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ON THE QUARTZ KERATOPHYRE AND ASSOCIATED ROCKS OF THE NORTH RANGE OF THE BARABOO BLUFFS.

BY

SAMUEL WEIDMAN

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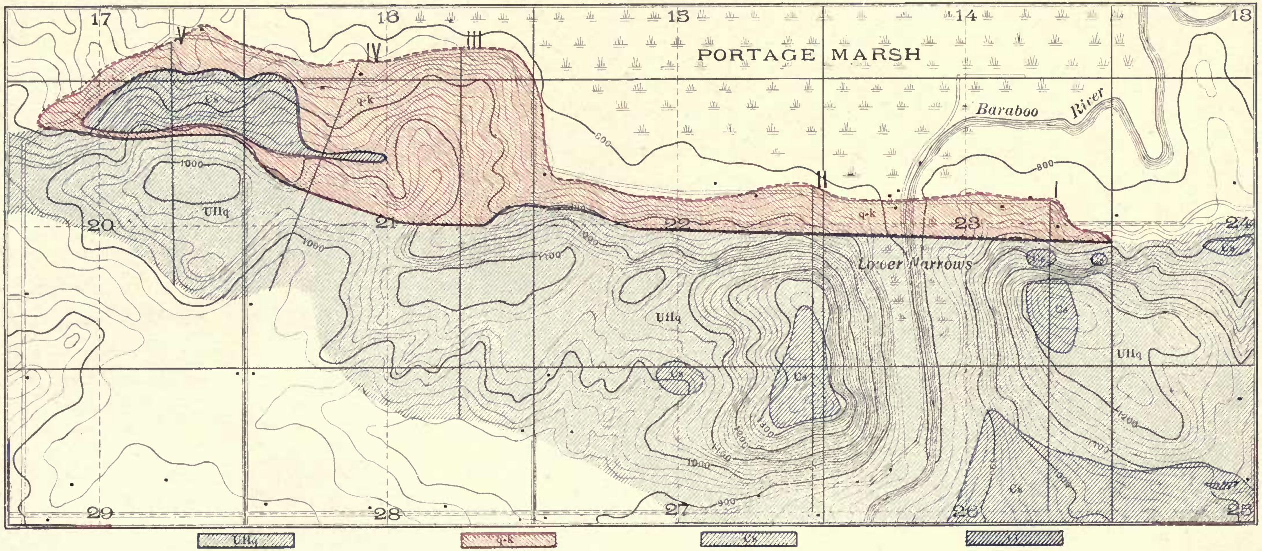

U. Huronian Quartzite. Quartz keratophyre. Cambrian Sandstone. Cambrian Limestone.

GEOLOGICAL MAP OF A PORTION OF THE NORTH RANGE OF THE BARABOO BLUFFS.

By Samuel Weidman.

Scale: 1½ inches = 1 mile.

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ON THE QUARTZ KERATOPHYRE AND ASSOCIATED ROCKS OF THE NORTH RANGE OF THE BARABOO BLUFFS.[1]

BY SAMUEL WEIDMAN.[2]

CONTENTS.

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In the south central part of Wisconsin, extending across the middle portions of the county of Sauk and for a short distance into that of Columbia, there arises above the surface of the surrounding area two long ranges of hills or ridges. These ranges trend across the country in an east and west

[1] A thesis submitted for the degree of Bachelor of Science in the Geology Group of the General Science Course, University of Wisconsin, June, 1894. Read before the Geological Society of America at the Baltimore meeting, December, 1894.

[2] This paper is the result of work undertaken and executed under the direction of Professors W. H. Hobbs and C. R. Van Hise. To the former I desire to express my thanks for superintending the work in the laboratory, for preparing the photo-micrographs, and for other valuable help, and to the latter for giving me aid and suggestions in the field study. I also desire to express my obligation to Mr. C. F. Austin who kindly furnished the chemical analysis for this paper.

direction for a distance of nearly thirty miles, and are known as the north and south ranges of the Baraboo Bluffs. In altitude they vary from a mere rise above the surrounding country to a height of five and even six hundred feet.

The north range, which is not so prominent as the south range, is joined to the latter at the eastern and western extremities, forming thus a canoe-shaped chain of bluffs, enclosing within a depressed area three or four miles broad at its widest part. Near the western end, where the Baraboo River enters the area, and also near the eastern end, where it emerges again, the north range is broken down by deep gorges known respectively as the Upper and the Lower Narrows.

The rock material of the Baraboo Bluffs is mainly of bedded quartzite, over whose upturned edges lie horizontal beds of sandstone and conglomerate, capping and flanking the ranges. Besides these sedimentary rocks there occurs in the vicinity of the Lower Narrows a considerable area of eruptive material.

The geology of the sedimentary rocks [1] has already been quite well worked out. The quartzite, which belongs to the Upper Huronian formation, is usually hard and massive, but in a few places there occur beds and zones of quartzite schists and slates. The dip of the quartzites is always to the north, and varies from 15° at Devil's Lake in the south range, to 60° at the Upper Narrows and even 90° at the Lower Narrows in the north range. This ever increasing dip from the south toward the north indicates, as shown by the Wisconsin geologists,[2] that the two ranges are the remnants of the north half of a great anticlinal fold. The sandstone and conglomerate, as well as a few small areas of limestone, all of which are of Upper Cambrian age, lie in horizontal beds capping the ranges.

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[1] Correlation Papers — Archean and Algonkian, by C. R. Van Hise. Bulletin 86, U. S. Geological Survey; pp. 105–107, 111, 140, 148.

[2] The Baraboo Quartzite Ranges, by R. D. Irving. Geol. of Wis., Vol. II; pp. 506, 507.

The eruptive rock, which was described as quartz porphyry by the state geologists, is a quartz keratophyre, and occurs in contact with the quartzite along the north side of the north range in the vicinity of the Lower Narrows. This rock was not discovered until 1874 or 1875 by Irving and his co-workers upon the Wisconsin Geological Survey, and all results of work done upon this formation are embodied in the state geological reports.

Irving [1] in 1877 described the porphyry as occurring on the west side of the Baraboo River at the Lower Narrows. He considered the porphyry to be very distinctly bedded, with an east and west strike and a dip of 58° to 60° to the north. He also found that near the quartzite it changes to a distinct schist, which he thought to be allied to the greasy quartz schists at Devil's Lake. Farther west at the northern limit of the porphyry, he found the much fractured area. A schistose structure, which is apparent in places, was taken as bedding and as evidence of the clastic origin of the rock. A specimen was analyzed and found to contain 71.24 per cent. of silica and a notably large quantity of soda as compared with potash.

Chamberlin,[2] in 1882, mentioned the massive quartz porphyries which overlie the Baraboo quartzites and referred to their origin as yet in doubt. According to him they might be either a metamorphosed silt-like sedimentary rock; or they might be of eruptive origin, in which case they must have constituted immense overflows of molten rock closely allied in chemical composition to rhyolite.

Irving,[3] in 1886, in referring to the Baraboo quartzites, stated that "the bedding structure of the quartzite of these ranges and of its associated schists and felsitic porphyries, which are taken to have been great eruptive flows, I studied with a great deal of care a number of years since * * *." It is evident from this that he was inclined to

[1] The Baraboo Quartzite Ranges, by R. D. Irving. Geol. of Wis., Vol. II; pp. 513–515.

[2] General Geology of Wisconsin, by T. C. Chamberlin. Geol. of Wis., Vol. I; p. 87.

[3] On the Classification of the early Cambrian and pre-Cambrian Formations, by R. D. Irving. 7th Ann. Rept. U. S. Geol. Surv., 1885–6; p. 407.

change his opinion as to the origin of the quartz porphyry. He, however, made no re-examination of the area, and it must be supposed that he was led to change his views on account of his knowledge of the extensive eruptive areas in the Lake Superior region.

II. FIELD GEOLOGY.

The accompanying map, Plate 1, shows the relations and extent of the different rock formations which occur in the vicinity of the Lower Narrows. Four distinct types of rock are seen to outcrop, representing the quartz keratophyre, Upper Huronian quartzite, Potsdam sandstone and conglomerate, and the Lower Magnesian limestone. The cross sections of Fig. 1 cross the range, and in a measure show the structural relations and vertical extent of these formations. For the purpose of convenience the reverse order will be taken in describing these formations.

LIMESTONE.

On the south side of the range, and near its summit, in the northwest ¼ of Sec. 25, is a ledge of dolomitic limestone overlying the sandstone. It is non-arenaceous, and contains many small cavities lined with calcite. In determining its stratigraphical position, one is met with difficulties owing to the peculiar fluctuations in level of the horizontal formations in the Baraboo region, but from the *Dikellocephalus* fauna which it carries, and from its lithological characters, it has been considered[1] as being at least not below the Lower Magnesian.

SANDSTONE AND CONGLOMERATE.

Overlying both the older formations of quartzite and quartz keratophyre there occur capping and flanking the

[1] Geol. of Wis., Vol. II; pp. 594, 595.

range horizontal beds of sandstone and conglomerate of the Upper Cambrian epoch. The conglomerate is composed of pebbles and boulders, varying in size from a fraction of an inch to more than a foot in diameter, imbedded in a matrix of quartz grains, stained more or less with ferruginous material. The conglomerate is found in great abundance in the ravines.

The sandstone which carries the *Dikellocephalus* fauna is interbedded with and overlies the conglomerate. It is composed of rounded quartz crystals in a matrix of silica, containing considerable oxide of iron. The sandstone caps the ridges in thin beds, but along the sides of the range, as in the area of cross-section V of Fig. 1 (see also Plate 1), it reaches a thickness of forty-five or fifty feet.

QUARTZITE.

The quartzite is a hard compact rock, and has a reddish purple hue, with a tendency to granular texture. The bedding is not everywhere distinct, but in places it is quite plain. At the contact of the quartz keratophyre along the ridge the bedding dip conforms to the dip of the overlying keratophyre schists, but farther south, at the top of the ridge, the dip is increased to 90°, and sometimes apparently dips to the south. On the south side of the range, however, it again dips 75° or 80° to the north. Everywhere the quartzite is jointed, and in many places the rock is seamed with reticulating veins of pure quartz, in which, at times, are to be seen small particles of specular iron ore.

QUARTZ KERATOPHYRE.

Areal Extent.— From the map it is seen that quartz keratophyre extends along the north face of the range for a distance of over three and one-half miles. Its most eastern limit is in the northeast corner of the southeast ¼ of Sec. 23, and its most western is found in the northeast ¼ of the northwest ¼ of Sec. 20, thus extending along the range in a slightly north of west direction. In Sections 16 and 21 the thickest portion of the eruptive mass is found, for its contact with the quartzite at this place is distinctly shown near the northern boundary of the southeast ¼ of Sec. 21, from whence it extends north forming a broad ridge cut by ravines, with its northern limit near the middle of the southeast ¼ of the southeast ¼ of Sec. 16.

It is apparent that Irving did not find the keratophyre extending as far east or as far west as a closer study of the area reveals, for it is described as only reaching from the Narrows to the south side of Sec. 16.

The Contact.—The contact between the eruptive rock and the quartzite is well defined, except where a bed of soil overlies it. At the eastern end of the area in Secs. 22 and 23, where the keratophyre occurs as a narrow strip, the quartzite is of a higher altitude than the keratophyre, and stands out as a vertical cliff from ten to thirty feet high. In the region from the center of Sec. 21 eastward, the contact is easily made out, and it is seen that its direction conforms very closely with the strike of the underlying quartzite, which is slightly south of east. From the center of Sec. 21 across the greater part of the northwest ¼ of this section, the contact was not seen, but it was clearly made out at the boundary of Secs. 20 and 21, near the southwest corner of the northwest ¼ of the northwest ¼ of Sec. 21. From this place eastward the actual contact was not seen, but many schistose blocks of keratophyre were found near the outcropping quartzite, and as the keratophyre was found *in situ* in the northwest ¼ of the northwest ¼ of Sec. 20, the contact is thought to be very near the line indicated upon the map. The eruptive rock at the contact occurs as schist, but the quartzite forms massive beds, and is fresh and unaltered. Dikes and veins from the eruptive rock were closely searched for the whole length of the ridge at the contact, with the thought that the eruptive mass might be intrusive and not extrusive, but no such phenomena were found to occur.

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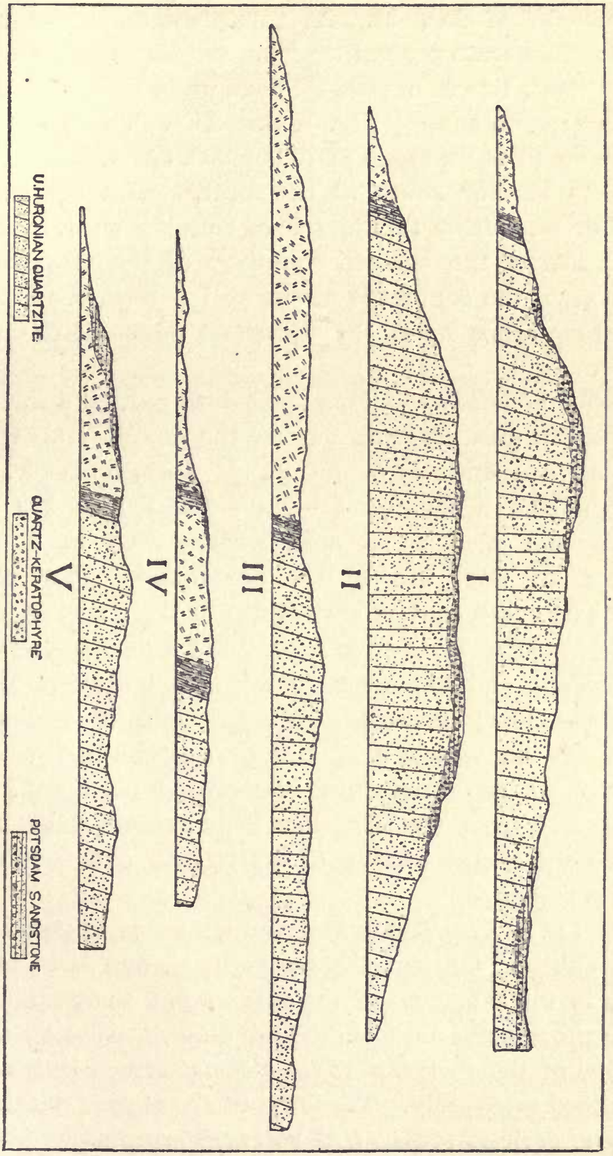

SECTIONS ACROSS THE NORTH RANGE OF THE BARABOO BLUFFS.

Horizontal and vertical scales are one inch to eleven hundred and fifty feet. Base line of sections is eight hundred feet above Lake Michigan.

The contact between the quartz keratophyre and the Cambrian sandstone and conglomerate is well shown in the northwest ¼ of Sec. 21. At this place a narrow strip of the conglomerate projecting from the large sandstone area to the west, lies in horizontal beds upon the dipping edges of the sericite schist (Fig. 1, Sec. IV). These schists dip to the north at an angle of 75° or 80°, essentially the same as those farther south at the contact with the quartzite. Farther west from this tongue of conglomerate, in a ravine which marks the eastern boundary of the massive sandstone area, the contact is again well shown, the horizontal sandstone lying upon the upturned edges of the sericite schist.

Absence of Bedding.— This rock does not, like the quartzite, exhibit stratification, but on the contrary all traces of bedding are entirely wanting. It does, however, at the contact form a zone of schists from 150 to 200 feet in width, and also in a considerable area in the northwest ¼ of Sec. 21, schists are found. The cleavage planes of these schists always dip to the north at an angle of 75° or 80°. Irving[1] in describing this area, speaks of the schists, and whenever he does so he invariably mentions the clearly defined bedding which the rocks show. Although he was one of the first geologists who later learned to recognize the importance of distinguishing schistosity from stratification, it is evident that he committed the common error of taking the one for the other in this region.

Types of Rock.— The eruptive rock as it appears in the field exhibits marked local variations, due both to conditions in the eruptions of the magma and to dynamic action since the general outflow. These differences allow a classification of the rock into three distinct types, which will be described separately. These types are normal quartz keratophyre, sericite schist, and volcanic breccia.

[1] Geol. of Wis., Vol. II; pp. 513-515.

Quartz keratophyre.—The quartz keratophyre, which forms the normal rock type of the whole eruptive area, as it occurs in the narrow strip at the eastern extension of the area is not much fissured, but is jointed and cut by reticulating veins of quartz. It forms rounded ledges and grades into the sericite schist zone, which lies to the south of it. The rock[1] is very fresh, and breaks with a conchoidal fracture. It is red in color, containing in about equal numbers many beautiful red and white feldspar phenocrysts, some of which are three-eighths inches in diameter. These are imbedded in a brownish red matrix. The rock on the eastern side of the Lower Narrows contains fewer phenocrysts than that on the western side. Both phenocrysts and groundmass become red on weathering.

Farther west, at the large northward projecting ridge which occurs in the northeast ¼ of Sec. 21 (Fig. 1, Sec. III), the keratophyre[2] is found to be unlike that farther east, in that it is much fractured, and the feldspar crystals are rarely apparent in the hand specimen. Reticulating quartz veins from a fraction of an inch to three or four inches in thickness are quite numerous. The fractures which cut the rock run in all directions, so that it breaks and weathers in small fragments, bounded on all sides by plane surfaces. On the weathered surface the rock is a reddish brown, but within it is of a darker hue.

Within the eruptive area are many detached blocks of quartz keratophyre. Some of these blocks are quite different from the quartz keratophyre found in place. A detached block[3] which was found upon the summit of the range in the northwest ¼ of Sec. 21, unlike the quartz keratophyre found *in situ*, is black in color, and on close examination it shows fluxion structure. Several blocks of similar black colored quartz keratophyre were found near

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[1] Specimens 3089 and 3090. The specimen and thin section numbers referred to in this paper are those of the University of Wisconsin Collection.

[2] Specimens 3075 and 3092.

[3] Specimen 3080.

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the exposure of volcanic breccia at Mr. Hewitt's place in the northeast ¼ of the northwest ¼ of Sec. 21.

Specimens from some of these blocks have a large number of small phenocrysts while others show but few. These phenocrysts are a light colored feldspar and usually plagioclase. It is possible that this black quartz keratophyre has its origin in the porphyry areas to the northeast, but it may be that a closer examination of the area would reveal it in place.

Sericite Schist.—Wherever the quartz keratophyre comes in contact with the quartzite, there occurs a zone of sericite schist from 150 to 200 feet wide. These schists are a dynamic alteration of the quartz keratophyre and they gradually pass into the latter, and hence are not, as Irving[1] supposed, closely related to the magnesian schists which occur at Devil's Lake. The schists vary in color from the reddish brown of the quartz keratophyre to a grayish white. In texture they are quite friable and are easily cleaved. They carry a considerable number of feldspar crystals, some of which have weathered out leaving cavities that are usually lined with iron oxide. In some specimens iron pyrite is seen. Some of the grayish white schists contain many greenish brown areas of cherty-like material, which the microscopic examination shows to be secondary quartz, the rock being a pseudo-breccia.

Besides the schists at the contact, there occurs within the area of quartz keratophyre in the north half of the northwest ¼ of Sec. 21, a large area of schist (Fig.1, Sec. IV), which is capped by sandstone and conglomerate, and which, like the schist at the contact, has a dip of 75° or 80° to the north. In all respects it is like the schist at the contact, except that feldspar crystals in the hand specimen are rare.

Volcanic Breccia.—There occur within the eruptive area several good examples of volcanic breccia. Within the

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[1] Geol. of Wis., Vol. II; page 513.

contact zone of schists in the southwest ¼ of the northeast ¼ of Sec. 22, there is an outcrop of volcanic breccia[1] fragments in which usually have the typical flow structure about them. A similar exposure[2] occurs at the contact near the center of Sec. 22. The included fragments in the rock of both the above localities are of a hard pink rock, and unlike the schist in which they are imbedded they are relatively unaltered. In the field these fragments were taken to be a pink quartzite, but the microscopic slides show them to be an acid porphyry.

The best exposures of breccia,[3] however, were found on the north side of the road opposite Mr. Hewitt's house, in the northeast ¼ of the northwest ¼ of Section 21. This outcrop exhibits a schistosity, the dip of the cleavage planes being 75° to the north and the strike a little north of east. The fragments forming this breccia are much larger than those found in the other schists and are usually angular and elongated in the plane of schistosity. They vary in size from an inch to a foot in diameter, and were at once taken to be of eruptive origin.

The fragments of this breccia represent several rock varieties. One is brownish pink in color and is composed almost wholly of secondary spherulites which are from two-eighths inch to three-eighths inch across. On the surface of the exposure these secondary spherulites have weathered out, leaving cavities lined with quartz, which makes them appear much like amygdaloidal cavities. Another variety is a brownish gray schistose rock which contains many feldspar phenocrysts, some of which have weathered out leaving cavities filled with black ferruginous material. Other fragments are composed of a dull lead colored rock, slightly schistose and having no phenocrysts.

A large number of loose blocks[4] was found in the road

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1 Specimens 3084 and 3085.

2 Specimen 3081.

3 Specimens 3093, 3094.

4 Specimen 3096.

near the house of Mr. Montgomery, in the southeast ¼ of the southeast ¼ of Section 17. This rock on its weathered surface shows very clearly the flow structure about the included fragments. Unlike the fragment-bearing rock *in situ* this is not markedly schistose, is not much altered, and the included fragments are few. The weathered surfaces seem to give evidence of a few large and widely separated spherulites, but none of these were included in the sections which were prepared. An outcrop of fresh breccia[1] in the northwest ¼ of the northwest ¼ of Sec. 21, shows numerous phenocrysts of feldspar intermingled with small rock fragments.

Conclusions Drawn from Field Study.—The work in the field shows the areal extent of the eruptive rock to be somewhat greater than was formerly supposed. A marked difference is found in the rock as it outcrops in various places. The contact closely conforms in direction for the greater part of the distance, with the strike of the underlying quartzite beds and the dip of the cleavage planes of the contact schists agrees with the dip of the quartzite. Volcanic breccia occurs in considerable quantity in various localities. All the phenomena observed during the field study are evidence that the porphyry in its several phases represents a volcanic outflow which took place over beds of quartzite. During the elevation which followed, the overlying eruptive rock was in part metamorphosed into schist.

III. Microscopic Geology.

The structure of the rock, as it is presented by the microscopic sections in the laboratory confirms the evidence gathered in the field for the extrusive character of the quartz keratophyre. The porphyritic structure is developed in all the types of rock, being well shown in the volcanic

[1] Specimen 3079.

breccia and sericite schist as well as in the unaltered quartz keratophyre. The porphyritic minerals are chiefly the feldspars, quartz occurring very rarely in phenocrysts. The few that are found are intensely corroded, and the indications are that they were once much more numerous, the rock being at this earlier period mineralogically as it is now chemically a quartz keratophyre.

Two analyses of the rock have been made, one by Prof. W. W. Daniells for the State Geological Survey, the other by Mr. C. F. Austin during the preparation of this paper. Below are given the analyses of the Baraboo rock in comparison with quartz keratophyres from other localities.

	I.	II.	III.	IV.	V.
$Si O_2$	70.97	71.24	72.42	73.00	71.9
$Al_2 O_3$	13.84	12.20	13.04	15.61	13.4
$Fe_2 O_3$	3.21	1.71	.68	—	.6
$Fe O$	.78	5.44	2.49	1.95	
$Ca O$	1.26	.98	.66	.79	.2
$Mg O$	.20	.13	.58	—	1.0
$K_2 O$	1.57	1.86	4.97	.88	.2
$Na_2 O$	6.27	4.29	3.44	4.95	12.6
$H_2 O$	.74	.81	1.21	1.06	.5
$C O_2$	.79	—	—	—	—
$P_2 O_5$	.08	—	—	—	—
$Ti O_2$	.25	—	.40	—	—
$Mn O$	—	.97	.09	—	—
$Ba O$	—	—	.15	—	—
$Li_2 O$	—	—	tr.	—	—
$S O_3$	—	—	—	.76	—
Total	99.96	99.63	100.33	99.00	100.00
Sp. Gr.	—	—	2.62	2.63	—

I. Quartz keratophyre from Mühlenthal zw. Elbingerode and Rübeland, Harz. (Jacobs)[1]

II. Quartz keratophyre from Baraboo, Wis. (Daniells.)[2]

III. Quartz keratophyre from Pigeon Pt., Minn. (Bayley.)[3]

IV. Quartz keratophyre from Baraboo, Wis. (Austin)

V. Quartz keratophyre from Mt. Elizabeth, Australia. (Howitt.)[4]

It is seen that the Baraboo rock compares very well in composition with the quartz keratophyre of other regions. The large amount of soda as compared with potash in this rock, as shown by the analyses, indicates the presence of a feldspar whose composition corresponds with a soda-orthoclase. The excess of soda over lime in the Baraboo rock also indicates that the plagioclase present contains a large per cent. of the *Ab.* molecule. The specific gravity of the orthoclase and plagioclase as determined by the Thoulet solution was found to be about 2.63, both varieties being apparently the same. This high specific gravity of the feldspars is explained by the large amount of soda in their composition, and in part, also, by the particles of oxide of iron which they contain.

A macroscopic description of the several types of rock as they appear in the different parts of the eruptive area has already been given. As the microscope shows the structure of these types to be essentially the same both as regards the minerals of the first generation and the ground-mass, the phenocrysts and accessory minerals will first be described, and then the various structures of the ground-mass.

Feldspar Phenocrysts.—Feldspar constitutes almost the only porphyritic mineral. Soda-orthoclase and plagioclase are about equally abundant. Sometimes both varieties are equally distributed in the same slide, and at other times a single variety only is present. Microcline

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[1] Quoted by Zirkel, Lehrb. d. Petrog., 2te Aufl., Vol. II; p. 334.

[2] Irving, Geol. of Wis., Vol. II; p. 515.

[3] Bayley, Am. Jour. Sci., (3) Vol. XXXVII; p. 61.

[4] Howitt, Roy. Soc. Victoria, 1883, p. 25. Quoted by Rosenbusch, Min. u. petrog. Mitth. Vol. XI; p. 177.

is found to some extent as both large and small phenocrysts.

The phenocrysts vary in size from two-tenths millimeter to four millimeters across. The crystals are more or less altered to sericite, sometimes completely, but at other times only slightly. The alteration takes place very often at the boundary of the feldspar, and forms zones of sericite surrounding the crystal. At other times the fine sericite needles are promiscuously scattered throughout the phenocryst. Very often the feldspar is replaced by secondary quartz. At times[1] it is only partly replaced, but very often the angular shape which the secondary quartz assumes indicates that there has been a complete replacement of the feldspar.

Numerous beautiful examples were observed of bent and broken crystals due to the motion of the magma after the crystallization of the phenocrysts (Plate 2, Figs. 1 and 2). Broken phenocrysts are not uncommon phenomena of effusive rocks. As the viscous streams of lava, including the crystals of feldspar, flowed over the surface, the motion within the mass bent and broke the phenocrysts. Sometimes they are merely cracked or broken, but very often the broken parts are separated from each other (Plate 2, Fig. 2), allowing a thin stream of groundmass to flow between the dismembered parts. It very often happens that the crystals of feldspar, both the broken and unbroken ones, have their corners rounded by corrosion. The embayments in the feldspar shown by some of the slides[2] show plainly this resorption.

Quartz phenocrysts.— This usually abundant mineral as a primary constituent of the acid rocks, occurs very rarely as phenocrysts in the Baraboo quartz keratophyre. In a total of thirty-two slides examined from this region only four were found to contain porphyritic quartz, and these showed only a few crystals, all of which were of small

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[1] Section 3084.1

[2] Sections 3079 and 3089.

size. All, however, show by their rounded appearance and embayments, the resorption effects of a corroding magma, and thus they indicate that they were once of larger size and probably more numerous. Some[1] of the quartz-phenocrysts, like those of feldspar, show the effect of a moving magma by being cracked and broken.

The small number of quartz phenocrysts present would apparently indicate that this rock is a keratophyre rather than a quartz keratophyre. Mineralogically it is a keratophyre; but the analyses show it to compare very closely to quartz keratophyre in the amount of silica contained, and the few corroded quartz crystals seem to indicate that the rock was originally a typical quartz keratophyre, though the silica per cent. has been somewhat increased by the secondary quartz present.

Accessory Minerals.—Ilmenite is an abundant accessory constituent occurring in small and large crystals. It is commonly either partially or completely altered to leucoxene. The alteration to leucoxene along the gliding planes of the ilmenite is well shown in one section.[2] Sometimes the ilmenite has gone over to well crystallized sphene, which is commonly mingled with more or less of the impure variety. In some cases (Plate 3, Fig. 1) the crystals of ilmenite are partly replaced by secondary quartz, the latter occupying the space of the former, as in the replacement of the feldspar crystals.

Biotite occurs in considerable abundance in a few of the sections. It is crystallized into small blades which are scattered promiscuously throughout the groundmass and in longer blades[3] arranged in sheaves, or in aggregates which seem to be about small cavities in the rock.

Zircon occurs to a small extent, sometimes being bounded by its usual crystal planes. It is frequently associated with the ilmenite.

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[1] Section 3073.

[2] Section 3080.

[3] Sections 3079 and 3080.

Magnetite occurs in considerable quantity as shown by the action of the magnet on the powdered rock, and the microscopic sections show it disseminated in small particles throughout the groundmass. Besides the magnetite there is considerable amorphous iron oxide or ferrite present, which appears as a red substance about cavities [1] and in streaks through the groundmass.

The Groundmass.—The groundmass of the quartz keratophyre is holo-crystalline and composed of quartz and feldspar, stained more or less with oxide of iron. It is crystallized in at least three structures which are common to volcanic rocks. viz.; the fluxion structure, the poikilitic structure, and the spherulitic structure.

Fluxion structure.—In all the sections examined under the microscope the rock shows clearly sinuous lines of flow in the groundmass. These lines of flow curve and wind about phenocrysts, and give them the appearance of eyes. They also curve about the fragments and between the broken parts of fragments and phenocrysts. The fragments about which flowage is apparent in the hand specimen have also a flow structure of their own and in one case [2] a fragment within a fragment showed the typical flow lines under the microscope. One section [3] (Plate 3, Fig. 2), shows quite well the flow structure in a volcanic breccia, in which the lines of flow in the fragments are at right angles to those in the surrounding mass. In the sericite schists the fluxion structure is clearly defined, which as well as the field relations proves them to be the metamorphosed equivalents of the quartz keratophyre.

Poikilitic Structure.—This structure, which has recently been described by Haworth,[4] Williams,[5] and others, is quite

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[1] Section 3076.

[2] Section 3084.1

[3] Section 3096.

[4] A Contribution to the Archean Geology of Missouri, by Erasmus Haworth. Am Geol., Vol. I; p. 368.

[5] On the use of the terms Poikilitic and Micropoikilitic in Petrography, by G. H. Williams. Jour. of Geol., Vol. I; pp. 176-179.

common in acid volcanic rocks, and occurs to some extent in these rocks. This structure is not apparent in ordinary light, but in polarized light on revolving the stage, small areas in the groundmass appear alternately dark and light in patches, giving a mottled appearance. These areas are composed of irregular grains of quartz in close contact with feldspar. They do not have sharp extinction individually, but gradually pass into one another as the stage is revolved. Sections[1] taken from the fractured rock show this structure better than the others.

Spherulitic Structure.—The spherulitic structure is well developed in many of the sections examined. Some of the spherulites are a primary crystallization and are composed of radial fibres of feldspar associated with quartz, and occur in small circular and semicircular areas,[2] and in larger fan-shaped forms[3] (Plate 2, Fig. 2), like those described by Iddings[4] from the Yellowstone Park rhyolites. They are scarcely perceptible in ordinary light, but in polarized light the usual distinct dark cross is seen. Besides those showing the radiating structure there also occur some spherulites which have a granular texture, and are of secondary origin. Similar secondary spherulites have recently been described[5] from the acid volcanic rocks of South Mountain. In the Baraboo quartz keratophyre these secondary spherulites as they appear in the thin section are much larger than those of primary origin. In the hand specimen, too, the only spherulites found are the secondary ones. One of the specimens[6] shows many such spherulites one-fourth inch across, with lines of flowage passing around them. Under the microscope these spherulites[7] ap-

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[1] Section 3075.

[2] Section 3074.

[3] Section 3080.

[4] Obsidian Cliff, Yellowstone National Park, by J. P. Iddings. 5th Ann. Rep. U. S. Geological Survey; pp. 276-279.

[5] The Structures, Origin, and Nomenclature of the Acid Volcanic Rocks of South Mountain, by F. Bascom. Jour. of Geol., Vol. I; pp. 817-819.

[6] Specimen 3094.

[7] Sections 3085, 3094a and 3094b.

pear to be composed of grains of quartz of smaller size than that which replaces the feldspar, and which is otherwise aggregated in the groundmass. Within the secondary spherulite, too, the quartz seems to be associated with sericite and iron oxide, whereas the secondary quartz otherwise aggregated is free from these minerals. One section[1] which contains secondary quartz partly surrounding one of the secondary spherulites shows very plainly both in ordinary and polarized light the difference between the two structures.

The aggregations and general appearance of the secondary quartz in the groundmass is of considerable interest in these rocks. The secondary quartz of the groundmass most generally forms interlocking areas of grains of various sizes, and it is possible that much of it may be chal cedony. Large reticulating veins of quartz up to two inches in width have been described as occurring in large numbers in the eruptive rock in the field. The thin sections likewise show many minute veins of secondary quartz ramifying throughout the rock. The quartz often occurs in angular forms, when it very probably is a replacement of ilmenite and feldspar. The spherical shape which the secondary quartz assumes is a very noticeable and interesting feature (Plate 3, Fig. 1). These spheres vary in size from one-tenth of a millimeter to one and five-tenths millimeters across, and usually have an elliptical outline, with the boundary sometimes slightly crenulated. The quartz in these spheres differs from that in the secondary spherulites in being of coarser grain, and in being also unassociated with sericite and iron oxide. Some of the sections,[2] show very large areas of secondary quartz. This secondary quartz is also apparent in the hand specimen, where it appears in areas about an inch in diameter resembling greenish brown chert, and the rock is considered a

1 Section 3085.
2 Section 3077.

pseudo-breccia. These secondary quartz areas, as seen under the microscope, appear to be composed of much finer grains of quartz than that which is aggregated in spheres and angular shapes. The groundmass outside of these areas shows the fluxion structure, is not mingled with the fine-grained secondary quartz, and there is no characteristic arrangement of the minerals at the boundary between the two.

CONCLUSION.

The eruptive rock of the Baraboo region is thus shown by chemical analysis to be a quartz keratophyre, whereas its mineralogical composition alone would class it rather as a keratophyre. Typical volcanic structures of the groundmass are clearly shown. The broken phenocrysts and the marked fluxion structure indicate the usual motion of a lava flow. In the field are found outcrops of volcanic breccia, some of the fragments of which are likewise volcanic breccia. The quartz keratophyre, like the bedded quartzite, lies unconformably below the horizontal formations of the Upper Cambrian. The dip of the cleavage planes of the schists conforms to the dip of the underlying quartzite beds, which is at a high angle to the north, and the general direction of the contact agrees with the strike of the quartzite beds and the strike of the schists of eruptive origin. The changes in the general direction of the contact in the western portion of the area indicates that the quartzite beds were eroded previous to the deposition of the porphyry. It may be that the quartz keratophyre eruption took place when the underlying quartzite beds were horizontal, in which case the eruptive material must have had the enormous thickness of 3,300 feet, as shown by its areal extent from north to south. Or it may be that one or more elevations had taken place in the quartzite previous to the eruptive flow, in which case its actual thickness cannot be estimated. Since no quartzite lies to the north of the eruptive area, the quartz keratophyre is probably the topmost member of the Huronian rocks in this region, and was upturned by the orographic movement which tilted the quartzite beds into their present position.

EXPLANATION OF PLATES.

PLATE 1.

Geological Map of a Portion of the North Range of the Baraboo Bluffs. The scale is one and one-half inches to the mile.

PLATE 2.

Photographs of Thin Sections.

Fig. 1.

Volcanic Breccia. Section 3079. Polarized light, × 25. This figure shows a large number of fractured soda-orthoclase phenocrysts. Near the lower side is a fragment of foreign rock. The figure also shows crystals of ilmenite partly altered to leucoxene. The groundmass of this slide shows the fluxion structure, though less plainly than many of the others.

Fig. 2.

Black Quartz Keratophyre. Section 3080. Polarized light, × 25. This section was prepared from a block and shows a large broken phenocryst of soda-orthoclase. In the lower left-hand corner are several small crystals of soda-orthoclase, belonging to a younger generation than the large broken one. Quite near the large phenocryst in the upper part of the figure are a few radial fibres of biotite. The groundmass shows clearly the lines of flow passing between the parts of the phenocryst. The groundmass

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also contains spherulites, a large fan-shaped one being quite well defined in the upper right-hand corner of the figure.

PLATE 3.

Photographs of Thin Sections.

Fig. 1.

Fragment of Volcanic Breccia. Section 3085. Polarized light, × 25. In the upper part of the figure is seen a crystal of ilmenite, partly replaced by quartz. Through the groundmass, which shows fluxion structure, are elliptical areas of secondary quartz.

Fig. 2.

Volcanic Breccia. Section 3096.1. Ordinary light, × 25. This section was prepared from a block and shows in the figure a fractured rock fragment, which has flow lines at right angles to the flow structure of the groundmass. The space between the broken parts of the fragment is filled with secondary quartz. The groundmass of the rock and that of its imbedded fragment are essentially the same.

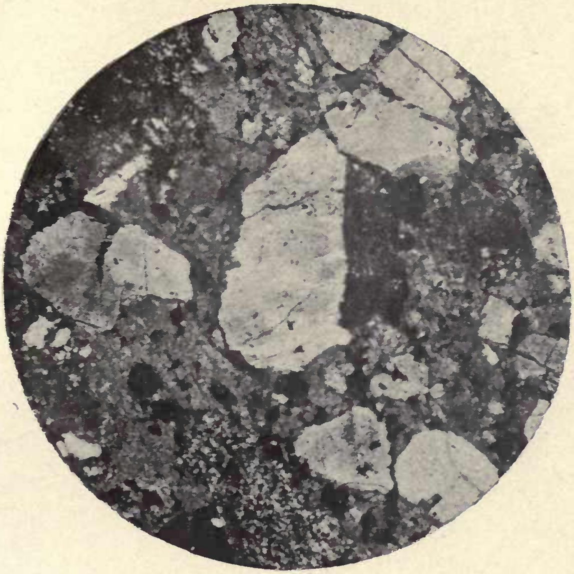

Fig. 1.

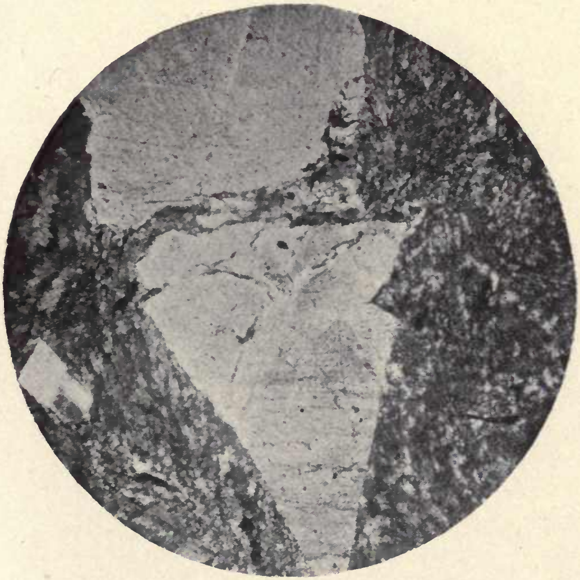

Fig. 2.

Fig. 1.

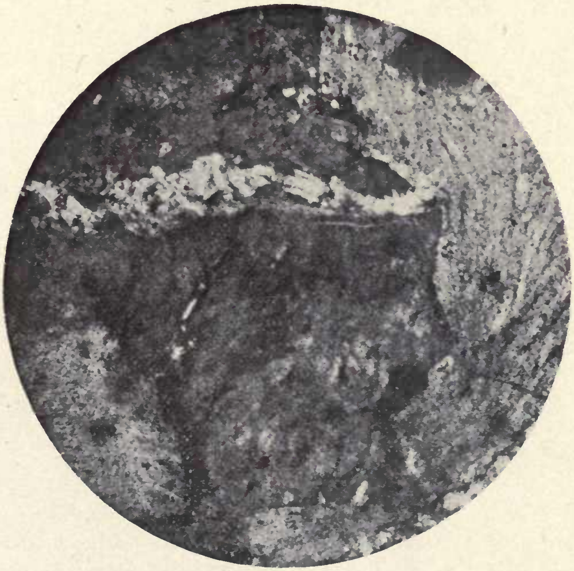

Fig. 2.

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