# THE BAXTER HOLLOW GRANITE CUPOLA*

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Abstract

The Baxter Hollow granite is interpreted as an intrusive into the Baraboo (Huronian?) quartzite. Cleavelandite dike apophyses in the advancing roof are brecciated and modified to a very unique biotite-bearing type of xenolith.

## General Statement

The Baraboo quartzite is a pre-Cambrian inlier in the Paleozoic strata of south central Wisconsin, occurring as a well known "canoe shaped" fold (1). The quartzite is probably Huronian in age. On the south margin of the fold, where Otter Creek flows through Baxter Hollow, a granite body is exposed below the quartzite. The granite is shown here to be intrusive into this quartzite. Since this is a controversial question to which attention has been given in the literature, this point is discussed in detail. The granite is regarded as a cupola subsidiary to a large batholithic mass which extends through central Wisconsin. The purpose here is (a) to discuss the intrusive relationship, and (b) to trace as far as possible the unusual rock types encountered.

## History of the Problem

In 1904 S. Weidman (2) first described these igneous rocks as a granite "varying in color from grayish to reddish and (which) consists of feldspar, quartz, and a small amount of dark mineral." He considered the rock as part of the pre-Baraboo quartzite basement.

Later Alden (3) quoted Steidtman to the effect that the granite was intrusive into the quartzite. Steidtman had expressed this view in a letter to F. T. Thwaites but withdrew his conclusion.

Stark (4), in 1932, concluded that the granite was basal to the quartzite. He described a "dark green phase" of the granite, which due to lack of any intrusive relationship, he attributed to magmatic differentiation.

Field (5) concluded (a) that the granite was basal to the quartzite and that the quartz-tourmaline veins found in the quartzite did not come from the granite, and (b) that "the granite of the area, other than the medium-grained pinkish type, are results of the assimilation of the basic material by the granite." A very small, isolated, outcrop of a basic rock was found in this area by Field—it is still unexplained.

* This work was supported in part by a grant from the Wisconsin Alumni Research Foundation.

## Regional Relationship of the Cupola

Throughout central Wisconsin granite is exposed which, though varied lithologically, is interpreted by Emmons (6) as apparent phases of one batholithic mass. The batholith is thought to extend north at least to Wausau, east to Shawano, and south-east to New London. The granite at Montello, because of its granophyric nature, is regarded as part of this same body. Emmons regards the pegmatite dikes at Waterloo and the Baxter Hollow body as still farther southward expressions of this same batholithic mass. That is, only the roof of the batholith is exposed and the contact with the overlying rocks is, in this part of Wisconsin, nearly horizontal.

Granophyric roof rock material is quarried at Montello and at Red Granite. The rock is medium to fine grained and is composed essentially of a myrmekitic intergrowth of quartz and feldspar. An overlying rhyolite is found nearby at Endeavor. Elsewhere in the region the granite shows variations suggestive of assimilation and hybridization. This effect ranges from migmatites and metagabbros through diorite and rapakivi granite to biotite granite and even syenite. Several phases of this broad problem are now being studied in detail by others and will be reported on in due time. The present study is to be regarded as one of such a series.

The Baxter Hollow cupola is regarded as one of the upward extensions of the underlying magmatic body referred to above. Rhyolites and associated rocks, in general, underly the quartzite. Near Denzer, about three miles west of Baxter Hollow, is a water laid tuff. The Merrimac rhyolite flow is about five miles to the east. Only at Baxter Hollow, of the Baraboo district, is granite found. The shape or extent of the granite body is concealed by the Paleozoic strata, but its direct connection with a parent body is suggested by the marked indications of hydrothermal activity on the upper side.

The proximity of an intrusive igneous body is also suggested by veinlets which cut the quartzite. Small veins of quartz and specular hematite are well distributed in the Hollow and have been reported at the Lower Narrows and elsewhere. Veins of quartz and tourmaline occur in both Baxter Hollow and Pine Hollow (three miles apart). Sericite is found in the quartzite near the granite at Baxter Hollow and has been reported elsewhere in the district. At Ableman's, pockets of sericite in the quartzite appear to have been filled by ground water which has gathered the sericite from the quartzite above. A diorite outcrops near Denzer.

## Age Relationships

Major interest doubtless centers on the age relationships of the granite and the quartzite. Both field observations and laboratory study support the conclusion that the granite is younger than the quartzite. The following observations are chosen as pertinent:

1. There is a notable shear zone below the quartzite and above the granite. This shear zone differs from the rest of the granitic rocks in being mainly gray in color, rather than the prevailing red or pink. At no point was the contact seen between this gray sheared rock and the quartzite, though the quartzite may be traced to a point within 5 or 6 feet of it.

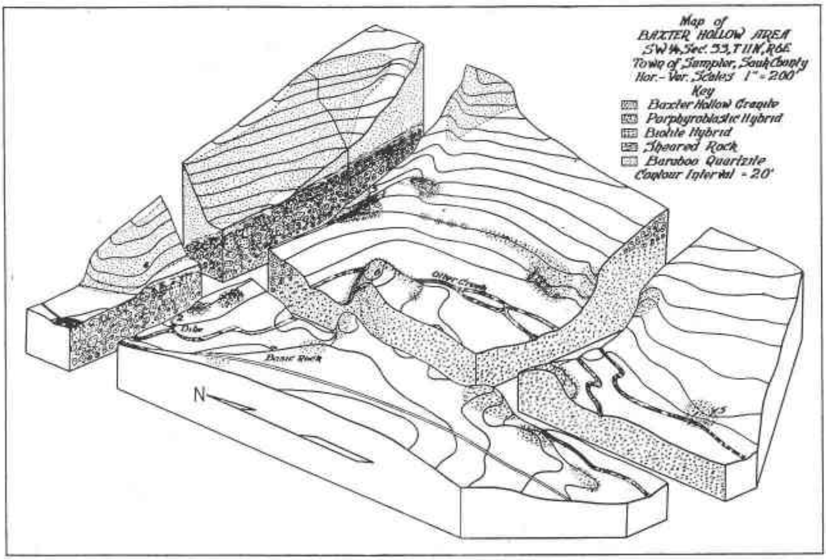


FIG. 1.

Although the evidence seems good that the shear zone is beneath and parallel to the quartzite, yet another possibility was considered and rejected; namely, that it is a vertical shear zone cutting the quartzite and the granite. Fracture cleavage in the shear zone would satisfy either hypothesis. Selected as a deciding factor is the distribution of sheared rock outcrops as shown in the accompanying map (Fig. 1) and also as mapped by Field. They lie in a plane which is parallel to the bedding planes of the quartzite. Confusion is introduced by the fact that all but one of these outcrops lie in a nearly vertical plane which strikes about east-west and is almost parallel to the mapped cliff faces.

This shear zone hides the immediate relationship between the granite and the quartzite. The competent member serves as a buttress against which shearing is developed—a type of occurrence frequently recorded in the literature. In fact, on the other side of the Baraboo syncline, at the

Lower Narrows where the quartzite with its basal conglomerate rests on rhyolite, the shearing is concentrated in a relatively narrow zone near the quartzite. At a comparatively short distance from the quartzite the rhyolite is massive. It is fair to assume then that both shear zones are younger than the quartzite and represent the shearing of whatever rock underlay the quartzite. There remains to examine now the relative ages of the granite and the sheared rock.

2. Although the main granitic mass is composed of angular blocks 'floating' in granite, there is a uniformity to the whole, apparently to be attributed to the reaction of the granite with its stoped material. This

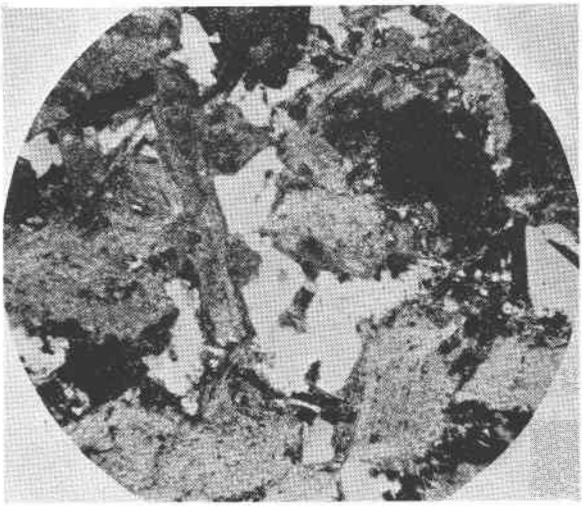

FIG. 2. Photomicrograph (×30, crossed nicols) of cleavelandite dike rock showing tabular feldspars highly sericitized and poikilitic quartz.

is discussed later. One is not conscious, however, of more than an occasional dike of granite cutting the main body. But in the shear zone, especially at one point (point 1 on map) small, but definite reticulating apophyses of red granite cut the sheared rock. It seems immaterial whether these apophyses are frozen granitic liquid or hydrothermal solutions from the granite—the conclusion that the granite is younger still holds. It should be added that where the apophyses cut the sheared rock, the cleavage is largely, but not entirely, destroyed—presumably the rock is made over in part. Since an apophyse of pre-quartzite age would not necessarily be destroyed on shearing, then the field facts, though strongly suggestive, are not definite proof of a younger granite.

3. Under the microscope there is evident a definite relationship between the amount of sericitization in the rocks underlying the quartzite

and the proximity to the quartzite. Remote from the quartzite the feldspars in the granite apophyses are fresh enough that their twinning is observed, extinction may be measured, and the feldspar may be identified by any of the standard methods. Near, and in the shear zone on the other hand, the feldspars are thoroughly sericitized—commonly so much so that only their outline, sericite pseudomorphous after feldspar, remains to identify their former presence (Fig. 2, point 2 on map). This observation is sufficiently consistent to indicate a relationship between the granite and the shear zone. If such a relationship is true—that late hydrothermal solutions from the granite have altered the sheared rocks—then of course the granite is younger than the quartzite. The only alternative view is that the shear zone has been a locus of solution channels from which solutions emanated. The first explanation is chosen as much the simpler and more plausible. The shear zone shows no lit-par-lit injection.

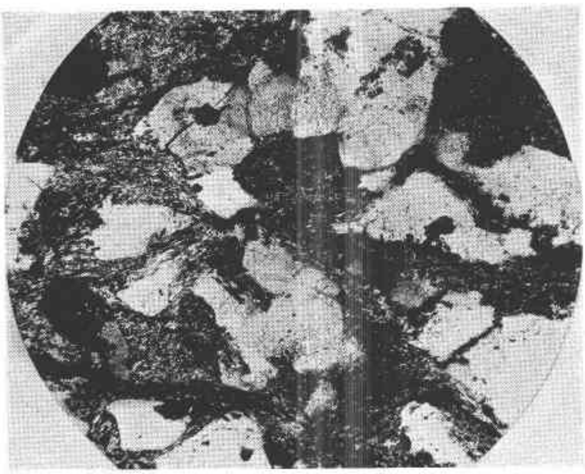

FIG. 3. Photomicrograph (×80, crossed nicols) of sheared rock. Notice quartz poikilitically enclosing sericite—all quartz in photomicrograph has a common orientation.

4. Rock from the shear zone, in general, shows the customary sheen on its cleavage surface in hand specimen and shows good alignment of mica in thin section, though this is often obscured by later alterations of a sericitic nature. Most significant is the poikilitic quartz which characterizes all specimens examined from the shear zone. There is no tendency for the mica to bend around these quartz crystals (Fig. 3, point 3 on map). It is a fair conclusion that much of the sericite and a great deal of the quartz postdates the shearing.

5. Thin sections of the quartzite, near but above the shear zone, show shattering and sericitization; the sericite being distributed interstitially in brecciated portions of the rock (Fig. 4, point 4 on map). In general however, there is little evidence of actual igneous material in the quartzite.

6. A general gradation in three respects exists in the hybrid rocks below the quartzite. Exceptions to this gradation have been found, but are apparently quantitatively unimportant. These gradations are in respect to the degree of sericitzation, the number of porphyroblasts, and the

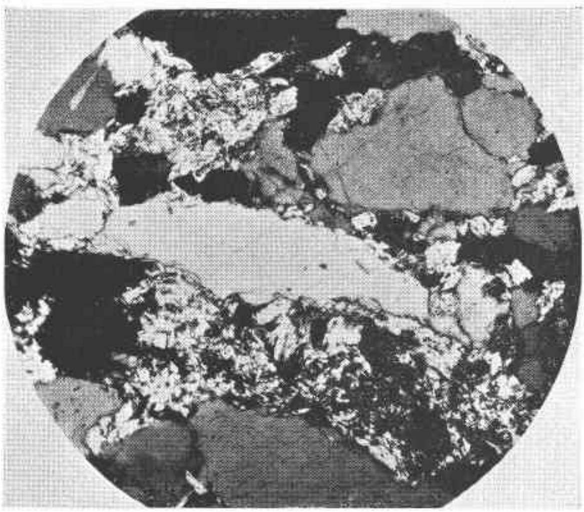

Fig. 4. Photomicrograph (×95, crossed nicols) of sericite in quartzite above shear zone.

amount of poikilitic quartz. The increase in sericitization approaching the quartzite is described in paragraph 3 above.

If the quartzite with its present attitude (strike E-W, dip 12° N) were extended toward the south, it can readily be seen that the rocks at the south end of the Hollow are farthest below the quartzite, and those at the north end are nearest the quartzite. The gradations then are from the rocks at the south end of the Hollow to those at the north end.

The gradation in respect to the number of porphyroblasts can best be observed in the hand specimen. The rocks at the south end of the Hollow are characterized by an abundance of porphyroblasts and are called the porphyroblastic hybrid. The porphyroblasts decrease rapidly in number toward the middle of the Hollow and are apparently non-existent at the north end. Thus, the rocks grade from a porphyroblastic hybrid remote from the quartzite to an even-grained hybrid (later described as biotite hybrid) adjacent to the quartzite.

The gradation in respect to the type of quartz was observed in numerous thin sections of rocks throughout the Hollow. Again exceptions have been found, but the generalization is true. The quartz varies from small grains in random orientation in the rocks farthest from the quartzite (Fig. 5, point 5 on map) to large patches with a common orientation, poikilitically including feldspar crystals in rocks nearest the quartzite (Fig. 3 or 6). Poikilitic quartz is especially abundant in the shear zone adjacent to the quartzite. Therefore, there is an apparent increase in size of the quartz grains (or in poikilitic quartz) as the quartzite is approached.

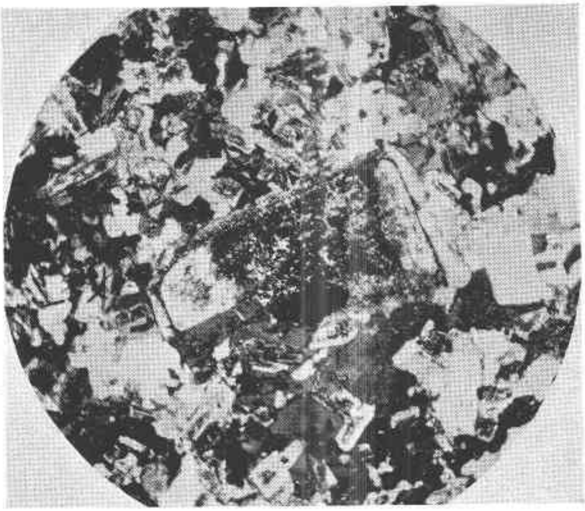

FIG. 5. Photomicrograph (×30, crossed nicols), of porphyroblastic hybrid at south end of Hollow. Notice zones of sericite on porphyroblast.

These several observations fall into a logical sequence of events in the following interpretation. Folding and intrusion progressed simultaneously, as is usually true, though folding was not at all severe at this locality. A shear zone quite apparently developed before the intrusion reached the quartzite, or at least before the last effects of the intrusion reached the quartzite. As the granite encountered the quartzite base, folding continued, whereby, to a considerable extent, the active shear zone served as a seal to the granitic juices. The word 'juices' seems especially appropriate here since there is comparatively little evidence of real granite liquid and an overwhelming amount of sericitization, indicating much hydrothermal activity. Possibly some of the stoped blocks in which the exposed granite abounds, are quartzite—that is mere speculation. It will be suggested below that they are, in part at least, arkose or rhyolite. In any case, the field facts suggest that the ability of the granite to stope was virtually suspended at this stage, otherwise more clean red granite and less hybrid would be expected.

This interpretation is offered to account for the following facts: (1) The extensive sericitization and development of poikilitic quartz near the quartzite; (2) The limited penetration of the quartzite by any part of the granite; (3) The cleavelandite dikes discussed below; and (4) The varied course of hybridization to be discussed next.

## Rock Types Within the 'Granite'

The rock types in the Hollow have a special interest, in that they illustrate the chemical effect of the intrusion on a host of stoped blocks, and some of them suggest the effect on the intrusion of the same stoped blocks. The mutual effect has gone so far that the original rock types of the intrusive or the wall rocks are not available for examination.

The most 'normal' intrusive material is granophyric; the least modified of the wall rock type is apparently an arkose or coarse tuff. All rocks below the quartzite show more or less sericitization and usually much more than the average granite. Except for narrow zones on feldspars of a few of the rocks (Fig. 5), there is little fresh feldspar to be found. The sericitization appears in two dominant aspects—very fine, masking alterations, and a coarser development in which the individual flakes are easily seen under low power. This coarser type commonly, but not always, occurs as a reticulating network of microscopic veinlets.

Before discussing further generalities, let us review the rock types in detail. The main rock types in the cupola, which in general grade into one another, are: (1) the Baxter Hollow Granite (normal red granite), (2) biotite hybrid, (3) pegmatite hybrid, (4) porphyroblastic hybrid, (5) arkose, (6) sheared rock, and (7) the cleavelandite dike rock. The accompanying map shows the areal distribution of these rock types as far as generalization seems possible. The only other rock type of importance found in the Hollow—the Baraboo Quartzite—has been repeatedly described in detail (1) and needs no further description here.

The compositions of the rock types, as determined by Rosiwal analysis, are tabulated in Table 1. The albite-anorthite ratio of the plagioclases for all rock types was determined in two ways for each grain selected for study—(1) from the Fedorov migration curves (7), and (2) by extinction angles in the zone at right angles to (010), measured from (010) to alpha, using the curve of Michel-Levy. All data were obtained from grains oriented on the five axis Universal Stage. The results check within the accuracy of the extinction angle curve and Fedorov's curves.

*The Baxter Hollow Granite.* The 'normal' granite is red to light pink,

TABLE 1

| Rock Type | % Feldspar | % Quartz | % Biotite or Chlorite |
|---|---|---|---|
| (1) Granite | 66.2 | 29.1 | 4.6 |
| (2) Porphyroblastic Hybrid | 71.2 | 25.5 | 3.2 |
| (3) Pegmatite Hybrid | 68.9 | 22.2 | 8.9 |
| (4) 'Arkose' | 66.0 | 34.0 | — |

very fine grained, and contains few dark minerals. Only some of the pegmatoid veins approach the coarseness of a normal granite. The feldspars are sericitized and have a reddish tinge. Much of the plagioclase is more sericitized than the orthoclase. The plagioclase generally shows albite twinning and has a composition of $Ab_{95}An_5$. Orthoclase and plagioclase are found in the ratio of about 2:1. Minor amounts of microcline and microcline perthite are also present. Biotite is the only important dark mineral and is green, in flakes, and in places is altered to sericite or chlorite.

*The Biotite Hybrid* (see matrix of porphyroblastic hybrid in Fig. 5). This hybrid is a gray-green rock which varies considerably throughout the Hollow in texture and percentage of dark minerals (biotite and chlorite). Textures range from a fine grained 'arkosic' type to a pegmatoid poikilitic one. The feldspars vary from small, irregular, slightly sericitized grains to heavily sericitized, long tabular or lath shaped crystals. The quartz in the finest grained rocks generally occurs as small individual grains with random orientation. In the coarser textured rocks the quartz grains are larger and poikilitic, that is, patches of quartz have a common orientation. The biotite (generally partly altered to chlorite) varies from small rectangular specks to long slender blades cutting across quartz, feldspar, and other blades of biotite. The type of feldspar is hard to determine because of sericitic alteration, but there is an apparent increase in the amount of plagioclase in the coarser textured hybrid. In the coarsest grained biotite hybrid the feldspar is dominantly plagioclase. The composition of the plagioclase in these hybrids varies from $Ab_{100}An_0$ to $Ab_{94}An_6$. Near the quartzite the biotite hybrid appears to be 'soaked' with granite; red feldspar grains stipple the rock. In thin sections of this 'soaked' hybrid the form of feldspar remains, but the mineral is sericite poikilitically included by quartz.

*Pegmatite Hybrid* (Fig. 6, point 6 on map). This pegmatite hybrid is undoubtedly the most interesting and baffling rock in the Hollow, both petrographically and genetically. Its peculiar appearance in the field first prompted Dr. Emmons and later the writer to undertake a restudy of the area in an attempt to learn its origin. It is the coarsest grained biotite hybrid and is characterized in thin section by long laths of feldspar, poikilitic quartz, and long blades of biotite; and, in the field by a peculiar fracure. It is called pegmatite hybrid to distinguish it from the 'normal' biotite hybrid since its origin is thought to be somewhat different. In order to facilitate the recognition of this rock in the field, it may be described as pale greenish-brown in color and breaking with a rough surface composed of irregularly oriented plane facets, rather than the consistently rough surface of the ordinary granite or inclusion. Both features are to be attributed to cleavage within the biotite flakes.

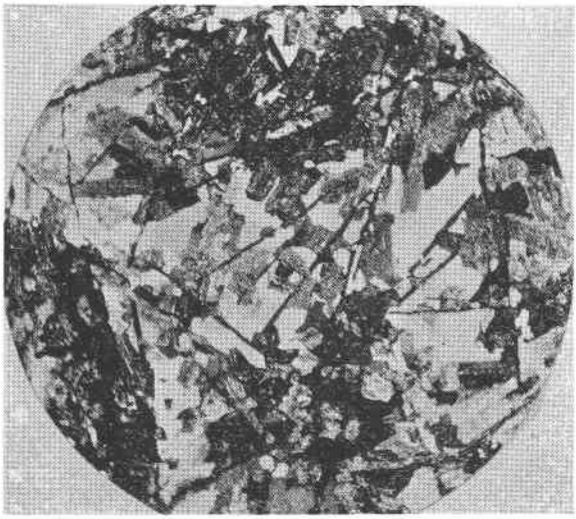

FIG. 6. Photomicrograph (×30, crossed nicols) of pegmatite hybrid showing poikilitic quartz and long blades of biotite.

A few facts concerning the occurrence of the pegmatite hybrid may well be given here. This rock occurs almost exclusively as apparent inclusions in what is now red granite or porphyroblastic hybrid, or what probably were the main solution channels. It must not be forgotten that the 'normal' biotite hybrid which grades into the pegmatite hybrid also occurs there. Sharp contacts can be found between the pegmatite hybrid and nearly all other rocks in the Hollow. Particularly numerous are sharp contacts with the red granite. The only place where the pegmatite hybrid could not be found was directly below the quartzite outcrops at the north end of the Hollow. This will be discussed later.

*The Porphyroblastic Hybrid* (Fig. 5). This rock varies from a gray hybrid (essentially a fine to medium grained biotite hybrid) with few porphyroblasts to a light tan hybrid with abundant porphyroblasts. The biotite hybrid occurs here as inclusions cemented by the porphyroblastic hybrid. The porphyroblasts are almost exclusively plagioclase and they range in size from microscopic to one-half inch in diameter. They are generally either euhedral and evenly sericitized or are rounded and have zones of sericite (Fig. 5). The evenly sericitized euhedral porphyroblasts usually have a composition of $Ab_{95}An_5$, while those with clear outer zones have compositions of $Ab_{85}An_{15}$. Porphyroblasts with compositions between $Ab_{95}An_5$ and $Ab_{85}An_{15}$ are also present. Occasionally the plagioclase is zoned—the core being $Ab_{95}An_5$ and the outer zone being $Ab_{85}An_{15}$. The matrix of quartz, feldspar, and biotite enclosing the porphyroblasts frequently exhibits evidence of crushing. Biotite and chlorite occur both as flakes and thin blades. Black biotite flakes are conspicuous in the hand specimen in the crushed zones between inclusions of biotite hybrid in the porphyroblastic hybrid.

*The 'Arkose.'* The 'arkose' is a fine grained rock composed of quartz and feldspar in a mosaic pattern. The 'arkose' is generally found intimately intermingled with the red granite in the more prominent dikes or apophyses. It does, however, have a sharp contact with the granite in all cases observed. It is much finer grained than the granite, but has essentially the same composition except for the absence of biotite. The feldspar is largely orthoclase, about one-third being plagioclase. The feldspar is reddish colored and only slightly sericitized as compared with the other rocks in the area. The quartz occurs as small rounded grains in random orientation.

*The Sheared Rock* (Fig. 3). The sheared rocks as shown on the map occur in a zone 10 to 20 feet thick directly below the quartzite. The minerals in the sheared rocks are quartz, feldspar, sericite, and biotite partly altered to chlorite and magnetite. The quartz generally poikilitically encloses masses of sericite and feldspar. The feldspar is almost completely altered to sericite. The sheared rock nearest the quartzite is quite schistose, becoming less and less so as it grades down into the granite and biotite hybrid.

*The Cleavelandite Dike Rock* (Fig. 2, for picture of dikes see reference (6) Figs. 1 and 2). The feldspar in the dike rock has a cleavelandite or tabular texture in the hand specimen, but it is difficult to see that texture in thin section. The photomicrograph does show one lath-shaped crystal completely altered to sericite. The quartz is poikilitic and the feldspar is almost completely altered to sericite. The texture of the dike rock is quite similar to that of the pegmatite hybrid except for the blades of biotite.

## Genesis of the Rock Types Within the Granite

As previously stated, the map and cross sections show the areal distribution of the rocks as far as possible. It is evident that the massive biotite hybrid, penetrated by granitic stringers, veins, and dikes, is nearest the quartzite and the porphyroblastic hybrid, with many small biotite hybrid inclusions, is farthest away. Since the hybridization process was progressive, many stages in the development were frozen; hence the varieties recorded. There is an apparent gradation from any one type to any other —particularly from the 'arkose' to the biotite hybrid to the pegmatite hybrid—if specimens are selected with this purpose in mind. Therefore, virtually any interpretation which depends on such a gradation may be 'proved' by specimens. Similarly, rather sharp boundaries may be found between almost any two rock types, which in turn may be used to prove a lack of gradation.

The pegmatite hybrid apparently is the key to the origin of the Baxter Hollow rock types, and with that in mind an attempt will be made to trace the development of this unusual rock. A general history of the Hollow as I interpret it is this: Quartzite, presumably underlain by arkose or rhyolitic tuff, was folded and intruded. Into the initial fractures flowed the most mobile granitic juices, permeating and altering the wall rock, and then froze to form dikes like those mentioned above (see cleavelandite dikes). Continued folding and intrusion brecciated the arkose and the early formed dikes further and subjected both to the effects of the granitic juices. The usual metamorphic processes—recrystallization, growth, and development of biotite—altered the arkose to the normal biotite hybrid and the dike rock, essentially a cognate inclusion, to the present pegmatite hybrid. Thus the gradation getween the arkose and the pegmatite hybrid is the usual one between wall rock and the granitizing juices, except that here the initial intruding juices were solidified, later brecciated, and then subjected to the same metamorphism as the wall rock. The original texture of the dike rock probably accounts for the blade-like form of the biotite in the pegmatite hybrid. In this way the igneous nature of the quartz and feldspar, and the metamorphic appearance of the biotite is logically explained.

There is an apparent increase in sericitization and poikilitic quartz development as the quartzite is approached. This increase suggests a greater concentration of solutions near the quartzite, a condition which requires explanation. Although other explanations may be suggested, the following one appears to satisfy the field facts as outlined. The greater aggregation of inclusions is near the quartzite, which is also where shearing is greatest. Movement at this horizon would create an area of low pressure to which the more mobile constituents of the intrusive should migrate, hence the greater amount of solution action. It is entirely reasonable that, more remote from the quartzite, the present prophyroblastic hybrid was earlier a different type of rock, more nearly similar to the normal biotite hybrid which is immediately below the quartzite—but since altered to its present state by deeper burial in the granite magma.

The shear zone below the granite is regarded as an effective barrier to granitic juices. Some escaped into the quartzite as indicated above, but in general, solutions were trapped here. The effectiveness of this trap was enhanced by movement during intrusion. Solution channels through the shear zone were closed almost as fast as they were formed. The type of solution channel which prevailed in this general area is believed to be typified by the dike-like bodies mentioned above (see ref. 6, Figs. 1 and 2). This entire explanation, if correct, would involve a saturation of the shear zone rocks. This is in complete agreement with the facts in that, as pointed out previously, the sheared rocks are well recrystallized. In the field the sheared effect is very evident a few feet away and again by the use of a hammer. But the usual sheen which characterizes a schist is not as expected.

The fine grained red Baxter Hollow granite is thought to have been introduced very late in the history of the cupola along new fractures which followed the old solution channels and which tapped the original magma chamber.

## Acknowledgments

The writer gratefully acknowledges the continual assistance of Dr. R. C. Emmons in the laboratory, in the field, and in the writing of the paper. The cupola-like nature of the granite body and its relation to the quartzite were first recognized by Dr. Emmons.

The writer is also indebted to Ted Townsend and C. W. Gates for assistance in mapping the area. Thanks are also due Drs. W. H. Twenhofel, H. E. McKinstry, and S. A. Tyler for criticizing the paper.

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