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GRANITE REPLACEMENT IN BASIC DIKES MOUNT DESERT ISLAND, MAINE

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In the western part of Mount Desert Island, which lies about two-thirds of the way up the coast of Maine, is a belt of gabbroic rock one to two miles wide and twelve miles long. It is bounded on the west by quartzite, schist, and gneiss of the Bartlett Island series (Lower Cambrian ?) into which the gabbroic rock is intrusive. On the east the belt is severely brecciated and is invaded by biotite granite. Petrographically the gabbroic rock is extremely variable in texture, structure, and mineral composition. For the most part, however, it is composed predominantly of hornblende, biotite, and plagioclase with smaller amounts of quartz and potash feldspar.

Cutting the gabbroic material are numerous dikes composed of fine-grained diabase and fine to coarse-grained granite. These diabase-granite complexes resemble certain composite bodies, and for want of a better term will be referred to as composite dikes. The best examples of the dikes have been found along the coast (Lat.–44° 18′ 37″; Long.–68° 25′ 56″), where nearly continuous outcrop makes them traceable for distances up to 100 feet.

DESCRIPTION OF COMPOSITE DIKES

The dikes are as much as a few feet thick, but some of the best exposed and most striking are only a foot wide. The smaller dikes offer a clearer picture of their true character in three dimensions, particularly along the more rugged parts of the coast.

The ratio of granite to diabase in the composite dikes is highly variable. Some complexes are granite dikes enclosing numerous more or less rounded fragments of diabase (fig. 5, center right). Others are dikes of diabase more or less veined by granite (fig. 5, lower left). Still others are intermediate or gradational between these two extremes.

The diabase member of the dikes is in the center, and is separated from the older wall rock by granite. Even in the gently inclined or horizontal dikes, there appears to be no crowding of diabase toward either wall. Commonly the bounding granite is only a thin vein extending 10 or 20 feet, but granite nearly always margins the dike. These portions of the granite member, more or less confined to dike borders and margins, for convenience will be termed *lateral veins* (fig. 1). In only one dike (one foot wide) were portions of diabase in contact with gabbroic wall rock. These portions exhibit a finer-grained texture within one-quarter inch of the contact, and appear identical with the chilled selvedges

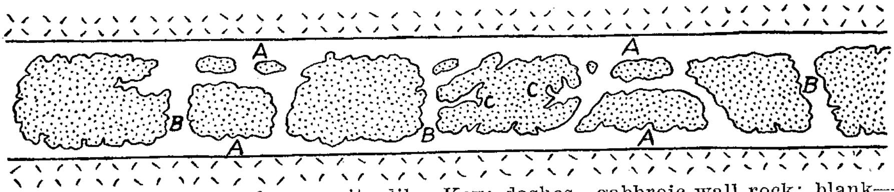

FIG. 1.—Elements of composite dike. Key: dashes—gabbroic wall rock; blank—granite; stipple—diabase dike remnants with rounded and irregular boundaries; A—lateral vein; B—transverse vein; C—irregular vein.

so common in basic dikes. The contact between granite and gabbroic wall rock is remarkably straight, but that between granite and diabase is highly irregular. Thus each lateral vein is highly variable in width.

The central member of diabase may extend 5 or 6 feet without interruption, but commonly it appears disjointed by veins of granite which cut across from one lateral vein to the other (fig. 5). These cross-cutting granite veins will be termed *transverse veins* (fig. 1). Commonly the diabase appears broken into many small blocks, each completely surrounded by granite. The blocks are generally rounded and elongate and are arranged in sausage fashion parallel to dike walls. That the long blocks have been rotated since their formation is not apparent from their present orientation. Locally the blocks are highly irregular and varied in shape, but are fitted together remarkably well, like parts of a jig-saw puzzle.

In addition to the lateral and transverse veins are numerous irregular veins and stringers (fig. 1), which show blunt terminations and absence of wedging walls, and like the lateral and transverse veins, exhibit pinch-and-swell structure and nonmatching walls. There appears to be complete continuity between all vein types, suggesting more or less contemporaneity in formation. No evidence was noted of one vein cutting another. Boundaries between diabase and granite members are sharp and commonly highly crenulate (fig. 5, upper right). Fingers and stringers of granite project into the diabase, and the more extensive intervening stretches are concave toward the diabase member. The granite nowhere appears chilled but locally is almost pegmatitic.

ORIGIN OF COMPOSITE DIKES

The observation that virtually all blocks of diabase are surrounded by granite appears to support the theory that the composite dikes are injections of granite magma which carried abundant diabase inclusions and aligned them parallel to dike walls. In one place, however, remnants of chilled selvedges of a basic dike were observed in contact with the wall rock. Another objection to this theory is that some of the diabase blocks are so large, compared with the width of the dikes, that it is difficult to conceive of them being carried in without being wedged or caught between dike walls. The perfection with which so many of the variously shaped blocks of diabase are closely packed is difficult to explain on this basis. The heavy diabase blocks do not appear to be crowded toward the lower walls of the gently inclined composite dikes.

The symmetrical distribution of acid and basic members throughout the composite dikes also rules out a theory of origin by differentiation in place of either a homogeneous or emulsive magma.

The injection of a granitic magma before complete crystallization of the diabase member seems unlikely, because of the marginal position of the granite and the infrequent occurrence of a chilled selvedge of diabase. Furthermore, intimate mingling of acid and basic material to give transitional types is not indicated.

The theory I favor is that basic magma was first emplaced to form diabase dikes. Later, jointed and disrupted at their contacts, the diabase dikes were invaded by granitic material to form felsic veins. The problem arises as to whether room was provided the granitic material by dilation of fractures in the diabase, by replacement of diabase along fractures, or by a combination.

Fractures running parallel to dike walls are common in basic dikes and are more closely spaced near dike margins. Such fissures would permit intrusion of granitic magma as well as localized replacement by granitic material; either might explain the lateral veins.

If the lateral veins are of dilation origin, however, why is the boundary against the gabbroic wall rock essentially a planar surface, whereas the boundary against the diabase generally appears crenulated and scalloped? If the veins are of replacement origin, an explanation is found in the structural control of the wall rock on either side of the fracture. Joints perpendicular to dike walls are commonly abundant and closely spaced in basic dike margins. If replacement, advancing from the marginal fissures, proceeded most rapidly along closely spaced perpendicular fractures, we would expect local development of granite fingers projecting well into the diabase, making a highly irregular boundary. Little or no jointing of the gabbroic

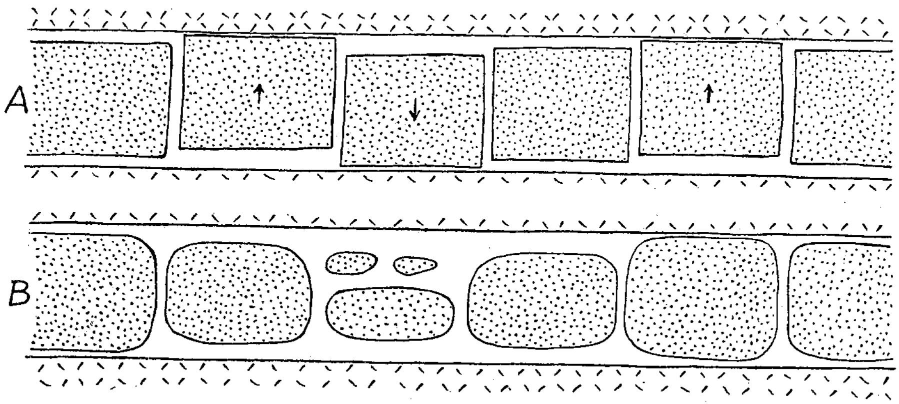

FIG. 2.—Schematic composite dikes. A—Transverse drift of dibase blocks in granitic magma widens lateral vein on one side. B.—Variation in width of lateral veins indicates differential consumption of diabase and not simply transverse block-drifting.

wall rock would make replacement ineffective, and the original straight contact would be preserved.

The great irregularity in width of the lateral vein is difficult to explain on the basis of dilation. The variation in width is believed to be due to the nature of jointing in the basic dikes. Where channels were numerous, as in closely jointed portions of the diabase, wide segments in the lateral vein developed. Some suggestion of this control is found (fig. 5, lower left) where a slab interrupts the lateral vein. Several small tabular masses of diabase appear as residuals of less-jointed material (fig. 5, center right). Were this a case of dilation we would expect to find an occasional slab at least slightly rotated.

A wide portion in one of the lateral veins is not necessarily matched by a correspondingly narrow portion in its counterpart. Very commonly, however, a wide portion in one lateral vein is matched by a wide portion in the other. Such facts are inconsistent with the concept that segments of the diabase member have drifted, in a fluid medium (granite magma), closer to one dike wall than to the other (fig. 2). The variable width of lateral veins, therefore, can best be accounted for by differential consumption of diabase along the vein.

Transverse joints are generally less common and, therefore, more widely spaced in the central portions of basic dikes than near dike margins. Such fractures, however, might

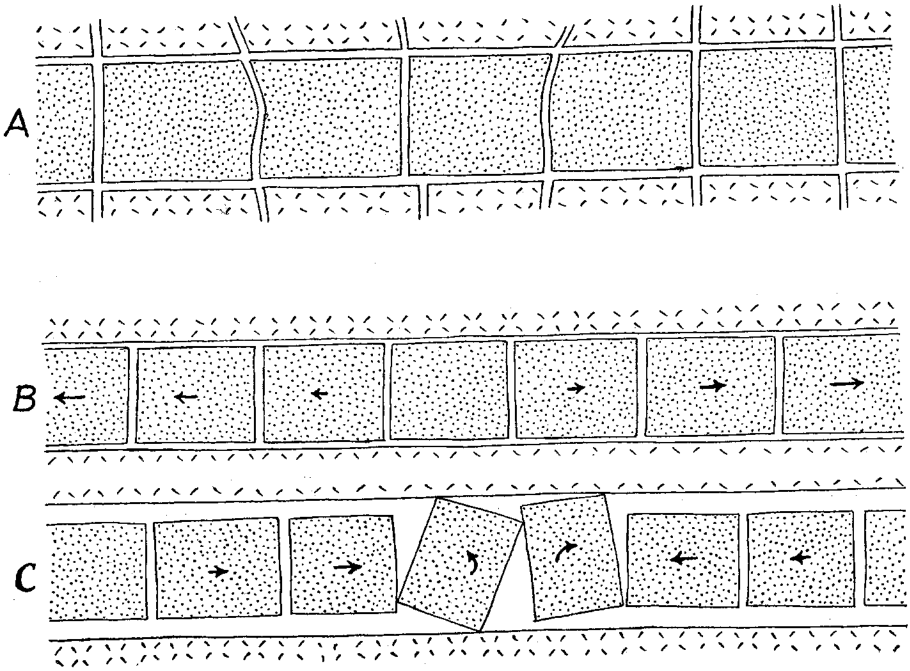

FIG. 3.—Formation of transverse veins in composite dikes.

permit entrance of a granite magma as well as localized replacement by granitic material from the marginal zone of fissures along which it was moving. The transverse veins might be explained by either process.

Emplacement of magma by dilation of transverse fractures to form veins would require considerable drifting apart of diabase blocks parallel to the dike walls. A three-dimensional field study indicates that block-drifting or overall extension of the diabase member in all directions in the plane of the dike wall would be required, but it is evident that such extension or drifting has not occurred. Extension of the diabase dike, if it occurred, might have ruptured the wall rocks with the result that transverse veins would extend far out into the gabbroic wall rock. This relation is not observed A few small granite veins cutting clear across the dikes are observed, but these are inadequate to explain dilation of the transverse joints as a whole.

Fig. 3A illustrates how jointing of a diabase dike and of the wall rock as well may produce diabase blocks separated by transverse veins of granite. Each transverse vein must normally be continuous or be associated with a vein extending out into the wall rock on either side of the dike. Fig. 3B lacks the extensions of transverse veins into the wall rock, but requires, on the basis of the dilation theory, a displacement of diabase blocks by sliding along the marginal fissures of the dike. The directions and relative amounts of block-drifting are indicated by arrows, relative to a central stationary block. Such drift parallel to dike walls and without rupture of wall rock is possible for relatively short distances, but a serious space problem is encountered if this principle is extended to distances actually observed. Fig. 3C shows that additional space needed for longitudinal drift could be provided only if certain diabase blocks were rotated, rotation being made possible by considerable dilation of the original diabase dike walls. Evidence for such rotation, however, was not found.

One dike in particular offers an excellent opportunity for a three-dimensional study. This dike is one-foot thick and is highly irregular, showing abrupt changes in dip and strike over distances of 10 to 20 feet. Considering the length and thickness of the diabase blocks compared with the thickness of the dike itself, it is difficult to see how these long blocks could have drifted past the sharp turns in the dike without being lodged between dike walls. Furthermore, there is no sign of crowding or rotation of diabase blocks.

Many features of the irregular veins and stringers indicate an origin by replacement, and there is no reason to assume that these veins have formed differently from the lateral and transverse veins. Pinch-and-swell structure, veins with non-matching walls, veins terminating in blunt ends, absence of wedge-shaped veins due to slight rotation of blocks, and local patterns of perfect packing of unusual-shaped blocks are all characteristic features here. Such features have been shown by Goodspeed (1, 2, and 3), Haff (4), King (5), and others to be reliable criteria for replacement veins. Space for the relatively large pockets of gran-

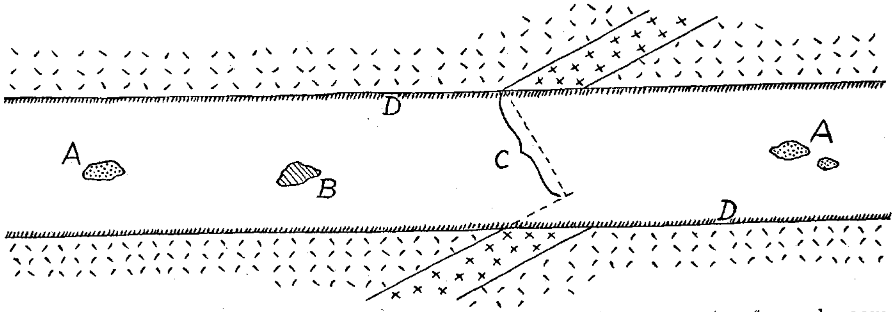

FIG. 4.—Theoretical pseudomorphic granite dike. A—remnants of nearly completely replaced diabase dike, B—remnant xenolith originally enclosed in diabase dike, C—offset of wall rock structure produced by diabase dike and not by granite, D—chill phase of diabase dike pseudomorphed by granite.

ite observed in some dikes must have been provided by consumption of basic material, because evidence of crowding, rotation, or lateral displacement of diabase blocks is lacking.

The evidence so far indicates that space for the granite in the composite dikes was provided largely by selective consumption or replacement of diabase dike rock. The possibility that some granite magma was involved in these dike reactions is not as yet ruled out. The next problem is to determine whether a granite magma did play a role and, if so, how much magma was involved.

The thickness of each composite dike is remarkably uniform for relatively great distances, and it seems a fair assumption that the original diabase dike in each case was also of uniform thickness. Assuming for the moment that no replacement occurred in a particular composite body, the amount of post-diabase dilation of dike walls necessary for the granite intrusion would be equal to the thickness of the composite dike minus the thickness of original diabase dike (same as thickness of diabase blocks). It is clear, however, that some consumption of diabase has occurred, and the true thickness of the original diabase dike can not readily be determined. It is possible, nevertheless, to establish a minimum value for the original thickness in such a case. This value would be equal to the thickness of the larger diabase blocks.

The difference between the thickness of the composite dike and the thickest diabase blocks within it is a measure of the maximum post-diabase dilation. Applying this line of reasoning to the dikes in question, we find that granite magma cannot account for more than a small proportion of the lateral veins. Quantitatively this amounts to a small fraction of an inch. It is conceivable that dilation was considerably greater for a short period, and that collapse of the walls to their present position occurred shortly after the granite magma started to crystallize. Such a concept, however, renders the objections to the dilation theory, already raised, all the more serious. We must conclude that only thin veins of magma, if any at all, were present.

If granite magma were to dissolve

diabase, thereby enlarging the openings for lateral veins, a continuous flow of relatively large quantities through lateral fissures would be required to remove the basic components without leaving clearer evidence of contamination. It seems doubtful that channels of this width could be adequately sustained. It is difficult to reconcile such a mechanism with the chill phenomena observed in well-substantiated magmatic veins and dikes of comparable width.

Looking at the transverse veins, we must conclude that, in general, only paper-thin dikes of granite magma could have existed. Yet many of these veins are now as wide as the lateral veins with which they are coextensive.

It seems unnecessary, therefore, to assume the presence of any granite magma in the composite dikes, but it must be admitted that a relatively small quantity may have existed. Space for the granite member was provided largely by replacement of diabase dike rock.

CONCLUSIONS AND COMMENTS

An attempt has been made to present some of the most convincing evidence of small-scale replacement of basic dike rock by granite at Mount Desert Island, Maine. This presentation is based largely upon field relations; detailed petrographic relations cannot be treated here.

It is concluded that granitic material, moving along lateral fissures and, to a lesser degree, along transverse and oblique fractures in certain small diabase dikes, replaced the mafic rock in a systematic fashion. The true nature of the material introduced is not known; it may have been an aqueous solution or a directed flow of ions or atoms. One thing seems quite clear, however; granite magma played, at most, a very minor role. The granite acquired room by replacement and not by dilation. The granitic material involved in this process is believed to be genetically related to the bodies of granite which outcrop immediately to the east. This study demonstrates that replacement of a basic rock by granite may be highly selective. The chemical reactivity of diabase dike rock, as compared with that of the gabbroic wall rock, may have been influential, but it is believed that rock structure, determined largely by jointing, prepared the way for replacing material and controlled both direction and extent of replacement. This study also shows that replacement boundaries may be very sharp, may be straight, or may be highly irregular.

1. None of these small diabase dikes was recognized to be completely replaced along its strike for more than about one foot, although the greater part of some dikes was replaced by granite for distances of several feet. It is not difficult to imagine that, if replacement had been carried to a more advanced stage, all diabase dike remnants would have been obliterated. Not only the possibility, but the probability, of completely replaced diabase dikes at Mount Desert Island must be recognized. Such dikes would be difficult to detect, but there are criteria to aid in their disclosure. Completely replaced dikes may be more common than we realize. Particularly in metamorphic and metasomatic terranes, old basic dikes may

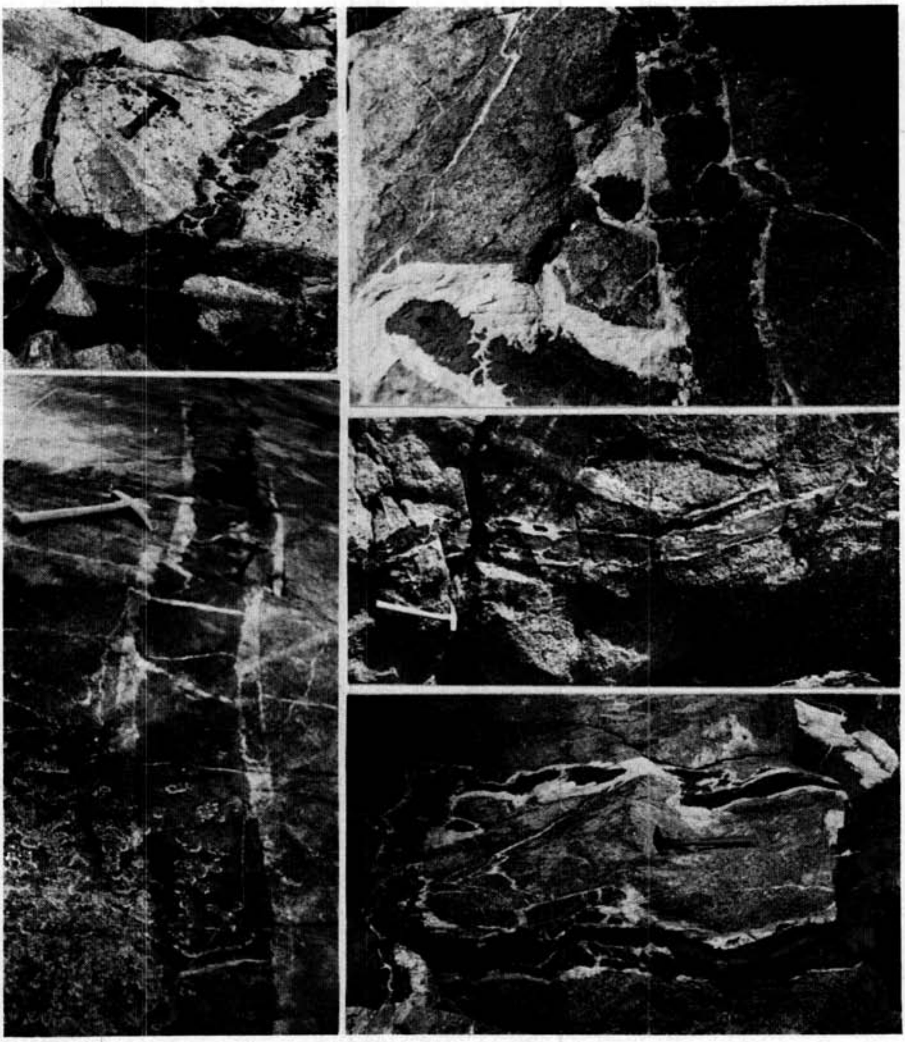

FIG. 5.—Composite dikes with centers of diabase and selvedges (lateral veins) of granite. Transverse and irregular veins of granite divide central basic member into distinct blocks, bounded by smooth to highly irregular surfaces. *Lower left* and *center right:* essentially planar views. Other views are three-dimensional, and, owing to uneven rock surface, misrepresent the uniformity of dike thickness and regularity of dike walls.

have been pseudomorphed by granite or pegmatite in great numbers, and so completely as to almost defy detection.

2. Inclusions of basic rock in some granitic dikes may represent unreplaced remnants of an old dike rather than fragments carried in, dropped from above, or buoyed upward from below (point A, fig. 4).

3. The possibility that xenoliths, inclosed in the original basic dike, survived replacement by granite after the dike itself has been consumed creates additional complications. Such inclusions could have been derived from the adjacent wall rock material or could be foreign to the area. Inclusions of wall rock were observed in several composite dikes on Mount Desert Island. These were completely surrounded by granite, but in some instances replacement of the diabase dike rock had not progressed far (point B, fig. 4).

4. Some completely replaced basic dikes may inherit characteristics of dilation dikes and give an erroneous picture of genesis. For example, a basic dike might produce offset of the wall-rock structures. After complete replacement, however, the new dike would still exhibit this dilation characteristic. Again it seems possible that the finer-grained chill zone of the original basic dike might be pseudomorphed by the replacing granitic material (points C and D, fig. 4).

5. A basic dike truncated by a younger igneous body and replaced by granite might erroneously suggest that the granite formed prior to the truncating igneous mass.

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