ART. XXXVIII.—*On the Association of Argillaceous Rocks with Quartz Veins in the Region of Diamantina, Brazil;*
by ORVILLE A. DERBY.

IN a recent excursion in the region about Diamantina, Minas Geraes, Brazil, the frequent association of the decomposition products of argillaceous rocks with the quartz veins with which the underlying metamorphic series of the district is threaded attracted attention. The phenomenon was the more striking because of its absence in a long stretch of road over a newer series in which quartz veins are equally if not more abundant.

The most frequent appearance is that of a selvage to the veins and of intercallations in the mass of the quartz of a reddish foliated clay apparently resulting from the decomposition of a micaceous rock. Less prominent in the surface exposures but quite frequent in the artificial openings that have exposed the inner portions of the veins, are nests and stringers of a structureless white clay (kaolin) that may be either farinaceous or indurated (lithomarge). The red clay was observed in a sufficient number of instances to warrant the assertion that it is a general, if not a universal, feature of the quartz veins of the region and that when it occurs it is constant throughout the entire extension, both lateral and vertical, of the vein. The distribution of the white clay, on the other hand, is patchy and considerable portions of a vein in which it is known to occur may be free from it.

A magnificent exposure of a vein of this character is afforded by the eastern wall of the great cutting of the diamond mines of São João da Chapada, of which an excellent view, reproduced from a photograph, is given in Boutan's monograph on the diamond (*Encyclopédie Chimique de Fremy*), and in a recent paper by the present writer in the *Journal of Geology* (vol. vi, p. 121). Contrary to the description previously given, based on a rapid examination made under unfavorable circumstances and with a limited experience in the identification of decomposed material, this cutting is made along the junction of a conglomeritic diamond-bearing quartzite, and an older fine-grained quartzite (itacolumite), both being profoundly decomposed and in many places indistinguishable except on the closest scrutiny. The eastern wall, which on account of its inaccessibility in the wet season, when it is defended by a frontage of quicksand, and of its superficial staining from the highly-colored overlying soil-cap has been described as a complex of various schists, proves to be a uniform mass of itacolumite with only a single argillaceous member that presents in a striking manner the above-mentioned association with vein

quartz. Throughout the entire length of the cutting, a distance of over 500 meters, runs a sharply-defined layer from 1 to 2 meters thick of argillaceous material with quartz which has received from the miners the name of *Guia* (Guide), because, as they state, diamonds were to be looked for below (or in front) and not above (or behind) the outcrop of this layer.

This layer consists principally of a mass of dark red foliated clay which is evidently a decomposed schist stained with oxide of iron. In several places that afford access to its interior, the central portion is seen to be occupied by an irregular but apparently continuous mass of vein quartz, that sometimes swells out so as to occupy half or more of the thickness of the layer, being in other places reduced to a thickness of a few centimeters only. Associated with the quartz is a pure white granular kaolin which in places is intimately mixed with small angular granules of quartz in a way that suggests a decomposed granite, but in general forms pockets or a selvage in or around the more massive portions of the vein. Outside of the kaolin, when this forms the marginal portion of the vein, or inclosed as angular fragments in its mass, is a minutely banded reddish, or yellowish, micaceous clay that appears to differ from the red clay composing the greater part of the mass of the *Guia* only in the absence of the intense staining with oxide of iron. The relations of the white kaolin with the banded clay is well shown on the scraped surface of a block that was brought away, and represented about one-fourth the natural size, in the accompanying figure, in which the dotted

portion represents the granular white kaolin and the shaded portion the banded clay. The unshaded streaks in the latter are also of white kaolin that differs from that of the vein in the less distinct granulation, but which in places, as at the lower right hand side, appears to be flame-like apophyses from it.

A very pure specimen of the granular kaolin kindly analyzed by Dr. Hussak gave: SiO_2 44.96 per cent, Al_2O_3 42.09 per cent, H_2O 13.25 per cent. This composition differs from that of a typical kaolin derived from a feldspar only in a slight excess of alumina which may perhaps be due to the precipitation with it of rare elements that are known to occur in the clay.

The quartz and kaolin are so blended that they must be considered as constituting a single geological body, and this can hardly be else than a rock of original granitic, or rather pegmatitic type. Moreover this body from the character of its contact, as shown in the figure, must have been eruptive. The character of the accessory elements is in accord with this view. Those that appear macroscopically are rare prisms of red rutile and handsome tabular crystals and groups of specular iron. The heavy residue obtained by washing is in parts very small, in other parts (where rutile abounds) very abundant, and with the appearance of being wholly anthigenetic. It consists principally of rutile partly in rather large sagenitic groups of octahedral form that are evidently pseudomorphs after some mineral of the regular system (possibly titaniferous magnetite) with extremely rare grains of anatase, magnetite, tourmaline and xenotime. The latter is in beautiful glassy prisms with short pyramidal terminations of rather large size that show a tendency towards crystals of macroscopic dimensions such as occur rarely in the concentrates of the mine. The rutile and anatase are evidently secondary, and of the presumably primary accessories, magnetite, tourmaline and xenotime, the latter is the most significant as thus far it is only known *in situ*, at least in Brazil, as an extremely constant and characteristic accessory of the ultra-acid (muscovite) granites and pegmatites. The absence (at least apparent, as in order to avoid admixtures only small quantities could be washed) of its almost constant companions, zircon and monazite, is noteworthy. In this connection it may be recalled that in a recent paper by Dr. Hussak,* on an auriferous quartz vein in the same series near Ouro Preto, these three characteristic granitic accessories were found together, and from this circumstance and from the occurrence of characteristic contact minerals the same conclusion was arrived at, viz.: that the vein is an ultra-acid phase of a granitic apophyse.

The colored clays of the Guia present the appearance of the decomposition products of a micaceous schist. As already stated, the distinct banding of white and colored portions, such as is represented in the figure, in the parts next to the quartz-kaolin vein, is probably due to minute interlaminated projec-

* Zeitschr. f. prakt. Geol., Oct., 1898.

tions from the latter, and in support of this view is the fact that the white bands are distinctly kaolinitic (though not granulated like the kaolin of the vein), while the colored ones are as distinctly micaceous. Aside, however, from these distinct white bands, there is an obscure lamination visible even in the most highly-stained portions. On a carefully scraped surface cut transverse to the lamination a few scattered rounded eyes of quartz are in some portions visible, which with the banded structure are very suggestive of a stretched quartz porphyry. These eyes occur both in the dark red clays and in the lighted colored ones, but are much more abundant in the latter than in the former. This fact taken in connection with the increased staining of the clay towards the margins of the mass and the apparent lack of a physical break between the lighter and the darker colored clays may, perhaps, be taken as an indication that the original rock was more acid in the central and more basic (or at least richer in iron) in the marginal portions of the mass.

On washing, both the dark and the light colored clays give, after a considerable loss as slime, an abundant residue of white micaceous aggregates (in the case of the red clay treatment with acid is necessary) with the aspect of sericite with rare granules of quartz that appear to come exclusively from the eyes. On separation of the mica and quartz by washing or the use of heavy liquids, we find an extremely abundant residue of mixed rutile and anatase (sometimes the one, sometimes the other predominating), which appear to come from original ilmenite represented by abundant black grains in the red and by rather rare, dirty aggregates of ill-formed anatase or rutile in the lighter colored clay. With the titanium minerals occur rarely minute prisms of tourmaline and prismatic fragments, rarely perfect crystals, of monazite of the peculiar type to be described farther on. All the elements of the residue are distinctly authigenetic and in this respect are in marked contrast with those of the adjoining quartzite, which with the same titanium minerals (with the exception of ilmenite) and tourmaline in perfectly fresh crystals contains an abundance of well-rolled zircons.

The Guia is thus a composite body that consisted originally of a vein, or dike, of a quartz-feldspar rock, presumably pegmatitic granite, injected into a micaceous schist that may have been originally either a sedimentary shale or a sheared eruptive. The appearance of the mass is exceedingly dike-like, but if a dike, it must have been injected along a bedding plane, or so nearly coincident with one as to simulate an intercalated layer. The characters above given of apparent porphyritic structure, absence of distinctly clastic elements, and

the presence of monazite, all favor the view of an eruptive origin and appear to be of more weight than those of schistose structure and apparent interbedding with the quartzite which are the most important that can be cited in favor of the opposite view. This question will be discussed farther on.

For an attempt to reconstruct the original rock of the colored portion of the Guia we have the positive indications of a schist free or nearly free from quartz and rich in sericite (or a micaeous mineral resembling it which for convenience will be called by that name), with an abundance of iron and titanium minerals, tourmaline and monazite, as characteristic primary accessories and with an entire lack of distinctly clastic elements which in a series with the degree of metamorphism of that about Diamantina could only be rolled zircons or regenerated tourmalines.* For the purpose of attempting such a reconstruction, specimens were collected of such rocks as from their general aspect might be suspected of representing the original type from which the Guia clays might be derived. From the numerous specimens examined from various localities, the comparative freedom from quartz and the abundance of sericite, of iron and titanium minerals and of tourmaline prove to be common characteristics of the phyllites of the region, which can only be distinguished as presumably original sedimentaries or eruptives by the presence or absence of distinctly rolled zircons (often of a size and abundance that seems extraordinary in rocks presumed to represent fine-grained sediments) and of monazites or zircons, or both, with the aspect of original primary accessories.

The rock which from its position and aspect seemed to be the most promising was a partially decomposed greenish schist found in loose blocks at the foot of the western wall of the cutting, and which, judging from appearances, was thought to have fallen from a layer somewhat similar to the Guia and only a few dozens of meters below it in the same geological series. This, however, proves to be characterized by an abundance of well-rolled zircons and of regenerated tourmalines and by an entire absence of monazite.

Another rock from the immediate vicinity and presumably from the deep rock cutting (mainly in hard itacolumite) for the drainage canal of the Duro mine (seen in the background of the above cited figure in the *Journal of Geology*), is a thor-

* See Derby, On the accessory elements of itacolumite, etc., this *Journal*, March, 1898. In this paper it was suggested that the lazulite that occurs quite frequently in the quartzites about Diamantina might have been derived from original clastic phosphates. This view is confirmed by an examination of more abundant material in which distinct but partially altered and corroded monazites and xenotimes were found in the heavy residue of nodules rich in secondary lazulite.

oughly sound, bluish, imperfectly laminated phyllite of which numerous blocks have been built into a wall at the mine-house. Some blocks have in the joint planes handsome plates of specular iron like those of the Guia clay. The rock is for the most part mottled with large yellowish blotches suggestive of enclosed crystals or pebbles, and on a polished cross section shows a minute banding with sheared eyes, corresponding to the blotches, suggestive of a sheared porphyritic rock. The most massive specimen shows evidence of shearing in two planes nearly at right angles to each other, and, in this, part of the original structure which, in the most of the specimens, has been obliterated by the two systems of shearing can still be observed. The appearance under the lens is that of an altered diabasic rock sheared to the point of obliterating the rectangular outlines of the feldspars without completely destroying them. The spots above referred to have the aspect of phenocrysts of feldspar that have lost something of their sharpness of outline. Microscopic sections show a general sericitic mass blackened in irregular bands and patches with a fine dust of iron ores which on being dissolved with acid leave whitish aggregates of a titanium mineral (anatase?). The heavy residue consists of a great abundance of iron and titanium minerals, the latter only rarely showing well-defined forms of rutile and anatase. The only other elements recognizable are rare grains of tourmaline and small prismatic fragments, rarely perfect crystals, of monazite. Some of the grains referred to this mineral may possibly be zircon, but if so they are perfectly fresh (not rolled), but indistinctly characterized. The original rock was apparently a basic eruptive very rich in iron and titanium minerals (ilmenite?) and with rare phenocrysts of the more acid element. So far as can be made out, this rock would on decomposition give exactly the characters of the red clay of the Guia. The principal difficulty in the interpretation of this rock and of the red clay of the Guia as a sheared and metamorphosed basic eruptive is the presence of monazite, which thus far is only known *in situ* in the acid eruptives or their metamorphosed representatives.

Two other rocks from the same region present certain characteristics in common with the one above described and if, as seems probable, they can be genetically connected with it, will serve to establish a graduation into a more acid type on the one hand (thus removing in part the difficulty above noted), and on the other hand into a better-defined basic type. From near the Serra do Gigante, several miles to the northward of São João da Chapada on the road from Diamantina to Grão Mogol, my friend and companion, Dr. Francisco de Paula Oliveira, brought a loose block of a peculiar cyanite-phyllite

full of enormous crystals of cyanite in an imperfectly laminated groundmass of sericitic appearance. The rock is free from iron ores, but extremely rich in minute aggregates of rutile and of extremely minute prismatic needles that are referred to monazite. The original rock was evidently a highly aluminous (feldspathic) one, with an abundance of a titanium mineral (ilmenite?) and of monazite, in which through shearing and the development of secondary minerals, all traces of the original structure has been obliterated. A very similar rock, but lacking the monazite, was found by Dr. Hussak on the Ilha do Fogo in the river São Francisco in front of the town of Joazeiro, where it presents the aspect of a dike in gneiss.

Some 15 or 20 miles to the southward of São João da Chapada, near the fall of the river Dattas close by the town of Gervêa, another imperfectly laminated phyllite was found outcropping in the road that strongly resembles that of São João but differs principally in the absence of monazite, in the preservation of the original rectangular outlines of the white mineral transformed into sericite, and in the great quantity of tourmaline that is evidently an element introduced in the metamorphism of the rock. In addition to the fine iron dust that on removal by acid leaves a dust of formless aggregates of titanium, the rock contains magnetite in considerable-sized grains and octahedral aggregates of an altered titanium mineral that strongly resembles those of decomposed perovskite described by Hussak from the diamond gravels of Agua Suja (Nunes Jahrb., 1894, ii, p. 297). Judging from the sharply cut rectangular outlines of the areas of sericite free from the iron dust, the original rock must have been largely composed of lath-shaped crystals like those of the plagioclase or melilite of diabasic or basaltic rocks, and with this conclusion the great abundance of the iron and titanium dust, that may be presumed to come from original ilmenite, and of magnetite with an octahedral titanium mineral, is in accord. The shearing has not been sufficient to obliterate the form of the white element and appears to have been anterior to the introduction of the tourmaline that lines the joint planes and has invaded many of the rectangular sericitic areas without passing beyond their limits.

There can be no reasonable doubt but that the rock last described is a metamorphosed and moderately-sheared basic eruptive and when it is recalled that "mixed dikes" have been described (see Zirkel, Petrographie, i, p. 784) in which a granite-porphry passes to a type that has been described as diabase or melaphyre, the hypothesis that the two rocks above described and the decomposed material of the Guia may be genetically related is not so extravagant as at first sight appears.

The most serious objection to bringing the Dattas rock into line with the others is the absence of monazite, but in regard to this it may be noted that this mineral (like the xenotime in the white kaolin) is so rare that it failed to appear in some of the tests made.*

The association of argillaceous material with quartz veins is also a prominent feature in the diamond mines about the little village of Sopa, about a dozen kilometers to the southward of São João da Chapada. The diamond-bearing material is here a decomposed conglomeritic quartzite entirely similar to that now on view in the mines of São João.† This rests unconformably on an older series of quartzites (itacolumites) with intercalated schists that is also profoundly decomposed. This lower series is abundantly threaded with small irregular quartz veins that frequently show included pockets and stringers of indurated kaolin and almost invariably partings and selvages of various colored schistose rocks or clays that closely resemble those of the Guia above described. The white kaolin which is less abundant and constant than in the Guia, affords the same residue of rutile and anatase with rare prismatic grains of xenotime. In a washing from the kaolin of the Bambá mine the residue, consisting almost exclusively of anatase with some grains approaching a macroscopic size, was nearly 0.05% of the quantity washed. In another from Misael's mine the residue is scanty, as in the greater part of the tests from the Guia, and consists principally of rutile with rare grains of anatase. In both the xenotime is in rare individuals, mostly in fragments, of comparatively large size showing a tendency to assume macroscopic proportions.

The schistose accompaniment of the veins at Sopa is, in the few cases observed in which it is well preserved, a well laminated, almost papyraceous, micaceous greenish schist that gives on decomposition an ash-colored, or reddish, clay, not distinguishable, except by its residue, from the clays derived from

* Owing to this circumstance, and to the difficulty of avoiding admixtures, the tests of the material from the Guia in which the rare accessories proved to be infrequent and inconstant, were many times repeated and with special precautions. The identification based on form, optical properties and behavior with heavy liquids was confirmed by microchemical tests for phosphoric acid and for cerium and yttria.

† The question of the diamond in these deposits will be discussed in another place. The conclusion presented in former papers, that the gem occurs in vein material, was based on the examination of a mass shown me in 1880 as a diamond-bearing body, but which I am now convinced was a detached section of the Guia, in which, according to the best obtainable information of the present day, no diamonds have been found, and which presents no evidence of having been worked. On the other hand, it is certain that one of the diamond-bearing bodies not now visible was closely similar to it in appearance, though perhaps not in original character and origin. The section of the Guia examined in 1880 was much richer in tourmaline than the parts washed on the recent visit.

the phyllites intercalated in the series in which the veins occur. A large "horse" left standing in the center of Misael's mine, and decomposed to a yellow ochreous clay, shows to the naked eye abundant pyrite (altered to limonite) and tourmaline, and affords on washing a very slight residue of quartz, much tourmaline in handsome prisms, and a comparative abundance of well-rolled zircons with rare grains of rolled rutile and still rarer ones of sagenite that, like the tourmaline, appear to be authigenetic. An ash-colored clay poorly exposed, only a few meters away and of very similar aspect, affords an entirely different residue characterized by an extraordinary abundance of minute sharp-angled prisms of monazite of peculiar type, with rare tourmaline and still rarer octahedral xenotimes often intergrown with zircon but altered to a yellowish mass that is difficultly distinguishable from the aggregates of titanium minerals so abundant in the various rocks of the region. There is here a complete absence of rolled zircon or of other elements that can be considered as allothigenetic. Specimens from two distinct outcrops of the green schist associated with quartz veins in the immediate vicinity of the mine show, along with much rutile that is evidently of secondary origin, a mixture of the characteristic elements of the two clays above described, that is to say, perfectly sharp crystals of monazite with well rolled zircons, both in considerable abundance. A polished cross-section of one of the more massive pieces of this schist shows a banded structure with alternations of a dark green with an ash-colored material. The two are so intimately interlaminated that they could not be completely isolated so as to give perfectly unmixed residues, but there is an evident concentration of monazite in the green and of zircon in the lighter-colored portion. Thus both the character of the residue and the aspect of the specimens indicate that this schist has been produced by the shearing and metamorphism of a mass of mixed material of which one part, corresponding to the "horse" of the neighboring mine, is characterized by allothigenetic zircons and the other, corresponding to the other clay of the mine, by authigenetic monazite. Thus the veins at Sopa appear to be highly-sheared bodies essentially identical with the Guia but more completely mingled with the adjoining rocks.

The observations above recorded indicate the presence in the older series of the region of dikes of a rock characterized by titanium minerals and monazite as primary accessories that have been sheared and metamorphosed together with the rocks into which they were injected, and that the schistose and presumably weak layers thus produced have more frequently than others been the seat of subsequent injections of pegmatitic material that passes to pure quartz. In the cases examined

the material of the supposed dikes is characterized, with the single exception of the Dattas rock, by the mineral monazite which, so far as at present known, may be taken as peculiarly characteristic of granitic magmas. The original dikes may therefore be presumed to have been acid porphyries, or basic phases of such porphyries. If, however, this conclusion is correct, all eruptives of whatever nature existing in the series previous to the uplifting and shearing must have suffered a similar change and afforded planes of weak strata favorable to the subsequent injection of pegmatites, or of other types of eruptives. In the overlying series to which the conglomeritic diamond-bearing deposits examined belong, the quartz veins observed show none of these characteristics and appear to be ordinary veins of segregation. The same is also the case with the very numerous and large veins observed along about fifty miles of road over a newer series of graywackes, slates and limestones in the region lying immediately to the west of the gold and diamond section of the Serra do Espinhaço. On the other hand, a number of scattered observations indicate that the veins of the gold-mining districts of the Serra do Espinhaço present characteristics similar to those of the diamond district and difficultly reconcilable with the current hypotheses of a purely segregational origin. In the only one that has been critically examined, that of Passagem near Ouro Preto, Dr. Hussak, as already referred, has found characteristic granitic accessories and contact minerals in a great sulphuret vein, and as the somewhat similar veins of the Pary and Morro Velho mines carry garnets in the one case and microscopic zircons in the other, it may be suspected that they will on close examination, for which material is unfortunately not at hand, give a similar result. Dr. Hussak has also shown in his various papers in the *Mineralogical Magazine*, on the remarkable association of minerals in the cinnabar-bearing gravels of Tripuhy, that these carry monazite and xenotime, the latter of the same type as in the Diamantina district, along with the curious titanio-antimonates of which one has been traced to a sericitic schist very similar in appearance to that above described, and to a pyritiferous sericitic schist found in place in the immediate vicinity in which rare prismatic fragments of monazite of the Sopa type were detected. Lithomarge with other peculiar clays are, with quartz, characteristic features of the topaz and euclase-bearing veins near Ouro Preto, and lithomarge is a constant accompaniment of the peculiar gold and iron-bearing *jacutinga* veins (?) in the iron ore beds of the same region. Thus the association of argillaceous materials with quartz veins is wide spread and varied in its occurrence, and the observations here recorded are suggestive of the necessity of a careful revision of the current hypothesis regarding the segregational origin of many of these veins.

Both the monazite and the xenotime of the clays and rocks above described and of the concentrated washings of the mines to which they have contributed, present peculiarities of form that distinguish them from the types that have hitherto been found in place in Brazilian, or other, rocks. The monazite crystals are invariably in elongated prisms with only the pinacoid plane developed giving forms that exactly resemble simple prisms of zircon with broken terminations. The extremities are most frequently broken, but occasionally one or two terminal planes are observed as in the accompanying figure kindly drawn by Dr. Hussak. The smallness of the extinction

a (100), b (010), x ($\bar{1}01$), w (101).

angle (1° – 4°) increases the resemblance to zircon, which is so close that only by chemical tests and the measurement of the angles (for which material of sufficient size was fortunately found in the diamond concentrates) could their true character be determined. The xenotimes are invariably elongated prisms with pyramidal terminations in strong contrast with the octahedral type, which is the only one hitherto found in the numerous rocks containing the mineral that have been examined. The crystals when perfect are as transparent and lustrous as zircons, but are quite subject to a milky alteration and are extremely brittle. They rarely sink to the extremely minute size of the generality of the monazite crystals and show a tendency to assume macroscopic proportions. Brown opaque crystals of this prismatic type up to 10 millimeters or more in length, are quite abundant in the concentrates of the mines about the village of Dattas, a few miles to the southward of the localities above described, and there can be no doubt that they come from quartz and kaolin veins like those of São João da Chapada and Sopa. The octahedral type which commonly occurs in the monazite-bearing granites and porphyries, and which was actually found in one of the clays from Sopa, is comparatively rare in the concentrates examined from the Diamantina region, but is abundant and of macroscopic proportions in those from the Lençoes region in Bahia. Perhaps its tendency to alteration noted in the Sopa clay may explain its rarity.

Since the above was written I am enabled, through the extreme kindness of Profs. Clarke and Hillebrand of the U. S. Geol. Survey, to add the following very minute and painstaking analysis of the peculiar rock from the Serra do Gigante, which, as indicated in the above discussion, is the most promising for giving an idea of the hypothetical original rock type from which the various schists here described may be presumed to be derived. At my request special attention was given to the detection of rare elements of which those of the cerium group and lithia were, from a preliminary examination, presumed to be present in an abundance that failed to be verified. Contrary to expectation, the rock proves to be chloritic rather than sericitic, though, as I am informed, the petrographic examination made in Washington confirmed the opinion formed here that the appearance of the predominant micaceous element is that of a muscovite mica. Contrary to expectation also, the rock proves to be basic rather than acid, and thus the principal difficulty in the way of the attempted affiliation with the Dattas and São João schists of diabasic, or basaltic, aspect is removed. On the assumption, based on the complete absence of recognizable allothigenetic elements, that the original rock was eruptive, no affiliation with any known type of which analyses are at hand can be made.

Analysis of Cyanitic schist, from Serra do Gigante, near Diamantina, Brazil, by W. F. Hillebrand.

	Whole mass.	HCl extract.	H ₂ SO ₄ ext.	Residue insol. in H ₂ SO ₄
SiO ₂	38.32	10.78	14.76	(23.56)
TiO ₂	4.93	.10	.20	(4.73)
ZrO ₂	.09	trace ?	?	(.09) ?
Al ₂ O ₃	28.16	10.42	14.77	(13.39)
Fe ₂ O ₃	2.24	(1.78)	(2.24)	none
FeO	4.02	(3.21)	(4.02)	"
(Ni, Co)O	.04	?	(.04)	----
MnO	.16	?	(.16)	----
CaO	.32	.34	.32	----
SrO	trace	?	?	----
MgO	12.04	9.34	(12.04)	none
K ₂ O	1.11	.26	(.26)	.85
Na ₂ O	.16	(.03)	(.03)	.13
Li ₂ O	strong trace	strong trace	(strong trace)	faint trace
H ₂ O, 105°	.55	(.55)	(.55)	----
H ₂ O, 220°	.45	5.36	6.80	.66
H ₂ O, 310°	.22			
H ₂ O, 310° +	6.79			
P ₂ O ₅	.47	.47	(.47)	----
S	trace	----	----	----
F	trace ?	----	----	----
	100.07	42.64	56.66	43.41

No boron, nor rare earths.

Notes to the Foregoing Analyses.

"The bracketed figures are either assumed or follow from direct determinations in one of the other columns.

An hour's treatment with concentrated sulphuric acid is sufficient for extraction of all the soluble constituents. Probably very prolonged action of hydrochloric acid would have had the same effect. The silica from the decomposed silicates separated on rotation in the insoluble form. The lithia belongs to a soluble mineral, for but a faint trace was found in the residue. The P_2O_5 is wholly extracted by dilute nitric acid; it can therefore hardly exist as monazite. Moreover, careful tests failed to show a trace of rare earths. Still the lime is quite insufficient to form apatite with all the P_2O_5 .

No formula for the soluble portion can be calculated from the analyses, but according to Professor Clarke it would seem to approach in composition an impure earthy chlorite.

The insoluble residue, after treatment by hydrofluoric and sulphuric acids, contained besides a large amount of unattacked rutile, practically only silica and alumina in the proportions required for cyanite. Assuming that the alkali of the residue belongs to sericite, as indicated by Professor Derby's letter accompanying the specimen, and deducting accordingly for the formula of typical muscovite ($KH_2AlSi_3O_{12}$), the following percentages remain after excluding all TiO_2 as rutile: SiO_2 19.62, Al_2O_3 10.24, H_2O .27. Again assuming that the alumina exists herein as cyanite and deducting Al_2O_3 and SiO_2 to correspond, there remains 13.66 per cent of free silica. This can hardly be opaline silica, for an hour's digestion of the insoluble residue with strong potassium hydroxide solution extracted but a fraction of a per cent of silica."

In view of the apparent disaccord in some points of this analysis with the results above recorded of the physical examination with batêa, heavy liquids and microscope, the latter has been repeated with special care and on a sufficient quantity (20 grams or more) to secure a reliable result. The presence in considerable abundance of free quartz and of rutile was fully confirmed, but no reliable trace of apatite or of zircon could be found. The former if present at all, which is doubted, must be in a proportion too small to account for more than an extremely minute portion of the phosphoric acid and lime, and the latter is certainly absent. The zirconia found in the analysis must be from some other mineral and presumably from the soluble constituents of the rock. A mineral closely resembling zircon, and like it heavier than cyanite, is completely dissolved out of a mixed residue by sulphuric acid, and in the solution very satisfactory tests for phosphoric acid and cerium were obtained, the latter being precipitated as oxalate, and verified by the Florence method in both a borax and salt of phosphorus

bead. Isolated grains gave also a very satisfactory microchemical reaction for phosphoric acid and a somewhat doubtful one for cerium, but no definite reaction for the latter could be obtained by the blowpipe method, probably on account of the smallness of the quantity of pure material available or of some disturbing admixture. On the strength of these observations and of the close resemblance in form and optical properties with the mineral from the Sopa clay, the original determination as monazite is maintained. The Sopa mineral is undoubtedly a cerium phosphate and apparently agrees in form with submacroscopic crystals from the diamond concentrates on which the angles of monazite were verified. It appears, however, to carry some titanium and lime, and possibly this peculiar type of monazite may present peculiarities of composition. The facility with which the mineral can be isolated from the Sopa schist gave an opportunity to determine roughly, by washing, its proportion as about 0.01 per cent. It is apparently much less abundant in the Serra do Gigante rock and therefore could hardly be expected to appear in the quantity ordinarily employed in a chemical analysis. It seems probable also that this rock carries some other undetermined phosphate.

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