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STRUCTURE OF THE "ELLICOTT CITY GRANITE," MARYLAND

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Introduction.—The Ellicott City granite is situated four miles west-southwest of the city limits of Baltimore, Maryland. The Patapsco River valley furnishes good exposures across the entire length of the granite body. Investigations were begun as a demonstration in granite-tectonic methods and were carried on in detail, because of the special situation of this peculiar granite mass. The map, figure 1, comprises the granitic area and a part of the surrounding wall rocks and their structure.

The Problems.—The geologic map of Maryland and of Baltimore county shows a granite body which seems to be discordant within the Piedmont region, the strike of its long axis being NW-SE whereas the general strike of the region is NE-SW.

It is clearly seen on the map that the granite intruded the gabbro and the Wissahickon schist, where the latter formed a salient that penetrates far into the large gabbro complex.

This peculiar position of the granite raises a few questions:

The mode of emplacement of the granite.

The structure of the granite and its relation to the wall rock structure.

The structural position of the granite within the Piedmont.

Granite and gabbro Granite and Wissahickon schist	} discordance or concordance?

Is the granite the top part of a hidden batholith?

The relation of the pegmatites to the system: Wissahickon schist, gabbro and granite.

The Rocks.—The rocks of the region are described in detail by E. B. Knopf and A. I. Jonas,[1] G. H. Williams,[2] H. Insley,[3] E. B. Mathews[4] and others. Several features are added here as they are of importance for the understanding of the structure.

The Ellicott City granite is considered to belong to the youngest series of intrusive rocks of the Piedmont region. It may be epi-Carboniferous.[5]

The granite shows a very distinct flow structure. Minerals and inclu-

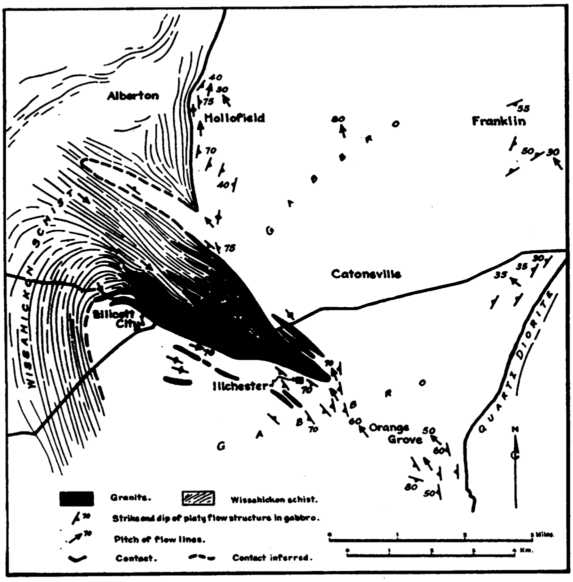

FIGURE 1

Map of the Ellicott City-Granite area and its adjacent wall rock.

sions are well oriented, see figures 2, 3 and 4. The flow structure can be seen under the microscope in oriented sections.

Inclusions within the granite are of special interest. Thousands of fragments of Wissahickin schist can be seen everywhere near the contacts. They can easily be determined on account of their structure and general aspect. Different from the schist are certain black inclusions within the neighborhood of Ellicott City (Weber Quarry). Knopf and Jonas[1] believe that they represent fragments of schist which are "almost swallowed up."

All the black inclusions show a very similar mineral composition. The gneiss or schist inclusions have their own structure preserved but it is not uniformly oriented parallel with the granite foliation. One can see under the microscope in oriented sections, that the linear orientation within the black inclusions is, however, perfectly parallel to the flow lines of the granite. Therefore, the structure of the black inclusions is believed to be of the same age and origin as that of the granite. Although schist fragments are oriented parallel with the foliation of the granite since the foliation plane and cleavage plane are parallel by coincidence, it is doubtful whether the linear stretching in the schist would have to be parallel to the flow lines in the granite.

In view of the difference in the structural arrangements of the two groups of inclusions, the writer suggests that the black inclusions may be regarded as Autoliths rather than Xenoliths.[6]

The pegmatites are banded, especially near Illchester and Orange Grove. Fine grained layers change with very coarse ones. As the banding is always parallel to the dike contacts, the strike and dip of the pegmatites can be determined with accuracy. The best example of a banded pegmatite can be seen below the dam near Illchester. Most of the pegmatites form large dikes, which dip gently eastward at an angle of approximately 20–30°. Because their debris covers the slopes of the Patapsco river valley they appear to be larger and more numerous than they really are.

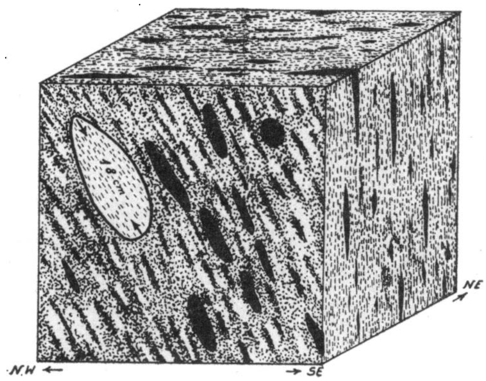

FIGURE 2

Schematic diagram of the structural elements in the granite (Weber quarry). Black: Autoliths of discoid shape indicating linear flow structure in their arrangement parallel to each other with their longest axis (front view).

The orientation of the pegmatites is closely connected with the structures of the granite and gabbro.

The gabbro (see Baltimore County rept., p. 107) is usually banded, and shows a very distinct linear flow structure. A detailed study of the gabbro structure has been begun by Charles Cohen at the Johns Hopkins University. The map shows strike and dip symbols for the gabbro only as far as is necessary for the understanding of the granite intrusion.

The Wissahickon schist forms the wall rock of the gabbro, granite and pegmatite. The schist represents the oldest rock within the above-mentioned group of rocks and the contact relations between it and the granite and gabbro are of special interest.

Structural Elements.—Structural elements in igneous rocks have been described so often in the literature, that the reader is expected to be acquainted with them. For information see: Ernst Cloos,[7] Hans Cloos,[8] Robert Balk,[9] a. o.

The elements found in this region are the following:

A. *Linear Structures*
  a. Parallelism of needle-shaped crystals
    Hornblende, titanite, epidote in the granite
    Hornblende in the gabbro
  b. Parallelism of spindle-shaped inclusions
    ? Autoliths in the granite
    Xenoliths in granite and gabbro
  c. Chain-like swarms of inclusions of all kinds in granite and gabbro.

B. *Platy Structures*
  a. Minerals of discoid shape
    Mica and feldspar in granite
  b. Inclusions of discoid shape
    Autoliths and Xenoliths in granite
    Xenoliths in gabbro
  c. "Banding" in gabbro
  d. Schlieren-like flexures in granite
  e. Dike-filled joints (pegmatite especially) in granite and gabbro
  f. Ordinary barren joints in granite and gabbro.

The elements in the granite are all primary, i.e., they originated within the stage of intrusion and consolidation of the magma. The layering in the gabbro is very likely primary and perhaps the linear stretching as well.

The above list of observable features is rather short compared with other regions of igneous rocks, e.g., the Sierra Nevada, California. In a previous paper[8] it has been shown that platy schlieren originate in response to differential flow in igneous rocks. Since schlieren are scarce in the present area, it would suggest that all parts of the magma except those near the contacts moved at approximately the same speed. Other considerations, about the shape of the space into which the granite was intruded, support this suggestion (see below).

The entire lack of schlieren combined with a large amount of Xenoliths and Autoliths suggests to the writer that schlieren are *not* always the remnants of assimilated inclusions, but the result of mineral accumulations by differential movements within the magma (see Hans Cloos). R. Balk has experiments in progress to demonstrate how movements within a magma can produce platy flow layers (schlieren).

Contact Relations.—1. Gabbro-Wissahickon schist.

The gabbro is intrusive into the Wissahickon schist and inclusions of schist in gabbro are abundant. They are oriented parallel to the gabbro banding and so assist in determining the direction of the flow structure. Discordant contacts are rare.

It is very striking that the salient of Wissahickon schist near Ellicott City was left more or less intact by the intruding gabbro (Fig. 1). The salient is not broken up but the flow structure of the gabbro follows this irregular contact, changing its strike approximately 90°. The gabbro-schist contact is an old pregranitic surface along which the granite entered conformably as a new factor.

2. Granite-Wissahickon schist. The granite-schist contact is much more indented and irregular than the gabbro-schist contact. It resembles a lit-parlit injection on a large scale. (See Figs. 5 and 6.) Thousands of small granite tongues penetrate the schist, following its cleavage and bedding planes. Fragments are torn loose and can now be found as long leaf-like inclusions oriented parallel to the granitic flow structure. In mapping the area it is almost impossible to determine a distinct line for

FIGURE 3

Platy flow structure in granite, horizontal view, see top of figure 2.

the contact, because it is obscured through the increase of schist fragments outward from the center of the granite mass. The percentage of granite dikes decreases, and the proportion of schist increases accordingly, until finally the schist predominates. The Wissahickon schist salient is completely soaked with granite and broken into thousands of inclusions. Proceeding to the northwest, the schist gains ground, and gradually becomes the sole bedrock.

3. Granite-gabbro. The granite-gabbro contact is entirely different. It is extremely smooth and simple and a very well defined black and white contact with hardly any irregularities. Only a few dikes of granite were found within the gabbro (see Fig. 1). The ratio between granite dikes in schist and granite dikes in gabbro would probably be 10,000:1. The

contact follows the gabbro structure, but only because the gabbro structure follows the schist contact. The granite followed that contact, and respected the gabbro, because of its much greater resistance.

Internal Structure.—The flow structures of the granite and gabbro follow the contacts everywhere. Their strike and dip is therefore determined by the shape of the space into which the magma was intruded.

The gabbro and its structure will soon be described by Charles Cohen in a separate paper. A few of his results are mentioned here for better understanding of the granite structure.

The gabbro structure follows the schist salient, bending from a northeast-southwest direction into a northwest-southeast strike, or perpendicu-

FIGURE 4

Front view of figure 2, Weber quarry, Ellicott City. North left—South right.

lar to the general strike of the region. The dip of the flow structure points toward a central axis which runs from Franklin (see Fig. 1) through Catonsville toward Laurel, Md. The granite cuts across this axis at an angle of 90°.

The granite foliation strikes northwest southeast, with only one exception in the northwest corner of the area, where the body turns into the regional strike, paralleling the strike of the Wissahickon schist. The contacts of the granite are parallel to each other and dip almost vertical. The platy flow structure parallels the contacts and dips almost vertical also. Only the flow lines (linear structure) show an exception. They plunge toward the northwest within the southern part of the granite body, and toward the southeast within the northwestern half of the body, thus indicating a center of intrusion approximately one mile southeast of Ellicott City.

Flow lines in the granite are parallel with the flow lines in the gabbro, both pointing toward the axial line mentioned before. It is very remarkable that the granite structure coincides with the gabbro structure. There are two explanations possible:

1. Flow lines in the gabbro and granite are of the same age. That would mean that the gabbro structure is a result of metamorphism at the time of granitic intrusion. In that case, the granite structure is primary and the gabbro structure secondary and superimposed.

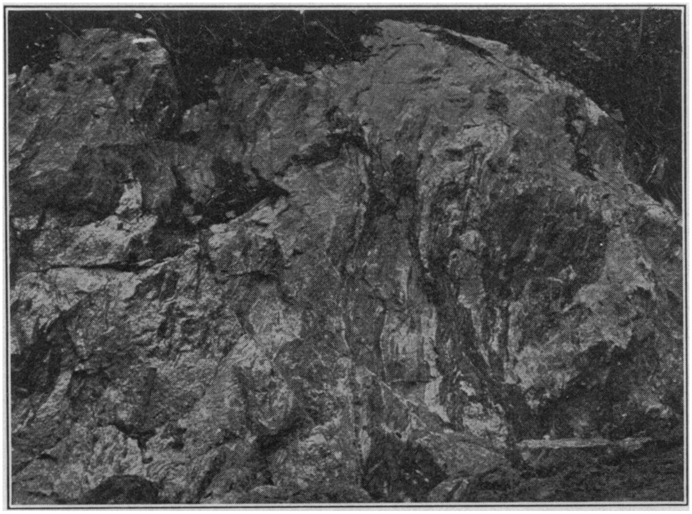

FIGURE 5

Typical contact between granite and Wissahickon schist. Main Highway Ellicott City-Baltimore, 2 miles east of Ellicott City.

2. Both structures are primary and both magmas entered the present chamber more or less through "the same door," following a similar direction.

The first case seems unlikely, because the gabbro structure follows the contacts everywhere and it is unimaginable that regional metamorphism should produce a structure, which follows the irregular contacts of a certain limited mass so closely. Furthermore, if the granite intrusion is connected with the metamorphism of the gabbro, it ought to be strongest near the granite, but that is not the case.

The writer believes that the granite and gabbro intruded through the same gap. The gabbro intrusion followed the mentioned axis and widened upward. The granite broke through where the axis is crossed by the granite body. The very gap is indicated by the flow lines in the granite.

Tension joints normal to the flow lines can be seen frequently wherever the flow lines are distinct. They are partly filled with pegmatites, e.g., near Illchester and Orange Grove. These pegmatites strike north-south and dip gently east. They are perpendicular to the linear stretching in the gabbro and the flow lines in the granite.

The pegmatite intrusion followed the granite closely, the interval between the formation of joints in gabbro and their vein filling must be greater than in the granite.

The Author's Interpretation.—The *gabbro* forms a wedge-shaped body, which narrows downward. It has been intruded *between* a number of gneiss domes which surround the gabbro today on all sides (see E. B. Mathews[10] and Baltimore County map[1]). The axis of this gap crosses the Patapsco river approximately one mile southeast of Ellicott City. A salient of Wissahickon schist was left intact by the gabbro, indicating a rather mild intrusive force of the magma.

The *granite* intruded into the weakest spot of the gabbro-schist system,

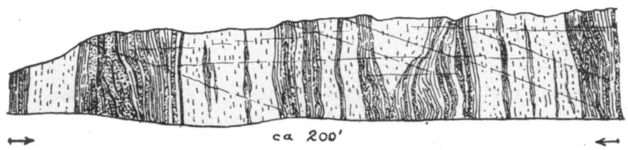

FIGURE 6

Section through the Granite-Wissahickon schist contact. Old Frederick road, east of Ellicott City.

namely, near the point where the schist salient crosses the axis of the gabbro body. The gabbro-schist boundary was used wherever possible but not sufficient space could be gained that way. We cannot assume that the small granite intrusion had the necessary force to push apart the very resistant gabbro blocks on each side along steep contacts. The only way out was *upward*, partly at the expense of the weaker Wissahickon schist. The latter was penetrated very thoroughly as the contact relation shows (see Figs. 1, 5 and 6.). A large amount of broken-up schist material was carried away, especially above the center of intrusion. The writer believes, therefore, that the space now occupied by granite was previously filled with schist. The granite intrusion began along the schist-gabbro contact and continued and widened during the process. Hardly any inclusions of Wissahickon schist are found above the focus of intrusion. The further we proceed to the northwest, away from it, the larger the percentage of unbroken schist until finally, several miles northwest from the main granite body the bedrock is Wissahickon schist exclusively. The gabbro blocks on either side of the granite remained unbroken and untouched.

The writer believes therefore that the granite body of Ellicott City is not the head of a larger batholith, which eats its way up into the crust at any place, but that we deal with "*selective intrusion*," for it has picked out the weakest spot available, beginning along petrographic boundaries, and widening the gap slightly by carrying away the flexible and strongly schistose material. Similar observations have been made in many other localities where batholithic intrusions were found on stratigraphic or tectonic boundaries (see H. Cloos, Riesengebirge[11]). The space which the granite occupies today was undoubtedly the easiest to get into and the only one which the granite could occupy without too much effort. The intrusive force seems to have been halted completely by the gabbro, but remained very effective within the Wissahickon schist. Further away from the main canal, the force died out rapidly and was not effective enough to disturb the schist seriously.

The different intrusive force of the gabbro and granite might very well result from the fact that the gabbro intruded into a space which widened upward, enlarging its horizontal surface constantly, but the granite was squeeezd into a narrow steep canal of constant cross-section.

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