubt that they are essentially of the same character. These frequently show a scale-like crust and irregular intercalations from a few millimeters to one or two centi-

meters thick of micaceous material that still retains a lithoid character and is composed almost exclusively of fine flakes of muscovite, which also occurs in considerable abundance and in larger flakes in the earthy and quartzose matter of the nodules.

Washings of the various phases of the topaz-bearing earth give a very abundant slime of earthy iron and manganese oxides and finely divided mica with a greater or less amount that is difficult to estimate of clay matter, leaving a comparatively insignificant residue of mica flakes and fine grains of scaly

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hematite. The normal earth free from visible kaolin of the specimen of fig. 2 gave 27.8 per cent soluble in hydrochloric acid, of which 3 per cent was manganese oxide, the rest being iron with a very perceptible trace of alumina. The darker earth of the brown clay nodules and that surrounding one of quartz gave about twice as much soluble constituents, that is to say of iron and manganese oxides. The residue after sliming is nearly free from quartz except when quartzose nodules occur. On removing the mica and iron a very slight heavy residue of minute grains and aggregates of rutile and needles of tourmaline remains with very rare and ill-formed grains of green anatase and a comparative abundance of a yellowish phosphatic mineral. The hematite grains are rare in the body of the earth but very abundant when the micaceous crusts above mentioned occur, and the tourmaline is distributed in a similar manner but is nowhere abundant. Rutile appears in all the washings, but is apparently more abundant in the main body

of the earth than in the nodules, while anatase only occurs sporadically. Zircon in extremely minute and usually ill-formed grains of difficult identification was found in the micaceous crusts but only sporadically in washings from other parts. The phosphatic mineral is usually in ill-formed aggregates that sink in the Klein solution, but a few rare crystals of rhombohedral form were detected. By microchemical and blowpipe tests (with the Florence bead) cerium was identified in these grains and this with the rhombohedral form and high specific gravity indicates that the mineral is the cerium-aluminum phosphate, florencite, recently described by Hussak and Prior. Topaz could only be found in some but not all of the nodular masses, but no trace of it could be detected in the main body of the earth free from inclusions. When found it was always in fragments of what had evidently been macroscopic crystals, no perfectly formed microscopic crystals being observed although they were carefully and confidently looked for.

The above observations afford a very insufficient basis for the determination of the original type of the topaz-bearing material, but in view of the interest of the subject and the slight probability of finding better preserved material for study, some hypothetical deductions may be hazarded. In this attempt at reconstructive geology two phases have to be considered, viz. the schistose one from which the earthy matter is directly derived by decomposition, and the original rock type from which this schist was derived by metamorphism accompanied by shearing.

In the schistose phase it is certain that the rock was essentially a micaceous schist, which, as the mica flakes, although minute, are for the most part well formed, can be designated as muscovite rather than as sericite schist. The mica contents of this schist must have varied from about 70 per cent in the normal parts free from segregations to about 30 per cent in the more basic and to almost nothing in the more acid of the latter. The iron and manganese contents varying in the inverse proportion are probably referable to original oxides* and in this case the schist must have been very similar in com-

* Probably but not certainly, as in the immediate vicinity there are extensive deposits of manganese ores that are residues from original carbonates and others that are presumed to be derived from original silicates, while examples of the complete replacement of an iron-bearing silicate (asbestiform amphibole) by limonite are frequent in the neighborhood. In the case in question, however, there are serious difficulties in the way of the hypothesis of the derivation of these hydrous oxides from either a carbonate or a silicate. The other conditions of the bed seem incompatible with the first, and the absence, at least apparent, of secondary silica in the vicinity gives a strong though not absolutely conclusive argument against the second.

position to the blue phyllite with which it is associated, differing principally in the presence of manganese and in the greater susceptibility to hydratization of the hematite grains, since in the residues only an insignificant amount of this mineral appears. This would give a muscovite schist normally free from quartz but heavily charged with metallic oxides and with scattered and more or less crushed crystals of feldspar and nodules of feldspar or quartz, or of mixed feldspar and quartz, with or without specular iron, rutile, topaz and muscovite. These nodules are frequently surrounded by a dark band more heavily charged with the metallic oxides than is the body of the schist and which may be either a primary or a secondary feature, most probably the former since nodules of a similar character and composition also occur. The accessory elements rutile, tourmaline, zircon (?) and florencite are common to both the normal schist and the nodules but are not prominent in either, while topaz, and probably euclase (not identified in any of the samples examined) appear to be confined to the latter. The larger undecomposed minerals of the nodules (quartz, topaz, specular iron, rutile and exceptionally euclase) usually show a certain amount of crushing which is in accord with the sheared condition of the rock as a whole and indicates that the nodular structure is a primary rather than a secondary feature. The circumstance noted by Eschwege and others that only very exceptionally do any of the minerals show double terminations probably indicates that the nodules were originally accompanied by drusy cavities that have doubtless disappeared in the shearing.

In a recent communication in this Journal I endeavored to show from the chemical and mineralogical characters of the schists of this region that many of them are probably sheared eruptives and suggested the hypothesis of decomposition and leaching prior to metamorphism to account for their peculiarities. One of the rocks there discussed is identical with the blue phyllite of the Caxambú mine and is from a topaz washing in the immediate vicinity, so that the arguments there presented are applicable to those here considered. The argument for an eruptive origin is somewhat weakened by the occurrence above noted of very similar, though more quartzose, rocks with clastic zircons on each side of the mine which perhaps may represent a mixture of eruptive and non-eruptive material. Be this as it may, the argument for decomposition and leaching, giving a concentration of iron oxide and alkalies necessary for the formation of a hematite-muscovite schist, still holds good and in this case the associated topaz schist may be presumed to have been similarly affected. An explanation is thus afforded for the peculiar composition of this rock, and with this hypothesis, that of a concentration during the leach-

ing of metallic oxides in certain nodules and about certain others becomes plausible. All things considered, however, it seems more probable that this last is rather due to an original and not a secondary feature.

The question of the original type from which, by shearing and metamorphism, this muscovite-iron-manganese schist was produced, is a more difficult one. Whether the blue phyllite was originally eruptive or not, there can be little doubt that the topaz-bearing schist enclosed in it was so. This is indicated by the character of its contacts, by the absence of clastic elements, by its manganese contents, and by its banded and nodular structure. Being eruptive, it must have been a rock without free quartz but with a comparative abundance of alumina-alkali silicates (feldspars or feldspathoids) and of iron and manganese minerals, which last, if in the state of silicates, must have been bisilicates containing lime and magnesia that have disappeared by leaching either in the recent decomposition, or, as seems more probable, before the metamorphism and shearing. The rock was probably porphyritic in structure (perhaps not necessarily so if an ancient period of decomposition be admitted) and full of segregated masses of both the more acid and the more basic constituents, in the former of which quartz, not a normal constituent of the rock, also appeared. These segregations must have been more or less drusy and in them several minerals, of which some were not normal to the rock, crystallized with one free termination.

The conditions above enumerated point to some member of the augite- or nepheline-syenite groups as the most probable original eruptive type. The rocks of these groups would afford the necessary alumina and alkalies to furnish the abundant mica free from quartz that characterizes the metamorphic schist, while their more or less basic phases would afford the metallic oxides as well, if the accompanying lime and magnesia can be supposed to have disappeared by leaching. Moreover these rocks are particularly subject to rapid alternations in texture or composition, or both, giving segregated masses, or *Schlieren*. In those known to me in various Brazilian localities both acid and basic segregations occur, and frequently one of the former character is surrounded by a zone more basic than the normal rock, thus giving the conditions noted in some of the topaz nests.

In this connection it is interesting to note that the study of the more normal schists of this and of the Diamantina region led to a similar conclusion, that rocks of the augite- or nepheline-syenite groups were probably represented among them, though in this case it seems necessary to admit that clastic as well as eruptive types occur. Combining the two series of observations, the hypothesis may be ventured of the existence in this

region (and various other similar ones in Brazil) of an ancient volcanic series represented by both massive and clastic types, characterized by soda-bearing rocks and ranging from soda-granite through augite- and nepheline-syenite to the extremely basic phases rich in metallic oxides that characterize these groups. In this regard the analyses by Gorceix of various schists from the Boa Vista topaz mine showing comparatively high soda contents are particularly significant. Perhaps also the association, at least apparent, of iron and manganese ores with the schists here discussed, may be taken as an indication in the same direction, but a discussion of the matter must be deferred to another occasion. On this hypothesis the later phases of the eruptives may be supposed to have been characterized by topaz-bearing dikes.

Although topaz has not been recorded as occurring in rocks of the types above mentioned, there is no apparent reason why it should not be found, since the only element required for its formation that is not normally present in them is fluorine, which in the form of fluorite and fluo-silicates is quite frequent in their segregations and drusy cavities. It is worthy of note that its almost constant companions in the granitic rocks in which it has hitherto been found, cassiterite and tourmaline, are only represented by the latter in insignificantly small proportions. Its characteristic companion, if it can be said to have one, is euclase, containing the element glucinum, characteristic of a number of the rare minerals of the nepheline-syenite pegmatites of southern Norway. It may also be noted that in these last mentioned rocks cerium occurs in forms different from the common one of monazite, thus presenting a certain analogy with its occurrence as florencite in the topaz-bearing earth of the Ouro Preto district.*

Whether the above guess as to the original character of the topaz-bearing earth proves correct or not, it is certain that the occurrence of the topaz in the Ouro Preto district does not differ so materially from the other known ones as has hitherto been supposed. That is to say, the mineral does not occur in an essentially magnesian rock nor is its matrix of presumably sedimentary rather than of eruptive origin. On the other hand, the rock cannot be positively identified with any in which the mineral has hitherto been found. Of the known modes of occurrence the only one that offers a more or less remote analogy is that described by Cross in the lithophyses of a rhyolite of Colorado and Utah. As lithophyses are essentially drusy cavities of peculiar character and as rhyolites differ

*This mineral, which was first detected by Hussak in alluvial washings from Tripuhy in the immediate vicinity of the topaz mines, has since been found in a number of diamond residues from the Diamantina district.

from acmite-trachytes and phonolites mainly in the higher proportion of silica, the analogy may be a closer one than at first sight appears.

Both Eschwege and Gorceix noted a linear arrangement of the topaz localities which is also suggestive of occurrence along one or more dikes. The older workings define quite clearly two such lines lying several kilometers apart, but recent prospecting in the soil cap shows that topaz occurs sporadically over much of the intervening belt.

Although the topaz is known to occur in other regions in Brazil, very little definite information can be obtained regarding it. Under the name of *pingos de agua* (water drops) rolled white and blue pebbles were for a long time an article of commerce at the little town of Minas Novas on the Jequitinhonha below Diamantina. This place was a center of trade in various gem stones, other than the diamond (aquamarine, chrysoberyl, tourmaline, spodumene, topaz and andalusite) coming from an extensive region lying between the Jequitinhonha and Doce, but for the most part, if not wholly, outside of the diamond region proper, where it is to be noted the minerals mentioned are extremely infrequent or wholly lacking in the miners residues that have been examined. Some years ago Dr. J. C. da Costa Sena of the Ouro Preto Mining School made a trip in this region and succeeded in finding most of these minerals both in gravel deposits and in the rocks but makes no mention of the topaz, from which it may be inferred that it does not occur in association with the minerals above named. The specimens from this region are often of considerable size, one in the National Museum of Rio de Janeiro being but little short of two kilograms in weight.

Some years ago a gentleman at Serro between Ouro Preto and Diamantina showed me some beautiful little doubly-terminated crystals of white topaz that had apparently been extracted from the original matrix and are presumed to be from somewhere in the vicinity, but I failed to learn the exact locality or conditions of finding. In the diamond region proper the topaz is a great rarity, although Gorceix reports having found it. Eschwege also reports it as occurring in a magnetite-bearing pegmatitic rock on the island of Pescaria near the little town of Sepitiba to the south of Rio de Janeiro. As there is a massif of augite- and nepheline-syenite near by, a detailed examination of this place may perhaps throw some light on the hypothesis above presented, but owing to quarantine restrictions it has not been possible to visit the place in time for the present paper.

São Paulo, Brazil, July 30th, 1900.