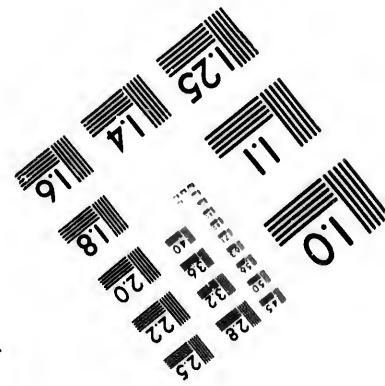
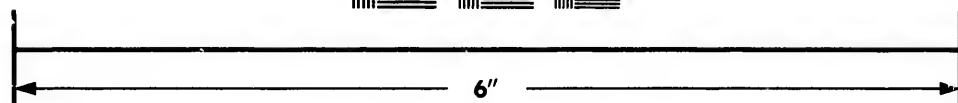
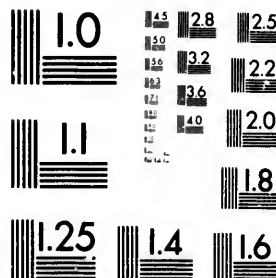
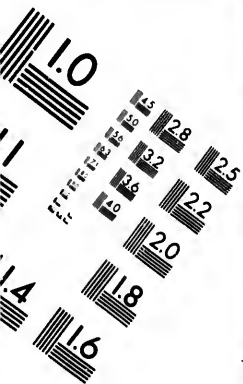


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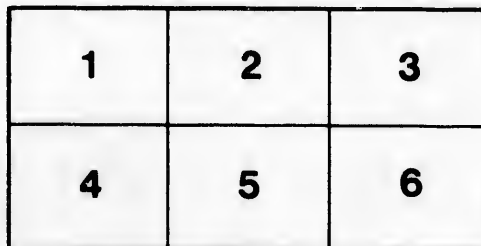
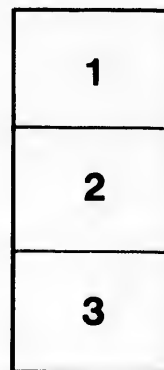
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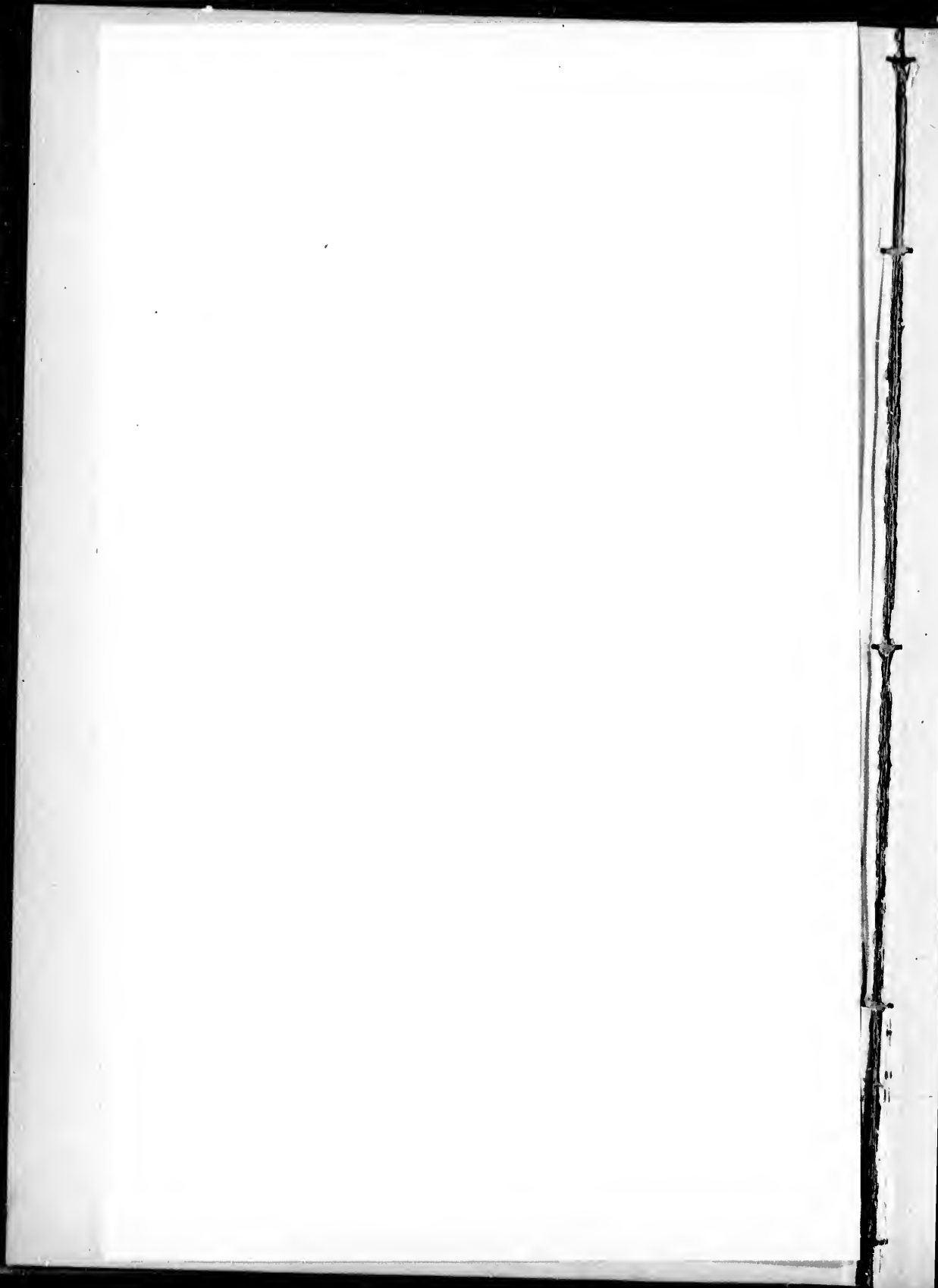
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ON
MALIGNITE,
A FAMILY OF BASIC PLUTONIC ORTHOCLASE ROCKS
RICH IN ALKALIES AND LIME
INTRUSIVE IN THE COUICHICHING SCHISTS OF POOH-
BAH LAKE.

BY
ANDREW C. LAWSON.

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INTRODUCTION.

POOHBAH LAKE lies in the District of Rainy River, in the Province of Ontario, Canada. The detail of its geographic relations may be ascertained by an inspection of the Hunters Island sheet of the

Geological Survey of Canada.* The geographic and geologic surveys necessary for the preparation of this sheet were under the immediate direction of the writer, and were well advanced at the time of his resignation from the Canadian Survey in 1890. The work was subsequently continued and prepared for publication by the writer's assistant, the late W. H. Smith, acting under instructions from the director of the survey. Although Mr. Smith was thoroughly devoted to his work and was a very competent geographer, his duties as such had, in the earlier years of his service, precluded his giving attention seriously to geological studies, and he therefore undertook the continuation of the writer's work practically as a beginner in geological research. The vigor and ability which he displayed in the execution of that task foreshadowed a successful career had he been spared to follow up the investigations so inaugurated.

Mr. Smith being thus unexpectedly called upon to complete a work with which he was familiar, but for which he had had no especial preparation, it is not surprising, nor does it in the least reflect on his memory, that some deficiencies should exist in his account of the geology of the region and in the accompanying map. Some of these may, as opportunity presents, be filled out by the writer, with perhaps better grace than by any other investigator who may follow us in this field.

Among the more interesting points in the geology of the region which were touched upon, but not fully discussed, in Mr. Smith's report, are the rocks of Poolbah Lake; and it is the purpose of this paper to present some observations upon these rocks which, it is hoped, may have more than a local interest.

The field data are based on a somewhat hurried but geographically complete examination of the shores of the lake during two days of the last season in which the writer was engaged in exploring the region, supplemented, for purposes of mapping, by some observations by Mr. Smith on Wink Lake to the west, and two short excursions by the writer on jungle trails, one from the north shore of the lake northward, and the other from the south shore southward.

*Annual Report, Vol. V, 1890-91. Part G.

The shores of the lake are occupied for the most part by a coarse syenite-like rock which is intrusive in the mica schists of the Couthiching series of the Ontarian system of the Archæan. This intrusive mass has a roughly elliptical shape in ground plan, with a longer diameter of not less than six miles, and a shorter diameter of about three miles. It has the same intrusive relation to the Couthiching schists as do the normal Laurentian biotite granites and hornblende granites and their gneissic modifications. The mica schists strike around the mass so as to inclose it on all sides



FIGURE 1.—Sketch map of Poohbah Lake; showing relation of the laccolite mass to the Couthiching schists. A, nepheline-pyroxene-malignite; B, panidiomorphic-gneissic-facies of the same; C, garnet-pyroxene-malignite; D, a minor facies of the same; E, amphibole-malignite; F, Couthiching schists. The numbers 495, 501, 503, 506, and 510 indicate where specimens were taken. Scale, two miles=one inch.

The schists are well exposed on the north side of the lake and at its southwest extremity; and the known distribution of the same rocks in the region to the north, west, and south of the lake is ample warrant for the approximate delimitation of the intrusive mass indicated on the accompanying diagram, Fig. 1. To the northwest of the

lake only is there any doubt as to the position of the line of demarcation between the intrusive and intruded rocks. Along the north shore of the lake and on the shores of the narrow arm which leads to the outlet, the dip of the mica schists is to the N. N. W. away from the intrusive mass at angles of about 60° , but locally inclined as high as 80° . At the northeast corner of the lake, on the same line of strike, the schists are vertical or dip somewhat toward the mass. At the southwest end of the lake the schists are highly garnetiferous and dip beneath the mass toward the northeast at about 60° .

As will appear in the following pages, the intrusive mass is petrographically distinct from the ordinary Laurentian intrusives of the region, and this fact, together with its limited extent, its isolation in the midst of a schist belt, and the inward dip of the schists at the southwest end of the lake, suggest with much probability that it is laccolitic in its structural relations to the Couchiching rocks, the latter being without doubt metamorphic sediments. In age the mass belongs to the Archæan in the same sense and for the same reasons as do the granites and gneisses of the region which are commonly referred to as Laurentian, and which have a batholithic relation to the Ontarian rocks.

This laccolitic mass, although very clearly a geological unit, is not petrographically uniform. Three distinct types of rock may be readily discriminated in the field, and each of these presents subordinate variations. All three types have strongly-defined chemical and mineralogical characters, which preclude their specific identification with any other rocks known to the writer. In their structure, also, they present several features of exceptional interest. While these rocks thus appear on chemical and mineralogical grounds to be new types, they have a certain community of character which warrants their being grouped in a single family. To designate this family, it is proposed to use the term *Malignite*, from the Maligne River, the chief stream of the immediate district in which these rocks occur.

The Malignites are characterized as basic, holocrystalline, plutonic rocks, rich in alkalis and lime. Iron is present in but moderate proportion for rocks of such basicity, and is practically wholly

combined in the silicates, there being but mere traces of iron ores. Both iron and magnesia are, on the other hand, more abundant than is usual in the alkali-rich plutonic rocks. Mineralogically, their constant characteristic is the prominence of orthoclase, with which is often associated acid plagioclase in microscopic intergrowth. Quartz is wholly absent. The constant ferro-magnesian silicate is ægerine-augite, which may predominate, with but a moderate admixture of biotite, or may be subordinate and intergrown with a preponderant soda-amphibole, biotite being present as before. In one of the three types of malignite, melanite is an essential and very prominent constituent. In another, nepheline enters into the composition of the rock.

Such alkali-lime-rich rocks with low silica and moderate alumina, iron, and magnesia, find no place in the existing families of plutonic rocks. They are clearly not granites. They are too low in silica and too high in lime, and rather high in alkalis for syenites, if that term is to have any precision of significance. They have certain affinities with the nepheline-syenites; but here again their characteristically high lime contents, and in a less degree their low silica, bars the way to their admission to the family. Besides, only one of the three types contains nepheline, and that is petrographically, as well as geologically, much more closely affiliated with the other two which have no nepheline than it is with the nepheline-syenites. Neither are they to be placed in Brögger's newly-established family of the monzonites, since they are explicitly excluded by that author's definition of the characteristics of the family,* although the latter is a generously hospitable one for many a stray rock of hitherto dubious pedigree. Being orthoclase rocks, they belong neither to the theralites nor the diorites nor the gabros. How then shall we class them? Squeeze them in somewhere in an existing family, no matter how it vitiates the characteristics of the family? Such has been a too prevalent custom, and the process has gone on till some of our rock families have become unduly distended with foreign elements, each succeeding one more remote from the type than its predecessor, and relief is effected only by a violent disgorgement. By such a process of disgorgement

* Die Eruptionsfolge bei Predazzo, pp. 53, 54.

has the new plutonic family of the monzonites come into existence under the masterly treatment of Brögger, and a great distress is lifted from the diorites and syenites. It seems wiser to avoid the confusion arising from such periodic evictions from the older families by freeing ourselves from the crude idea that the number of families must be limited to those we already recognize. A crisscrossed scheme of classification in the early stages of the development of a science such as petrography is certainly a serious hindrance to the progress of philosophic ideas. It is better to err rather on the side of a somewhat diffuse classification at first, and to condense as relationships become clearer and more settled. With these considerations in mind the writer ventures to face a well-known and often-expressed prejudice against the introduction of new rock names, and to propose the establishment of the new family of the *Malignites* to accommodate the new rock types described in the following pages. These may be referred to as *amphibole-malignite*, *garnet-pyroxene-malignite*, and *nepheline-pyroxene-malignite*. In the petrographical descriptions the last named will be considered first.

NEPHELINE-PYROXENE-MALIGNITE.

Macroscopic Characters.—The rock is of a light gray color, being composed of light and dark colored constituents in about equal proportions, and presents the general aspect of a rather feldspathic dolerite of medium texture. The light-colored constituents comprise: (1) Orthoclase in part fresh and glassy and in part milk white; (2) a dead white mineral, nepheline, in a more or less decomposed condition; and (3) glassy, bright greenish-yellow apatite. The dark constituents are: (1) Lustrous black, elongated prisms of pyroxene in great abundance; (2) occasional foliæ of brownish black biotite; and (3) somewhat rare grains of titanite. When critically examined the hand specimens show by the uniform reflection of the cleavages that the orthoclase is present in large individuals, as much as 4 cm. in diameter, but the space occupied by the feldspar is so charged with all the other constituents of the rock that it does not otherwise appear prominent; and if it were not for the cleavage reflections, there would be no suggestion of its occurring in large individuals. In hand specimens it appears rather

as an aggregate of small grains in between the augites. The nepheline may be discriminated from the feldspar as dull white spots, which are quite abundant, but which present no sharply recognizable boundaries to the unaided eye. The apatite is remarkably abundant and occurs in elongated grains ranging up to 3 mm. in greatest diameter, which by reason of their yellow color, vitreous lustre and rather high refractive power, are prominent features of the hand specimens. The pyroxene prisms are several times longer than their breadth. The planes in the prismatic zone are well developed, but no terminal planes could with certainty be detected. The prisms have all possible orientations. The biotite occurs in plates which occasionally attain a diameter of 5 mm. It is, however, usually much smaller, and is a subordinate constituent of the rock.

The general gray color of the rock is occasionally blotched with darker patches, in which the pyroxene, in very much smaller individuals, preponderates greatly over the light-colored constituents.

Structure.—Under the microscope a remarkable feature of the rock is the poikilitic relation of the orthoclase to all the other constituents. Over large areas it extinguishes uniformly between crossed nicols, thus proving its physical continuity, although in the plane of the section it frequently appears in discrete areas. In several sections about 2x1.5 cm. in extent only one individual of orthoclase is present, and in this are imbedded all the other constituents. It is evident from this relationship that the orthoclase was the last mineral to crystallize, and that it represents, in fact, the residual magma after the other constituents had separated. None of the other minerals thus inclosed in the orthoclase appears to have any definite relation in space with reference to the host, but have a perfectly haphazard orientation. The large crystals of orthoclase, which thus serve as the paste of the rock, have no geometrical boundaries but are allotriomorphic with reference to one another. The fundamental structure of the rock may, therefore, be said to be allotriomorphic granular, and all of the constituents other than the orthoclase are of the nature of idiomorphic phenocrysts. None of the minerals of the rock seems to have separated in more than one generation if we leave out of considera-

tion the occasional patches of fine-grained black rock, which probably represent local more basic secretions.

The idiomorphic constituents only occasionally exhibit the rectilinear outlines of the ideally perfect crystals. Their constant approximation to these outlines is, however, characteristic of them.

Mineralogical Details.—The orthoclase is characterized throughout the rock by a molecular tension which manifests itself in undulatory extinctions. This is very probably a direct consequence of the conditions under which it crystallized. The orthoclase being the last product of the crystallization of the magma and forming large individuals inclosing all the other constituents, it would naturally result that there would not be opportunity for the adjustments due to change of density at the point of crystallization, or during cooling after crystallization. The orthoclase also presents under low powers a very dusty appearance, due to the abundance of minute interpositions. These are of two kinds: (1) Slender opaque rods frequently arranged in parallel position resembling schillerization products, and (2) minute opaque rounded bodies scattered irregularly throughout the mineral. There are, also, rarely occurring transparent microlites inclosed in the orthoclase, but no liquid inclusions were observed. No twinning structure was observed in any of the slides. For the most part the orthoclase is fresh, but it is cloudy in places as a result of decomposition. Both cleavages, parallel to OP (001) and to $\infty P\infty$ (010) are distinctly observable. In cleavage flakes parallel to OP, it was determined by aid of the quartz wedge that *a* lies parallel to the trace of the clinopinacoidal cleavage and that *c* lies normal to the same direction. The refractive power and double refraction are those of orthoclase.

The chemical character of the orthoclase was tested by subjecting small grains of it to the action of hydrofluosilicic acid, the result being an abundant crop of cubes of fluosilicate of potassium, with an exceedingly few more minute hexagonal crystals of fluosilicate of sodium, and occasional prismatic crystals, with rhombohedral terminations, which represent probably the corresponding compound of iron derived from the interpositions in the feldspar. The result of the test shows that sodium is present in the feldspar

in the merest traces, and that we have to deal with a true potash orthoclase. The powder of the orthoclase after digestion with hot hydrochloric acid remained unacted upon. Its specific gravity is between 2.56 and 2.57.

The pyroxene, which is abundant, is a deep green pleochroic variety, with a pronounced elongation in the direction of the c axis. It has the usual high refractive index, strong double refraction and distinct prismatic cleavage of the augites. In clinopinacoidal sections the maximum observed value for the extinction angle ϵ ; c is 59° . The pleochroism is in shades of green and yellow, but can not be adequately expressed by the simple formula usually employed. In sections normal to the acute bisectrix the optically positive character of the mineral is easily established by the use of the quartz wedge. Such sections contain a and b , and the orientation of these axes is readily determined by the interference figure. These sections show a feeble pleochroism a =sap green, b =whitish or yellowish green. The absorption is $a > b$, but in many cases the difference of absorption is so slight that no distinction can be made, and $a = b$. In sections parallel to $\infty P\infty$, containing the axes a and c , the pleochroism is also comparatively feeble, though generally more pronounced than in the last case; a = sap green, c = yellowish green to yellowish. The absorption is $a > c$. In sections normal to the obtuse bisectrix, containing b and c , the pleochroism is much stronger. In these sections c = yellow to amber, b = whitish green. The absorption is $b > c$. From these observations the general formula would be $a \geq b > c$, and the sections parallel to $\infty P\infty$ containing a and c might from this formula be expected to exhibit a pleochroism not less pronounced than any other section. This, however, is not the case. The very pronounced yellow and green pleochroism in sections approximately transverse to c , and showing the emergence of an optic axis, is a persistent feature of the mineral. If the axes of absorption are dispersed in the plane of symmetry, as has been suggested by Laspeyres*, the yellow c ray might be nearly normal to the optic axis, which lies near to c . But inasmuch as the clear yellow to amber does not appear in clinopinacoidal sections, this supposition of the dispersion of the axes of

*Z. f. Kryst., IV, 1880, 454.

absorption does not satisfactorily explain why the pleochroism should be so much more pronounced in sections transverse to c than in all other sections. The dispersion is $\rho < \nu$.

In thin sections the planes of the prismatic zone are fairly, sharply defined. Terminal planes, however, are absent, or are represented occasionally by blunted outlines. In size the prisms range from very small dimensions to a length of about 5 mm. and a breadth of from .5 to 1 mm. The average size of the prisms is probably about 2.5 x .5 mm. There is no pronounced extension of the crystals in the plane of the orthopinacoid. Twinning is not uncommon according to the usual law in which $\infty P\infty$ is the twinning plane. Minute interpositions and secondary products arising from alteration of the pyroxene are entirely lacking, but there are occasional inclusions of the other constituents of the rock, such as apatite, and sometimes, also, grains of magnetite, the latter mineral not being otherwise represented in the rock. Chemically the presence of sodium in addition to the magnesium, calcium, and iron was proved by treating minute grains of the pyroxene, with hydrofluosilicic acid. An abundant deposit of the characteristic hexagonal crystals of fluosilicate of sodium was obtained. From the above-noted characters it is evident that the pyroxene is an *ægerine-augite*.

The nepheline occurs in the rock under different conditions of crystallization. For the most part it is scattered through the orthoclase in idiomorphic, cloudy white crystals which rarely exceed 1 mm. in diameter, the average size being about .5 mm. These crystals show well-defined crystal boundaries in the cross sections, which are commonly hexagonal, pentagonal, rectangular, etc., in shape. They have evidently preceded the orthoclase in the crystallization of the magma. Other occurrences are allotriomorphic with reference to the prisms of *ægerine-augite*. These, too, have evidently antedated the orthoclase. There are, however, in the slides, areas of nepheline which have blurred and hazy or irregular outlines interlocking with the orthoclase, in which they are imbedded as if the mineral had in these cases crystallized simultaneously with the orthoclase. Finally, there are occasional areas where the nepheline and orthoclase present a most remarkable micropegmatitic in-

tergrowth, as will be described more particularly below. In general, it seems to be true that the nepheline crystallized after the ægerine-augite, and for the most part before the orthoclase, but that a subordinate portion of it crystallized simultaneously with the latter.

The nepheline is generally charged with decomposition products, but remains sufficiently intact to reveal its optical character. Numerous sections were observed cut approximately normal to c , which yielded in convergent light the uniaxial interference figure. By the aid of the $\frac{1}{4}\lambda$ mica plate, the mineral was proven to be negative. The index of the refraction is low, and the double refraction is weak. Cleavages are occasionally detected, and to these the extinction is parallel. Slender colorless microlites (apatite) are sparingly present as inclusions. The decomposition products are either fibrous and polarize in brilliant colors with parallel extinction, or they are cloudy kaolin-like aggregates. The development of these secondary products seems to have induced a molecular tension in the undecomposed nepheline, since between crossed nicols it generally manifests an undulatory extinction.

When treated with dilute hydrochloric acid, the surface of the thin sections of the nepheline gelatinizes and stains readily. If, prior to staining, the solution be allowed to evaporate, an abundant deposit of cubes of sodium chloride is obtained. These microchemical reactions were repeated several times on different slides with uniform results, and, in some instances, grains were so treated which had previously yielded the uniaxial interference figure. The character of the mineral as nepheline is thus established beyond question.

An interesting feature of the rock is the micropegmatitic intergrowth of the nepheline and orthoclase. This is observable in a limited number of areas which appear as somewhat cloudy spots in the midst of the fresh pellucid orthoclase. Under high powers of the microscope, they present a curious vermicular appearance, resembling, if the homely simile may be used, a layer of vermicelli in a plate of clear soup. The vermicular rods are usually very slender and long. They are disposed either in a parallel or slightly divergent arrangement, or present a curiously contorted appearance. Sometimes they have a comb-like appearance, and are arranged as a series of club-like bodies nearly normal to an axis composed of a

bundle of slightly divergent rods into which the lateral club-like bodies pass. These vermicular rods sometimes overlap and cross one another, but never intersect. Different rods may be seen one above the other in the thickness of the slide. They frequently branch from a common stem. These rods are composed of cloudy nepheline, and in the ordinary preparations the structure is difficult to study. If, however, the slide be treated with dilute hydrochloric acid and stained with fuchsin, the nepheline rods are very sharply marked off from the orthoclase with which they are intergrown, the rods being colored, and the orthoclase colorless. The orthoclase extinguishes sharply as a unit in common with that beyond the area of intergrowth. Figure 2 illustrates the morphology of the intergrowth, which seems to be very similar to an intergrowth of the same minerals in the rock borolanite described by Teall.*

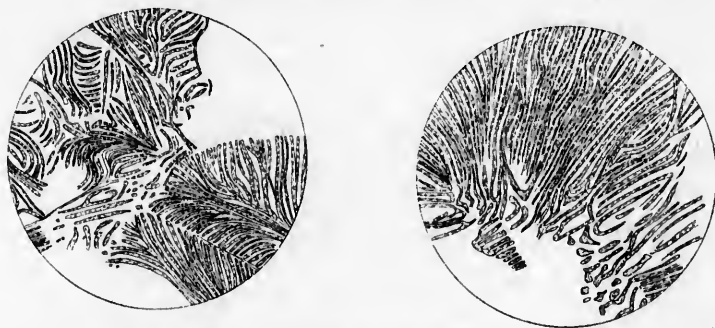


FIGURE 2.—Intergrowths of orthoclase and nepheline in nepheline-pyroxene-malignite. The shaded parts are nepheline and the clear orthoclase.

The apatite is remarkable for its abundance, and for the size of its crystals. It occurs in stout prisms having a maximum length of about 3 mm. These are very striking features of the slides, and the mineral can not be regarded as playing a merely accessory role. The crystals are all perfectly fresh and water clear, but exhibit quite a marked relief, and a very notable total reflection of the light on the borders and along the cracks, the presence of the latter being a

*Trans. Royal Soc., Edin. Vol. XXXVII, Pt. I, No. 11, 1892.

constant feature. The mineral has the usual weak double refraction of apatite, polarizing in blue grays of the first order. It is uniaxial and optically negative. The crystals differ from the apatite micro-lites usually observed as accessories in many rocks in the somewhat uneven or obtusely serrate outline of the crystal boundaries. The terminations of the prisms are often rounded. Fragments of the mineral are easily isolated in a pure condition. These fragments dissolve in hydrochloric acid, and when to the solution a minute drop of sulphuric acid is added, a copious precipitate of characteristic gypsum crystals is obtained. When fragments are dissolved in nitric acid and treated with ammonium molybdate, the canary yellow precipitate indicative of phosphoric acid is obtained. The specific gravity of the mineral as determined by the use of Klein's solution is 3.250. The identification of the mineral as apatite is thus placed beyond a doubt.

The biotite calls for no special description, as it is very sparingly represented in the rock, and exhibits the ordinary well-known characters. As is usual with the mineral, its boundaries are irregular, and have a corroded appearance. The titanite is quite accessory to the general mineralogical composition of the rock, but occurs in grains sufficiently large to permit of its positive identification. In one slide a few grains of pyrite were detected, but the occurrence of this mineral is quite exceptional.

Chemical Characters.—An analysis of the rock was made for the writer, by Mr. F. L. Ransome, Fellow in the Department of Geology of the University of California, to whom the writer here desires to express his obligations. The results of this analysis are given in column I. Columns II, III, IV, V, and VI are analyses of Vesuvian leucitophyres taken from Roth's tables,* while column VII is an analysis of borolanite, taken from Teall's description of that rock.†

*Beitrag zur Petrographie, etc. K. Akad. d. Wiss. Berlin.

†*Loc. cit.*

	I.	II.	III.	IV.	V.	VI.	VII.
SiO ₂	47.85*	48.83	49.15	48.59	48.54	47.63	47.8
Al ₂ O ₃	13.24†	15.34	13.37	19.58	14.86	15.11	20.1
Fe ₂ O ₃	2.74	7.39	6.65	4.38	4.17	6.07	6.7
FeO.....	2.65	3.34	5.88	4.56	4.82	3.34	.8
CaO.....	14.36‡	13.63	10.73	9.12	11.89	15.70	5.4
MgO.....	5.68	4.65	5.30	3.12	5.75	4.66	1.1
Na ₂ O.....	3.72	1.41	3.08	2.15	2.71	1.18	5.5
K ₂ O.....	5.25	3.68	6.55	6.27	6.45	3.87	7.1
H ₂ O.....	2.74			.12	.16	1.61	2.4 (ig.)
P ₂ O ₅	2.42	1.83		2.04		1.65	
SO ₃02		.15		.05	.4
Cl.....		trace		trace		.06	(Baryta .8)
TiO ₂21		.7
MnO.....					1.18		.5
Total.....	100.65	100.12	100.71	100.08	100.92	100.93	99.3
Sp. g.....	2.879	2.76			2.65	2.74	

* Mean of 47.91 and 47.79.

† Mean of 13.33 and 13.16.

‡ Mean of 14.54 and 14.19.

With very moderate digestion 28.14 per cent. of the rock dissolves in hydrochloric acid.

An attempt was made to estimate the proportions in which the constituent minerals are present in the rock, and the following results were obtained:—

	Proportion of Minerals.	Specific Gravity.	Product.
Ægerine-augite.. { Ægerine..... 5.60 Diopside..... 27.92 Hiddenbergite 9.50 Augite..... 5.15 }	48.17	3.299 <i>d</i>	158.91
Orthoclase.....	20.90	2.56 <i>d</i>	53.51
Nepheline.....	19.62	2.60 <i>a</i>	51.01
Apatite.....	5.81	3.25 <i>d</i>	18.88
Biotite.....	2.00	2.90 <i>a</i>	5.74
Titanite.....	1.00	3.50 <i>a</i>	3.50
Water.....	2.70	1.00	2.70
	100.20	<i>d</i> =determined <i>a</i> =assumed	294.35

The specific gravity of the rock as thus estimated should be 2.93, while the actual specific gravity is 2.879. We have thus a check upon the approximate estimate of the proportion of the different minerals present.

Petrographic Relations.—If the rock having the mineralogical characters set forth in the preceding pages were the only facies of the Poohbah Lake laccolite, and the rock were considered only as a mineralogical aggregate, without reference to its chemical composition, it would probably be classed with the nepheline-syenites. Its intimate mineralogical affiliation with other important facies of the same mass, which can not possibly be classed with the nepheline syenites on mineralogical grounds, serves, however, to cast serious doubt upon such a reference. This doubt leads rapidly to a denial of the correctness of the reference the moment we inspect the chemical analysis of the rock and compare it with that of representative nepheline-syenites. We see at once that its low silica contents, 47.85 per cent., and the high lime, 14.36 per cent., are alone sufficient to segregate the rock from the nepheline-syenites, heterogeneous as that family is. The proportion of magnesia, 5.68 per cent., is, moreover, quite at variance with that of the nepheline-syenites. It is worthy of note, too, that the potash is in excess of the soda, while the reverse is generally true of the nepheline-syenites. On the other hand, the nepheline-pyroxene-malignite is chemically closely akin to certain Vesuvian leucitophyres, as may be seen by an inspection of the analyses given in the table. From these it chiefly differs in its more moderate content of iron and alumina. It appears therefore that we have in this malignite the plutonic equivalent of a well-known volcanic rock—the leucitophyre of Vesuvius.

In addition to the broad characteristics which segregate this rock from the nepheline-syenites, certain other features may be alluded to, which, although from a taxonomic point of view are probably of minor or varietal significance, have considerable intrinsic interest. These are the peculiar poikilitic structure of the rock, the total absence of plagioclase, and the remarkably high proportion of phosphoric acid revealed by the analysis. None of these is to be held a distinctive or constant feature of this chemical type of basic plutonic rock; but they combine to add interest to this occurrence of it, and to emphasize its unique character. It is, moreover, noteworthy that in its high contents of phosphoric acid the nepheline-pyroxene-malignite is even approximately paralleled by no other rocks save the Vesuvian leucitophyre, with which it is on other grounds correlated.

Panidiomorphic Gneissic Facies.—There are many variations in the general appearance of the nepheline-pyroxene-malignite in its exposures on Poohbah Lake. These are chiefly due to variations in the coarseness of the rock, or to the degree of disintegration of the rock. There is, however, besides these a distinct local facies which deserves special notice, although, unfortunately, its relations to the main mass were not determined beyond the fact that the one graded with the other. It is a peculiarly foliated or platy rock, which, although having the same mineralogical composition as the normal facies, presents a very different structure. The constituent minerals are, as before, orthoclase, ægerine-augite, nepheline, apatite, titanite, and biotite. The relative abundance of these is, however, somewhat changed. The orthoclase is relatively more abundant and the ægerine-augite less so than in the non-foliated facies. Nepheline occurs in about the same proportions, but the apatite is more sparingly represented. Titanite is more plentiful than biotite, but both play an accessory rôle.

The structural differences between this facies and the normal type of nepheline-pyroxene-malignite are radical. The orthoclase instead of crystallizing in large allotriomorphic masses having a poikilitic relation to all the other constituents is here idiomorphic. It occurs in plates tabular to $\infty P \infty (010)$ ranging in size from 3 to 7 mm. and from .5 to 1 mm. thick. The ægerine-augite commonly shows idiomorphic forms or approximations to these, and appears in general to have in part antedated the orthoclase and in part been contemporaneous with it in crystallization. The nepheline is idiomorphic usually, and inclosed in the orthoclase, but occasionally is moulded against the earlier ægerine-augites. The apatite is idiomorphic, but the titanite is allotriomorphically interlocked with the ægerine-augite and rarely shows its characteristic crystal outlines. In structure, therefore, the rock may be said to be panidiomorphic. This statement, however, fails to express the most striking structural feature of the rock. This consists in the parallelism of the orthoclase plates. Since these plates are the chief constituent of the rock, their disposition in one plane, with but a moderate amount of overlapping, as with shingles on a roof, gives the mass a very platy or scaly appearance, when viewed in fractures parallel to this

plane. It presents a distinct gneissic foliation in fractures transverse to the plane in which the plates lie. The foliation is clearly original, and there is no suggestion of cataclastic or even protoclastic structure in thin sections of the rock. The orthoclase is remarkably free from the molecular tension which is so characteristic of the normal facies of the rock. The plates of orthoclase are commonly slightly curved, and in some cases even distinctly bent, but the phenomena of extinction due to this fact are quite different from the optical tension shown by the poikilitic orthoclase of the normal rock.

The minerals of this facies of the rock have generally the same characteristics as in the normal type. The ægerine-augite presents the same pleochroism. The orthoclase is charged in the same manner with dusty and rod-like interpositions, the latter usually arranged in definite planes and presenting all the characteristics of "Schüllerization" products. The orthoclase differs, however, from that of the normal type in being frequently twinned on the Carlsbad law. It is practically quite fresh and sanidine-like, kaolinization products being only occasionally observed in small areas. The nepheline shows the same degree of alteration to cloudy products, and the large apatites have the same irregular cracks and irregularity in detail of their crystal boundaries as in the normal rock.

THE GARNET-PYROXENE-MALIGNITE.

General Features.—This malignite presents at least two fairly distinct facies, which grade into one another in the same mass. The dominant of these occupies the greater part of the south side of the lake, being interrupted only by limited areas of rocks of the nepheline-pyroxene-malignite type, whose special relations to the garnet-pyroxene-malignite are not well defined, owing to the dense vegetation. The minor facies is confined, so far as observation goes, to the northwest corner of the west end of the lake near the contact with the mica schists. The dominant facies presents a remarkable appearance and appeals to the petrographer's eye as a unique rock. The most prominent mineral is orthoclase, which appears in the form of huge, thick plates of a light flesh tint imbedded in parallel position in a dark green, moderately fine-grained

holocrystalline matrix. These idiomorphic orthoclases are tabular, parallel to the clinopinacoid, and commonly attain a length of from 4 to 6 cm., and a thickness of from 3 to 5 mm. They are in many cases twinned on the Carlsbad law. The basal cleavages are in all cases well developed. In addition to these large crystals there are also smaller irregular grains of the same feldspar scattered through the dark green matrix of the rock, but still showing a more or less pronounced tendency to assume tabular forms and thus grade into the large porphyritic crystals. It is evident from an inspection of the rock that the porphyritic orthoclases antedate the matrix in which they are imbedded, but that the crystallization of the latter set in before the orthoclase molecule was completely precipitated from the magma, so that the residual orthoclase crystallized with and became involved in the aggregate of minerals which constitute the matrix. There is thus no hard and fast line between the bulk of the orthoclase which appears as large crystals and the moiety having the smaller and less regular forms. See Plate 18.

Microscopic Characters.—Under the microscope the orthoclase shows a constant and well-developed microperthitic intergrowth with albite. The latter mineral is readily distinguished from the orthoclase by its somewhat stronger double refraction, its difference of extinction, and in many cases by its lamellar twinning. It is identified by its extinction angle against the basal cleavage in cleavage flakes parallel to the clinopinacoid of the orthoclase. In these flakes the orthoclase has an extinction angle of about 4° , and the plagioclase an angle of 16° to 18° , with an average of $17^{\circ} 22'$, so that there can be little doubt of its being nearly pure albite.

The albite is intergrown with the orthoclase in thin lenticular plates, which lie parallel to the orthopinacoid of the latter and give striped sections in the zone P : M as of overlapping spindle-shaped bodies. In these striped sections the orthoclase is generally somewhat cloudy, while the albite is clear, so that the striped appearance is apparent without the use of crossed nicols. In sections parallel to the orthopinacoid the orthoclase gives an interference figure in which the plane of the optic axes lies parallel to the trace of the basal cleavage. Sometimes the albite of the microperthite appears to be in optical continuity with grains of albite on the periphery of

the orthoclase, and there are occasional quite separate grains of the albite in the slides, which are doubtless genetically connected with that of the micropertthite. These are the only plagioclase feldspars in the slides.

The dark green matrix in which these large idiomorphic orthoclases (micropertthite) are imbedded is a hypidiomorphic granular aggregate of ægerine-augite, melanite, biotite, titanite, and apatite, stated in the order of their abundance, together with the subordinate proportion of micropertthite and albite above alluded to. As accessory minerals occur magnetite and hematite in exceedingly sparing quantities in a few slides. Of these minerals the titanite and apatite are commonly idiomorphic, although occasionally they are quite irregular in outline and are allotriomorphically interlocked with the other minerals. The three principal constituents, ægerine-augite, melanite, and biotite, seem to have crystallized simultaneously and are entirely allotriomorphic, although the pyroxene shows the usual tendency to elongation parallel to *c*.

The ægerine-augite has the same optical characters as those already described for its occurrence in the nepheline-pyroxene-malignite. In some few cases, however, it is of a less deep green color and may indeed be nearly colorless. These are rather exceptional occurrences, and are doubtless due to a local poverty of the ægerine molecule. Twinning on $\infty P \bar{\infty}$ is common. The melanite is in the form of reddish brown to yellowish grains, which are strictly isotropic. They are quite fresh and contain no inclusions as a rule. They have the high refractive index of the garnets and their characteristic irregular cracks. A coarse powder of the rock on being treated with hydrofluoric acid for 24 hours dissolved all the other minerals and left the melanite intact.

The biotite is a brown variety, shading into green locally, and calls for no especial comment.

The titanite appears in thin section in the form of brownish yellow crystals, which commonly exhibit the characteristic rhombic sections of that mineral. These crystals are usually prominent features of the slides and attain a size of 3 mm., though commonly they are about 1 mm. in length. They are more abundant than the proportion of titanitic acid found in the analysis would lead one to

suppose. The pleochroism is quite pronounced in shades of brownish red and yellow. In sections normal to the acute bisectrix the mineral proves to be optically positive.

The apatite has the same characters as those given for the mineral in the nepheline-pyroxene-malignite. The crystals are, however, smaller and less abundant than in that type of rock. The hematite is represented only by an occasional scale in some of the slides. It is of a deep red color, translucent on the margins, but opaque in the thicker central portions. A few grains of magnetite may be found by careful search, usually inclosed in the ægerine-augite. A canary yellow pleochroic mineral is found in some of the slides, but, on account of small dimension of the grains, could not be satisfactorily determined. It has a strong double refraction, but lower refractive index than epidote, and the extinction angle measured against the direction of elongation has a high value.

Chemical Analysis.—For the following analysis of this interesting rock, the writer is indebted to Mr. W. C. Blasdale, instructor in chemistry in the University of California.

Analysis of Garnet-Pyroxene-Malignite.

SiO ₂	51.88
Al ₂ O ₃	14.13
Fe ₂ O ₃	6.45
FeO	.94
CaO	10.81
MgO	3.44
Na ₂ O	6.72
K ₂ O	4.57
TiO ₂	.33
P ₂ O ₅	.96
H ₂ O	.18
Total	100.41
Sp. g.	2.88

From the above data it will be apparent that this malignite approaches in its mineralogical and chemical characters the basic

augite-syenite, laurvikite, of Brogger.* It differs rather radically, however, from that type of rock in being more basic, and in having a lower proportion of alumina, and higher proportions of lime and ferric oxide. These chemical differences find their mineralogical expression in the abundance of melanite. The somewhat higher proportion of magnesia is to be correlated with a larger proportion of pyroxene than is found in laurvikite. The structure of the rock, finally, is quite different from that of laurvikite.

Minor Facies.—The minor facies of the garnet-pyroxene-malignite, which occurs at the northwest corner of the southwest end of the lake, differs in appearance from the prevailing type, from the fact that the feldspar is more abundant, and is very much smaller in size, so that the rock presents a more uniformly gray color, and no striking contrast between the porphyritic constituents and the matrix. The feldspars, however, have the same platy habit, and exhibit a feeble tendency to parallelism. Those which are porphyritic have rather poorly defined boundaries, and they grade insensibly into the feldspar of the matrix. The structure of the rock as a whole may be fairly described as hypidiomorphic granular, although the tendency to platy habit extends to all the feldspar of the rock. Interlocked with the feldspar in allotriomorphic relation are melanite, ægerine-augite and biotite. Titanite and apatite are prominent, as before, but are sometimes also allotriomorphic. The melanite never shows crystal boundaries. Mineralogically the facies presents a distinction from the prevailing type in the greater proportions of melanite and biotite which are present, and the less proportion of ægerine-augite. Its chemical character has not been fully determined, but a partial examination of the rock kindly made for the writer by Miss S. Sharpe, in the chemical laboratory of the University of California, shows that it is somewhat more basic than the prevailing facies. This examination showed the presence of SiO_2 48.86, Al_2O_3 17.40, Fe_2O_3 7.67, FeO .48, Na_2O 8.13, K_2O 2.81. The specific gravity of the rock is 2.93.

AMPHIBOLE-MALIGNITE.

Mineralogical Composition.—That portion of the mass which is

*Die Mineralien der Syenit-pegmatitgänge, etc. Z. f. K. u. M. 16, 1890.

exposed along the northern shores of the lake, and which is here termed amphibole-malignite, may be best described by comparing it with the garnet-pyroxene-malignite. In its general aspect as viewed in the hand specimens, the rock differs from the garnet-pyroxene-malignite in the fact that the orthoclase crystals are smaller, and less sharply defined, while the dark green to black matrix in which they are imbedded is much coarser, owing to the predominance of a lustrous black amphibole in grains of large size. The feldspars have the same habit as before, except that their edges are ragged in detail, and that a considerable proportion of the groundmass is involved with or inclosed in the crystals, particularly on their periphery. There is also a less pronounced parallelism in the disposition of the orthoclase, although the rock is still distinctly gneissic. When viewed in thin sections, other mineralogical differences become apparent. As a result of the preponderance of the amphibole, the ægerine-augite is quite subordinate in amount, and is intergrown with the amphibole. The melanite, which is so characteristic a feature of the slides of the garnet-pyroxene-malignite, is wholly wanting. Biotite plays about the same rôle. Titanite is less abundant, and apatite remains about the same. The black amphibole proves to be difficult of investigation in thin sections, owing to its remarkably strong absorptive powers. As near as could be ascertained, it has moderately low extinctions on c , viz.: 12° to 21° , although it can not be said with confidence that 21° is the maximum angle. The disposition of the axes of elasticity could not be established, but if we assume them to be as in arfvedsonite, the pleochroism is a =deep green blue, b =deep greenish brown, c =dull yellowish green. Absorption, $a > b > c$. The hornblende cleavages are strongly developed, and the characteristic value for the prismatic angle was obtained by measuring cleavage fragments on the goniometer. Leaving aside the large orthoclases (microperthite), the structure of the rock is like that of the garnet-pyroxene-malignite hypidiomorphic granular, the titanite and apatite being the only idiomorphic constituents in the coarse groundmass in which the porphyritic orthoclases are imbedded.

Chemical Analysis.—The following analysis of the rock was very kindly made for the writer by Mr. J. W. Sharwood, instructor in chemistry in the University of California.

Analysis of Amphibole-Malignite.

SiO ₂	51.38
Al ₂ O ₃	15.88
Fe ₂ O ₃	1.48
FeO	4.37
CaO	8.62
MgO	4.43
Na ₂ O	7.57
K ₂ O	4.20
P ₂ O ₅	.98
TiO ₂	.12
H ₂ O	.42
Total	99.45

As compared with the garnet-pyroxene-malignite, the chief features of interest in this analysis are that, while the silica and total alkalis remain about the same in the two rocks, there is a decrease in lime and ferric oxide in harmony with the absence of melanite, and an increase in ferrous oxide and soda in harmony with the replacement of ægerine-augite by arfvedsonite.

CONCLUDING REMARKS.

The interest attaching to the rocks described in the preceding pages is twofold. To the systematist they furnish new material for any detailed scheme of classification of rocks. To the student of petrogenesis, to whom artificial schemes of classification are liable to be a hindrance rather than a help, they afford another instance of a very sharply-defined petrographic province in which the different types of rock are undoubtedly the products of differentiation from a common magma. As a problem in magma differentiation the field evidence and the material collected are unfortunately both too scant to permit of a satisfactory discussion. A few closing observations upon the inter-relations of the three types of malignite may, however, be offered. From the sketch map, Fig. 1, it will be apparent that the most basic or nepheline bearing type is quite subordinate in extent to the other two types

of rock, and that neither direct observations in the field nor inferences from the general distribution of the rocks suggest that it occupies a peripheral relation to the mass of the laccolite. In current discussions on magma differentiation it is usually assumed that the more basic portions of the products of crystallization in a magma basin are to be found on the periphery of the mass. This is undoubtedly true in many well-known cases. That it should be laid down as a general law is, however, questionable. The familiar phenomena of basic secretions in various rocks seem to have no genetic connection with the periphery of the masses in which they occur. Under certain conditions it is entirely conceivable, and even probable, that these basic secretions may acquire dimensions relatively great and be properly regarded as products of magma differentiation, as now understood, and yet have no connection with the periphery of the mass of the magma. Of such a character appear to be the areas of nepheline-pyroxene-malignite in the Poohbah Lake laccolite. The relative distribution of the other two types of malignite is not well known beyond the fact that the one prevails on the northern shores of the lake and the other on the southern. It is to be remarked, however, that, taking our orientation from the stratification of the Coutchiching rocks, the garnet-pyroxene-malignite is at the lower part of the mass and the amphibole-malignite at the upper part. From the further fact, however, that the laccolite mass has, as a solid rock, partaken of none of the disturbance, which has affected the Coutchiching series, it is probable that the latter was upturned prior to the invasion of the laccolite, so that our conceptions of the upper and the lower parts of the laccolite must be checked by this consideration.

The most striking fact which a review of the petrographical descriptions discloses is that intensely contrasted mineralogical, structural and textural variations are the concomitants of very moderate changes in chemical composition. This is well illustrated by a comparison of the analyses of the garnet-pyroxene-malignite and the amphibole-malignite.

	Garnet-pyroxene- malignite.	Amphibole malignite.	Difference.
SiO ₂	51.88	51.38	+ .50
Al ₂ O ₃	14.13	15.88	-1.75
Fe ₂ O ₃ } FeO }	7.39	5.85	+1.54
CaO	10.81	8.62	+2.19
MgO	3.44	4.43	-.99
Na ₂ O	6.72	7.57	-.85
K ₂ O	4.57	4.20	+ .37
			= .48
TiO ₂	.33	.12	+ .21
P ₂ O ₅	.96	.98	-.02
H ₂ O	.18	.42	-.24
Total	100.41	99.45	
Sp. g.	2.888		

Yet with these closely-allied chemical characteristics there are, as already pointed out, important mineralogical differences, the first rock containing an abundance of melanite and the second none; the first having much ægerine-augite and no amphibole, and the second much soda-amphibole and but a subordinate proportion of ægerine-augite. Again, the chemical differences between the garnet-pyroxene-malignite and the nepheline-pyroxene-malignite are not of a radical kind, yet one rock—that containing the smaller proportion of soda—is rich in nepheline, while the other has none. The rock containing the larger proportion of lime contains neither garnet nor plagioclase, while that with the less lime has considerable plagioclase and abundant garnet.

As regards structural variations, the most interesting point is that connected with the relative order of crystallization of the orthoclase in different types of the rock. In the nepheline-bearing rock it was clearly the last to crystallize, and forms a mesostasis in which other constituents are imbedded poikilitically. In the garnet-bearing rock quite the reverse is the case, since the bulk of the orthoclase is in the form of the huge porphyritic crystals imbedded in a paste of the other minerals. If we suppose that

in the two portions of the magma which resulted in the two types of structure the crystallization of the orthoclase was simultaneous, we have an explanation of this curious reversal of sequence of crystallization. If the more basic or nepheline-bearing facies of the laccolite be, as seems very probable, of earlier consolidation than the rest of the magma, the normal sequence of crystallization obtained, and the orthoclase crystallized last, forming a residual mesostasis. But if this portion of the laccolite were in free communication with the rest of it, as seems certain, crystallization may have been inaugurated throughout the latter about the time that the orthoclase was forming in the more basic portion. This local crystallization of the orthoclase may be assumed, for lack of a better hypothesis, to have set up, by a sort of sympathetic action, the general separation of the orthoclase, out of its time, throughout the entire laccolite.

*Geological Laboratory,
University of California, February, 1896.*

