ART. XXV.—*The Ilmenite Rocks near St. Urbain, Quebec ;
A New Occurrence of Rutile and Sapphirine ;* by CHARLES
H. WARREN.

Introductory.—One of the notable occurrences of ilmenite, mentioned in treatises on mineralogy, is that near Bay St. Paul, a town located on the north shore of the St. Lawrence River, about sixty miles east of Quebec. This occurrence is more accurately located as being just west of the little village of St. Urbain in the parish of that name, which is located about ten miles north of Bay St. Paul on the River Gouffre. In the *Geology of Canada*, 1863, Dr. T. S. Hunt gives a brief description of this occurrence. He states that the ilmenite bodies are "intercalated in the stratification" of the anorthosite rock in which they occur. One bed, 90 feet thick, was traced for a distance of 300 feet, and was reported continuous for over a mile. Writing further, he states, "it contains in many parts orange-red transparent grains of pure titanitic acid." The density is given as from 4.56 to 4.66. A chemical analysis gave: TiO_2 , 48.60; Fe_2O_3 , 10.42; FeO , 37.06; MgO , 3.6. Total, 99.68. Just what type of ore this analysis represents is not stated, but assuming it to be a fairly correct analysis, the molecular ratio derived from it indicates that it was made on rutile-free material. The presence of the rutile appears to have been practically forgotten, at least no other mention of it occurs in the literature so far as the writer is aware. Its presence in the ilmenite was again noted in the summer of 1909 by Dr. W. R. Whitney of Schenectady, N. Y., while on a visit to the locality, and it was through the latter's interest in the deposit that the writer had an opportunity of visiting the locality in the spring of 1910. A representative collection of material was made at that time with the expectation of later using it for a thorough study of this unusual rock. A more careful examination of the material in the laboratory showed it to be more unusual in character than was at first supposed, but, unfortunately, it was also found that the material had suffered so much from alteration that it has been thought best to defer any exhaustive chemical study in the hope that fresher material may eventually be obtained, when it is also hoped that further details regarding the extent of the rutile-bearing portions may be also available.

The Enclosing Anorthosite.—Like so many other occurrences of ilmenite the containing rock of the St. Urbain deposits is an anorthosite. The extent of the anorthosite area in the present instance is not known, but it appears to be a large one, and may be, as was believed by Hunt, continuous with the

anorthosite located near Quebec, just north of the Chateau Richér, and known by that name. It is probably distinct from the great mass of anorthosite lying to the north and northeast about the upper waters of the Saguenay.

The anorthosite calls for no special description. It may be noted, however, that it is rather poor in femic constituents, and that such as occur are largely or wholly altered to chloritic or serpentinous products. The disseminated grains of ilmenite are always highly xenomorphic. Locally the rock shows some crushing, and throughout, the feldspars, which are chiefly andesine, show some evidence of strains.

The Ilmenite Masses in General.—The contacts with the ilmenite bodies are, as a rule, quite sharp, although there is in places some gradation. Along the contacts there is commonly a narrow band of a dark brown mica developed. Small spherical or irregular masses of ilmenite occur at many places in the vicinity of St. Urbain, also narrow dike-like streaks. The larger bodies appear in general to have the form of elongated masses, sometimes dike-like in their general outlines. The elongation follows an indistinct gneissoid structure in the anorthosite, which here has an east-westerly direction. The dip is usually highly inclined, although some of the ore bodies bend over and lie almost horizontally, conforming, doubtless, to local flexures in the enclosing rock.

Large Deposit of Rutile-free Ilmenite.—One of the two most important exposures of the ilmenite rock is found about one-half way up the hillside, which rises rather steeply directly west of the village of St. Urbain and forms the western rim of the broad valley of the River Gouffre. The ilmenite has been partially uncovered, and probably a few thousand tons were mined many years ago for iron. In fact, the ruins of an old smelter may still be seen just below the deposit. The total exposure at the old workings is perhaps 100 feet wide by 200 feet long (east and west.) Good outcrops occur at intervals for some distance to the west along the bed of a small stream which runs down the hillside at this point. On the south side of workings a dike-like body of very massive ilmenite is exposed and may be followed up the hill for some 200 feet. This has an average width of about 10 feet and near its upper end bifurcates, one branch bending off to the northwest. A few feet north of this, another dike, possibly ramifying below with the first, bends off to the north with a flattening dip until it becomes almost horizontal. Just north of this again comes another mass, which has been uncovered over an area measuring some 70 feet on a side, with a depth, as exposed, of some 20 feet. This is cut near its northernmost exposure by a narrow streak of anorthosite rock with a nearly vertical dip and an east-west trend.

Megascopically, the ilmenite rock from this occurrence consists essentially of a dense black, medium to rather coarsely granular ilmenite, through which are scattered small grains of feldspar, or its decomposition products, occasional grains of a dark green spinel, and plates of dark brown mica. Long exposure to surface weathering develops a brown limonite coat, but, as a whole, the ilmenite rock is very resistant to weathering processes. The ore, studied in thin sections and on polished surfaces, shows that the ilmenite, as well as the other constituents, lack altogether any crystallographic outlines. The ilmenite grains range in size from individuals $3\text{--}4^{\text{mm}}$ in cross section to ones $10\text{--}12^{\text{mm}}$, the average being perhaps $6\text{--}7^{\text{mm}}$. The feldspar is the same variety as that in the anorthosite and forms rounded grains. It is often largely replaced by secondary products. Lying along the border of many of the feldspar grains, next to the ilmenite, biotite is developed. This may lie parallel to the margin or may project out into the feldspar, sometimes replacing a good portion of it. Its occurrence is such as to suggest that it may be of later origin than the feldspar, developed, perhaps, during the late magmatic period, or during a subsequent period of metamorphism. It possesses a very marked pleochroism and absorption: light brown or almost colorless to deep reddish brown. The axial angle as measured with the microscope was found to be 10 degrees. It resembles closely mica, often observed in a somewhat similar connection elsewhere, and is doubtless an iron rich variety. Alteration changes it to a chlorite. The spinel is of a dull green color, feebly translucent, isotropic, and is to be referred to the variety pleonast. Its grains are entirely without crystalline outlines, and it occurs both with the ilmenite and about the feldspar grains. Quantitative estimates show that considerable portions of the ore will not contain over 2 to 2.5 per cent of accessories, but the general run will carry from 5 to 6 per cent.

Structure and Composition of the Ilmenite Grains.—Examined with a strong direct illumination, polished surfaces of the ilmenite show that individual grains are not of homogeneous composition, although all are identical in character. They are made up of a very fine lamellar intergrowth of two kinds of material. One kind, comprising what is roughly estimated as one-fifth to one-quarter of the whole, is of a bright steel-gray color and follows, as a rule, a nearly straight course across the grains. Many of them pinch out within the grain and in some the strips have the form of very flat, lensiform bodies; again they are slightly curved in outline. In width they vary from 0.003 to 0.02^{mm} . The second series are uniformly broader than the first and run from 0.036^{mm} to 0.09^{mm} in width. These are of a dull black color. The whole intergrowth suggests in

appearance a fine micropertthite structure. If a polished surface be immersed in cold dilute hydrochloric acid, the latter very soon shows the characteristic color of ferric chloride, becoming in the course of two or three hours quite strongly colored. The solution gives reactions for ferric iron only. Pure magnetite, similarly treated, dissolves somewhat more readily, but the solution reacts strongly for both ferric and ferrous iron. The steel-gray lamellæ are deepened by the action of the acid forming tiny grooves, indicating that it is this part of the intergrowth that is dissolved. As will be seen from the chemical analysis of the ore given later, the percentage of ferric oxide present is in general agreement with the percentage of the steel-gray lamellæ. These facts point strongly to the conclusion that the latter are *hematite in intimate crystallographic intergrowth with ilmenite*. It may also be noted that the ilmenite grains are not affected by an ordinary magnet, and indeed require a strong field on an electromagnet in order to be attracted to the point of picking up. Their weak magnetic properties indicate quite clearly that there is no magnetite present. The very fine powder rubbed on smooth white paper gives a dull brownish black streak (with perhaps a slight reddish tint) *identical* in appearance with the streak similarly obtained from a mixture of $\frac{3}{4}$ pure magnetite (black streak) and $\frac{1}{4}$ hematite (dark red streak).

To the writer this intergrowth appears to have some interest in connection with the composition of "titanic-irons" generally, and the disputed question of the isomorphism of hematite and ilmenite. While it is impossible to make an exact estimate of the amount of ferric oxide present as such in the intergrowth, the approximate estimate given above agrees approximately with the per cent of ferric oxide found by analysis. From this it appears that the amount of Fe_2O_3 mixed isomorphously with the ilmenite must be small. The excess of Fe_2O_3 so commonly reported in ilmenite analyses has generally been accepted to mean that the ilmenite and hematite molecules are isomorphous. If the ilmenite grains in the present instance possess the structure originally assumed by them on crystallization from the magmatic condition, the idea at once presents itself that the Fe_2O_3 present in ilmenite may be always in large part, at least, present in the form of a fine intergrowth, and the desirability of examining carefully prepared polished and etched specimens of ilmenite whose chemical composition is accurately known is at once apparent. It is of course by no means certain that the intergrowth is an original structure. The two molecules may have crystallized originally as an isomorphous mixture and subsequently, under changed conditions of temperature, etc., being no longer stable in the isomorphous

state, separated, forming the intergrowth described. Such a change may have been considerably facilitated by the metamorphism to which this rock has to some degree been subjected. It is to be noted that, although the two minerals have very nearly the same crystallographic constants, they differ somewhat in symmetry, and the accepted formulæ for the two are not strictly analogous, ilmenite being RTiO_3 and hematite Fe_2O_3 . It may, therefore, be questioned whether the crystallographic and chemical analogies of the two are sufficiently close to permit of isomorphous mixture to more than a very limited degree, but close enough to condition an intimate and definite crystallographic intergrowth. It is hoped that a further study of the relations existing between ilmenite and hematite and also magnetite when these molecules occur together may soon be carried out.

Deposit with Rutile-Sapphirine-Bearing Ilmenite.—The second, and in the present instance, the most interesting deposit, is located near the top of the same ridge as the previous one, about one-half a mile to the southwest. It has been pretty well exposed for a length of about 300 feet and for 50 feet in width. At one point the ilmenite rock has been opened up to a depth of about 15 feet and to a less depth in several others. Its contacts with the anorthosite, where exposed, have a roughly east and west trend and are nearly vertical. In the ore are several streaks of anorthosite which have also a nearly vertical extension and a more or less marked schistosity following much the same direction. There is also in the ore in places a feebly marked banding with the same trend. Further west and southwest of this deposit several small dike-like masses of ilmenite are exposed with the same orientation, but these carry no rutile, etc.

The mineralogical character of the greater part of the ilmenite rock in this mass is essentially the same as that previously described. The grain, however, appears on the average to be a little finer. A portion of the deposit differs from the rest and from other known bodies of ilmenite associated with anorthosite rocks, in containing a notable percentage of *rutile* and a smaller amount of the rare mineral *sapphirine*.

The rutile-bearing portion was first observed as a streak two feet wide, with a nearly vertical dip and an indistinctly marked banding parallel to the walls which ran east and west. The passage of this streak into the rutile-free ilmenite on both sides was very sudden. Toward the west the rutile-bearing portion widened, and was somewhat less sharply defined, and there is evidence which points to the occurrence of rutile-bearing bands and patches. It appears, however, to always change quite sharply into the rutile-free rock. It was traced for several hundred feet.

Cutting the ore-body in the rutile-bearing portion is a streak of anorthosite rock which itself carries more or less rutile. The rutile makes up from two to three per cent of this rock as nearly as it was possible to estimate it. It is associated with ilmenite and a considerable amount of biotite. These minerals are arranged along distinct lines of schistosity. No sapphirine has been noted in this rock.

The *rutile-bearing rock* is of a brownish black color and consists of a rather finely granular ilmenite thickly sprinkled with grains of an orange-red rutile, a smaller amount of feldspar, biotite, sapphirine, or their decomposition products, and spinel. The sapphirine cannot be distinguished without the aid of a good lens, and then only upon very close inspection, about the feldspar and ilmenite grains in the form of very dark, greenish black grains. The less altered ore is firm, but weathered portions are somewhat friable. All of the material collected shows more or less limonite along cracks and joints. In a limited portion of the rutile-bearing rock fairly numerous plagioclase grains or groups of grains, often larger than the average in size, are present. These feldspars sometimes reach a length of two or three centimeters and one centimeter in width, and are characteristically associated with a strong development of biotite plates.

Microscopic thin-sections of the rutile-bearing rock disclose a highly xenomorphic texture for all of the constituent minerals with the one exception of the spinel inclusions in some of the feldspar grains. The ilmenite forms an almost continuous background in which the other minerals lie. Its grains, although irregular in outline, are roughly equidimensional and are fairly uniform in size, their average cross-section being about 3^{mm} . They consist of the same lamellar intergrowths as previously described, but the two sets of lamellæ are narrower than in the former case, conforming to the smaller average size of the grains. The rutile is in the form of simple crystal grains or clusters of such, and is of a beautiful orange or golden brown color with a barely perceptible pleochroism. The cleavages are prominently developed. Twinning is rare. Individual grains attain a diameter of 3.5^{mm} . From this size they run down to mere specks, the average being in the neighborhood of 0.6^{mm} . It is distributed quite uniformly through the ilmenite and occurs also with the other minerals, being sometimes enclosed in their grains. The spinel is rather sparingly present and forms grains comparable in size to those of the rutile. In the feldspar-rich portions of the rutile-bearing rock, it also occurs included in the feldspars in the form of exceedingly minute crystals. These inclusions deserve a brief description. Many of the feldspars are crowded with them.

They are of a pale, dull green color and as a rule are definitely orientated with reference to the enclosing crystal. Just what the orientation is has not been made out. Many of the spinels have a highly perfect octahedral habit, the whole crystal coming into view with slight changes of focus. Other crystals show the characteristic cross-sections of distorted octahedrons, or form flat, triangular plates. These attain a diameter of $.015^{\text{mm}}$, though usually smaller. Again the spinels have the habit of relatively greatly elongated rods, or somewhat flattened blades arranged in lines across the feldspars. The inclusions are isotropic, although being wholly enclosed in the feldspar, which often exhibits a slight disturbance in its optical properties about the inclusions, they often seem to be slightly doubly-refracting themselves. Minute inclusions of sapphirine have also been noted occasionally associated with the spinels, but these have a different color and are irregular in outline.

The feldspars are an andesine like that of the anorthosite. They are as a rule quite evenly distributed and of fairly uniform size comparable with the ilmenite, but occasionally, as noted, they become more numerous and of larger size, and form groups of grains. Many of them show evidences of strains and slight bending. In even the fresher material collected the feldspar is usually partly replaced by secondary products, particularly where biotite and sapphirine were present with it, and in more highly altered specimens it is entirely gone.

The biotite is sometimes quite abundant and has the same characteristics as previously described. It is most intimately associated with the plagioclase, and where sapphirine is present it appears to have developed later than this mineral. Its position about the margins of the feldspar, or replacing part of it is here, as elsewhere, strongly suggestive of a later secondary origin. Its alteration is to chloritic products.

An occasional grain of apatite has been noted, but it is hardly present as more than a trace.

The *sapphirine*, which is of especial interest here, it being not only a *new occurrence* of this rare mineral, but also in a *new association*, seems to be confined to portions of the ilmenite rock which carry rutile. Even when alteration has destroyed both plagioclase and sapphirine, the characteristic alteration products enable it to be seen that the sapphirine has been a quite constant associate of the feldspar in the rutile-bearing portion. That there is some intimate relation between the feldspar and the sapphirine is shown by the fact that the latter generally lies between the feldspar and the ilmenite. It is often seen as a narrow band extending around the feldspar. (See fig. 1.) The band may widen out into a larger

mass. Again, the feldspar may be surrounded by sapphirine of nearly or quite equal area. About a single feldspar grain the sapphirine usually has, throughout the greater portion of its extent, a uniform orientation. The mineral also includes ilmenite and rutile grains, and in one instance, at least, has been noted in contact with spinel. Where the feldspar is more abundant the sapphirine is also more strongly developed and its grains have in some instances fairly continuous distribution

FIG. 1.

FIG. 1. Microphotograph of thin-section, showing plagioclase (white) almost entirely surrounded by sapphirine (gray) either as a narrow band or as larger grains between it and the ilmenite (black) or rutile (dark, mottled). The plagioclase shows many minute microlites of spinel. Magnif. about 90 ; ordinary light.

through the section, and often lie, with and without included ilmenite and rutile, between the feldspar crystals, or even included in them. In such sections as much as 20 per cent has been observed with about an equal amount of feldspar and rutile, a little spinel, and the remainder ilmenite. Here, the larger grains frequently attain a diameter of 3.0^{mm} , the aver-

age being somewhat smaller (0.4 or 0.7^{nm}). Quantitative estimates of the amount present indicate something like 3–5 per cent for the general run of the rutile-bearing rock.

No trace of crystallographic outline has been noted on the sapphirine and there is only a faint suggestion of two intersecting cleavages. The fracture is marked, being developed in the form of prominent irregular cracks and is highly conchoidal. The pleochroism is strong, a , pale, smoky brown to almost colorless, $b=c$, deep sapphire-blue, sometimes with a shade of green. The single refraction is strong, a , having been determined by the immersion method as approximately 1.729 for sodium light. The double-refraction is very low, not exceeding 0.005. The interference tints in many sections show deep berlin blues. The optical character is clearly negative, the axial angle rather large, and the dispersion is marked $r < v$. It is to be noted that the index of refraction is higher than that of the sapphirine from the original locality in Greenland in specimens studied by the writer.

The sapphirine from India* corresponds to that of the present locality very closely in color, and the index for a has been determined by the writer as about 1.726.

The sapphirine from St. Urbain shows nearly always a more or less extensive alteration not observed in the case of the Indian and Greenland varieties. This begins as a finely fibrous or foliated development along the curved fracture lines and margins. Further alteration develops a fine aggregate of more distinctly foliated material which suggests talc in appearance. These products become mingled with chlorite, biotite and ferruginous material, resulting from the alteration of the associated minerals, which renders it difficult to determine the exact character of the alteration. Nevertheless, the appearance of the alteration is quite characteristic and as noted above, permit it to be easily seen that the sapphirine was originally more abundant than at present.

The alteration of the sapphirine, as well as its intimate association with the other minerals, made it difficult to obtain suitable material for a chemical analysis. By means of an electro-magnet and heavy solutions, some 3 grms. sapphirine contaminated with the other minerals and alteration products were separated from a sample of rutile concentrates, generously placed at the writer's disposal by Mr. E. R. Berry of the General Electric Company of Lynn. In barium-mercuric iodide solution, grains of seemingly pure sapphirine sank just after

* Petrological Study of Some Rocks from the Hill Tracts, Vizagapatam District, Madras Presidency. Walker and Connor, Records Geological Survey of India, vol. xxxvi, Part 1, 1907. The writer is indebted to Professors Walker of Toronto and Palache of Cambridge, Mass., for specimens of the Indian and Greenland minerals which were studied in this connection.

epidote, specific gravity 3·54. Less pure grains continued to sink down to a specific gravity of 3·43. The true specific gravity probably lies somewhat above 3·5.

The material was further purified by fusing its fine powder with sodium carbonate, which has only a slight action on the sapphirine but decomposes the other minerals, including the rutile and the alteration products of the sapphirine. Something over a gram of material was obtained in this manner, which, examined under the microscope, was found to be entirely free from impurities, and upon this a chemical analysis yielded the results given below in column 1. In the other columns are given other analyses of sapphirine.

	I	II	III	IV	V	VI	VII
SiO ₂ -----	13·44	14·56	14·51	14·86	14·76	12·95	12·83
Al ₂ O ₃ -----	62·98	60·49	63·11	63·25	63·23	64·44	65·59
Fe ₂ O ₃ -----	----	----	Mn ₂ O ₃ ·53	----	----	----	·93
			CaO ·38				----
FeO -----	9·08	7·65	3·92	1·99	1·65	1·66	·65
MgO-----	15·28	17·13	16·85	19·28	19·75	19·83	19·78
Ign -----	----	·56	·49	----	----	·34	·31
Total.....	100·78	100·39	99·79	99·38	99·39	99·22	99·79
Sp. grs. ---	3·5	3·542	----	3·473	----	3·46	3·486

I—Mineral from St. Urbain, Quebec : Warren.

II— “ “ India : Walker and Collins, Records, Geol. Surv. of India, vol. xxxvi, Part I, 1907.

III— “ “ Fiskernäs, Greenland : Stromeyer, Unters., Misch. Mineralg., 1871, 391.

IV— “ “ Fiskernäs, Greenland : Damour, Bull. Soc. Geol., vi, 315, 1849.

V— “ “ Fiskernäs, Greenland : Schluttig, Inaug. Diss., Leipzig, xxii, 1884, and Zs. Kr., xiii, 74.

VI— “ “ Fiskernäs, Greenland : Lorenzen, Medd. Gronl., vii, 184.

VII— “ “ Fiskernäs, Greenland : Ussing, Zs. Kr., 15, p. 600.

Below are given the molecular ratios derived from the above analyses: FeO has been combined with MgO and listed as RO, Fe₂O₃ and Mn₂O₃ as R₂O₃.

	I	II	III	IV	V	VI	VII
SiO ₂ -----	0·224	0·242	0·242	0·247	0·246	0·216	0·214=
R ₂ O ₃ -----	·617	·593	·621	·620	·620	·631	·643=
RO -----	·508	·534	·475	·508	·516	·517	·502=
SiO ₂ -----	2·00	2·00	2·00	2·00	2·00	2·00	2·00
R ₂ O ₃ -----	5·51	4·90	5·13	5·02	5·03	5·84	6·05
RO -----	4·53	4·41	3·92	4·11	4·19	4·79	4·69

The ratios derived from the analyses of Lorenzen and Ussing (VI and VII) lead to the formula given by them, $\text{Mg}_5\text{Al}_{12}\text{Si}_2\text{O}_{27}$, although it is to be noted that there is a considerable deficiency in the RO figure in both cases, and in VI of R_2O_3 . The ratios derived from the analyses of Stromeyer (III), Damour (IV), and Schluttig (V) agree rather more closely with the formula $\text{Mg}_4\text{Al}_{10}\text{Si}_2\text{O}_{23}$. The ratios of the St. Urbain sapphirine lie about half way between these two formulæ, while those of the Indian mineral depart rather widely from both, although they perhaps favor the second type. Ussing, in discussing the composition of the mineral, attributed the relatively higher silica values of the older analyses of Stromeyer, Damour, and Schluttig to the presence of mica or other impurities. This criticism cannot apply in the case of the St. Urbain mineral, nor apparently in that of the Indian mineral; and as the analysis of the mineral presents no difficulties, it does not seem as if the differences can be attributed to analytical errors. The composition is that of a very basic silicate, and does not appear to conform to any simple formula. It seems probable that there may be some solid solution relation existing between the molecules which make up the mineral; at least this is the only apparent explanation of the variations in composition which it shows.

It may be noted that there are two types of the mineral from Greenland (see Ussing), one of a light blue color, the other having a deeper blue color and occurring in a more ferruginous association. Ussing suggests that the deeper blue color may be due to the presence of more iron in this type, an idea in keeping with the higher iron content of the St. Urbain and Indian minerals.

Origin of the Sapphirine.—In the case of the sapphirine from Fiskernäs in Greenland, the mineral appears to be of metamorphic origin, occurring, according to Steenstrup,* in small ellipsoidal or irregular masses in mica-schist or gneiss, high in MgO and Al_2O_3 but low in silica. Walker, in the paper alluded to, presents strong evidence to the effect that the Indian sapphirine is also of metamorphic (contact) origin, having been formed by the action of ultra-basic, spinel-bearing rocks of the charnockite series, on a sillimanite schist. Its occurrence as a metamorphic mineral in these two instances suggests strongly that it may be also of metamorphic origin at St. Urbain, an hypothesis which is perhaps also supported by the peculiar and intimate association of the mineral with the feldspar. If so, it must represent a reaction product between the feldspar and the spinel, although in the absence of any lime-bearing silicate of a secondary nature, such as epidote or hornblende, it is diffi-

* Medd. om Grøn., Kopenhagen, 1884, vii, 15.

cult to picture the exact character of the reaction which produced it. It is perhaps possible that it was formed by a reaction between the alumina and silica of the plagioclase and the spinel, some sodium and silica being eliminated and the remaining feldspar crystallizing as a somewhat more basic lime-soda feldspar. The optical properties of the feldspar associated with the sapphirine do not indicate, however, that it is more basic than that elsewhere in the ilmenite nor in the enclosing anorthosite. Nor is it at all clear why the sapphirine should not have formed in those portions of the ilmenite rock, also containing the same plagioclase but free from rutile, these having certainly undergone substantially the same metamorphism as the rutile-bearing portions. Taking everything into consideration, the writer believes that the sapphirine in this instance is a magmatic mineral.

Quantitative Study of the Rutile-bearing Rocks.—Two quantitative estimates (Rosival) of the mineral composition of the rutile-bearing rock have been made on large, thin sections, one cut from a sample which appeared richer than the average in rutile, and the other from a rutile-poor sample. The results were as follows :

Rutile	20.4	11.3
Ilmenite-hematite	73.2	84.5
Sapphirine	3.2	0.7
Rest	3.2	3.2
	<hr/>	<hr/>
	100.0	100.0

It is certain, as noted, that the sapphirine as judged by its characteristic alteration products was originally more abundant than at present, so that a part of the material listed as "rest" represents sapphirine once present. The average of the percentages for rutile is 15.8 per cent, which is probably not far from the true average rutile content of the rutile-bearing portion.

As stated, it has not been deemed worth while to make at present an exhaustive chemical analysis of the rock on account of its considerable degree of alteration. A fairly complete analysis* has, however, been made on a sample of the rutile-rich type similar to that on which the Rosival estimate, given in column I, above, was made. The results are as follows :

* This analysis was made by Mr. R. S. Anderson in connection with a thesis presented as one of the requirements for graduation in the course in Mining Engineering at the Massachusetts Institute of Technology. The work was done under the supervision of Professor William Hall of the Department of Chemistry, and the writer. Each result is the average of at least two, and in the case of FeO and TiO₂, of three determinations.

	Per cent	Molec. ratio	Ilmenite	Rutile	Hematite	Rest
SiO ₂ -----	2.24	0.037	----	----	----	----
TiO ₂ -----	53.35	.667	0.382	0.285	----	----
Al ₂ O ₃ -----	1.65	.016	----	----	----	----
Fe ₂ O ₃ ----	13.61	.085	----	----	0.085	----
FeO-----	24.49	.340	.344	----	----	----
MnO-----	.30	.004	----	----	----	----
MgO-----	4.04	.101	.038	----	----	----
CaO-----	.30	.007	----	----	----	----
	99.98	----	58%	22.8%	13.6%	5.6%

It is of course impossible, on account of the uncertainty as to the exact amounts of the accessory constituents present and of their composition, also as to the exact composition of the ilmenite molecule, to calculate the true mineral composition of the rock. An approximation may, however, be made by assuming that about one-tenth of the RO in the ilmenite is MgO, calculating the excess of TiO₂ as rutile and of Fe₂O₃ as hematite and neglecting the SiO₂, etc. Such a calculation gives the approximate results shown after the analysis in the table. The percentages summarized are: Ilmenite-hematite, 71.6 per cent: rutile, 22.6 per cent: rest, 5.6 per cent. These results are in fair agreement with the results of the Rosival estimate given in column I above. The hematite amounts to about one-fifth of the ilmenite-hematite mixture, which is a figure somewhat lower than that obtained by a very crude estimate made with the microscope on an etched specimen. The results are, as a whole, mutually confirmatory to a quite satisfactory degree.

While no attempt will be made at this time to classify the rock in the "Quantitative System," it is easily seen that it falls in a new position in the perfermane class, perhaps in close company with the interesting ilmenite-rutile-apatite rocks recently described* from Virginia by Dr. Watson. In view of the occurrence of so much free titanite oxide as primary rutile, it appears to the writer that it will be necessary to give TiO₂ a special significance in classifying this and analogous rocks in the "Quantitative System."

Origin, Crystallization, Name.—That the ilmenite masses in general so commonly associated with anorthosite or gabbroid rocks are the result of magmatic differentiation seems to be generally accepted. In the case of the rutile-sapphirine-bearing portion there appears to be no good reason to doubt that it represents a portion of one of these differentiated masses in which there was a notable excess of titanite oxide and a somewhat smaller excess of magnesia and alumina.

* U. S. G. S., Bull. 430, p. 206, et seq.

The texture of the rocks are thought to represent substantially that which developed upon crystallization from a magmatic condition. Like so many anorthosites the present one has undoubtedly been subjected to more or less dynamic action, but it does not seem to have been particularly severe about and in the ilmenite rocks. The rutile grains show no sign of strains nor crushing. Granting for the ilmenite-hematite intergrowth a secondary origin, which is open to question, its development could not have much, if at all, modified the original texture of the rock. The feldspar also shows but little evidence of severe strains or crushing. Furthermore, if we assume that both the sapphirine and the biotite are due to secondary reactions, during or subsequent to the actual crystallization of the magma, the changes involved are clearly incompetent to account for the formation of the rutile as a secondary mineral; nor is there any other evidence of mineralization or chemical changes adequate to produce it. It is, furthermore, most unlikely that if the rutile is of secondary origin its occurrence would be confined to portions of the mass, the remainder of which has been most surely subjected to the same dynamic and metamorphic action.

It is believed that the rutile-sapphirine-bearing rock represents a magmatic crystallization, and as such it is a new and extreme ultra-basic type, which is deserving of a distinct name. Accordingly the name *Urbainite* is proposed for it, with the expectation that the same stem will be used with an appropriate termination for its designation in the "Quantitative System" so soon as fresh material can be secured for a satisfactory chemical analysis.

Without going into a discussion of the question here, the writer ventures to express the opinion, founded in part on the textural and mineralogical evidence above presented, that these masses of ilmenite rock, if they are, as now believed, products of magmatic differentiation, have crystallized as units from partial magmas of like composition to the resulting rocks subsequent to their differentiation from the parent anorthosite magma, and that they have not been formed by the gradual accumulation of separate grains through a process of fractional crystallization.

Summary.

I.—Large masses of rock consisting largely of titanite-iron ore occur in anorthosite in the Parish of St. Urbain, Province of Quebec, Canada. These masses have in general an elongate form, sometimes dike-like, conforming to the structure of the enclosing rock.

II.—In the main they consist of ilmenite, hematite, with accessory andesine, green spinel and biotite. Throughout a con-

siderable portion of one of these masses, rutile is an essential and abundant constituent (ca. 15 per cent). In such there is also present a smaller (3–5 per cent) amount of the rare mineral sapphirine. The latter may be very abundant in certain limited portions of the rutile-bearing rock where plagioclase is also more abundant. It is intimately associated with the feldspar, commonly lying about its grains, often as a narrow band, and separating it from the ilmenite. Rutile is also present with ilmenite and biotite in a stringer of anorthosite closely associated with the rutile-bearing ilmenite rock.

III.—The rutile-sapphirine-bearing rock forms quite sharply defined portions of the ilmenite rock and appears to be of magmatic origin, representing a part of the segregation exceptionally rich in titanite oxide, to a less extent in magnesia and alumina, and deficient in silica.

IV.—A new occurrence of sapphirine is recorded and in a new association. Although possibly of metamorphic origin, like the sapphirine in the two occurrences previously known, it is thought in the present instance to be of magmatic origin. A chemical analysis made on material of exceptional purity shows that it resembles closely the sapphirine from the Hill Tracts, Vizagapatam District, India. It is pointed out that the molecular ratios derived from the analysis and from that of the Indian mineral show a considerable departure from the one usually accepted for the mineral, and do not correspond to any simple formula, and the existence of solid solution relations between the molecules making up the mineral are suggested.

V.—Microscopic and chemical evidence is presented to show that the titanite-iron of these rocks consists of an intimate, very fine, lamellar crystallographic intergrowth of ilmenite and hematite, in which the hematite makes up something like one-fifth of the mixture. It is pointed out that this relationship suggests that the Fe_2O_3 in so many ilmenites may be in large part, at least, present as hematite crystallographically intergrown and not as an isomorphous mixture.

VI.—A chemical analysis of the rutile-bearing rock, also quantitative estimates of the mineral composition as determined with the microscope, are given. These are in fair agreement, and show that the rock is unique in composition, and represents an extreme and new ultra-basic type of igneous rock. The name *Urbainite* is proposed to designate rocks of this type.

Mineralogical, Petrographical Laboratory,
Massachusetts Institute of Technology,
Boston, Mass.