WEB JOINT PATTERN OF THE CAPE NEDDICK GABBRO COMPLEX, SOUTHWESTERN MAINE

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ABSTRACT. Joints in the roughly circular gabbroic pluton of Cape Neddick, Maine, are radial and tangential and form a pattern resembling a spider web. Mafic dikes, though small and not numerous, form only a radial pattern. Both dikes and joints are considered to be related and appear to have formed in the solid pluton by a mild but sudden doming action. These conclusions corroborate Hussey's findings that the gabbroic pluton was emplaced as a series of explosive intrusions controlled by cone fracturing.

The Cape Neddick complex of York County, Maine, is an oval shaped body, about 4000 feet long, composed of gabbroic rocks. It has intruded and thermally metamorphosed the Kittery Formation (Silurian?) composed of thin beds of quartzite and phyllite.

Earlier studies of the complex include those of Wandke (1922), Haff (1939, 1941, and 1943), Woodard (1957), Gaudette and Sakrison (1959), and Eldridge (1960). The most complete study of the complex is that by Hussey (1961 and 1962) which not only covers the petrology and structure but relates the Cape Neddick complex to other basic igneous complexes in the immediate area. The following description is based largely on Hussey's investigation.

The complex is composed of gabbro, anorthositic gabbro, cortlandtitic gabbro and pegmatitic gabbro (Fig.1). Along eastern and southern margins of the complex is a belt of agglomerate composed of subangular fragments (up to 8 inches across) of basalt, felsite, porphyry, quartzite, phylite, and probably crystal tuff. The agglomerate is believed to represent an early explosive phase of the complex.

Gabbro forms the outer rock belt of the complex and is rather rapidly transitional into anorthositic gabbro nearer the center. Cortlandtitic gabbro occupies the central area and appears to form lenses or tongues in the other two rock types (Fig.1). Pegmatitic gabbro also forms lenses in the outer gabbro belt. The rock distribution in plan is typically annular and resembles that of many ring complexes of New England. As a group the rocks show various types of layering as well as igneous lamination. These planar structures strike parallel to the external and internal contacts of the complex and dip inward at an angle which generally decreases from the margin toward the center. The outer contact appears to be steep or to dip inward at a high angle.

Hussey (1962) concludes that the complex was emplaced by cone-fracturing that occurred in two distinct phases. In the first phase a steep funnel-shaped block of country rock was shoved upward during the intrusion of a dense gabbroic magma. Crystallization of this melt gave rise to mafic-rich rocks at depth and to the gabbro and anorthositic gabbro now seen in the outer part of the complex. Accumulation of crystals under gravity and later formation of interprecipitate minerals largely accounts for the layering

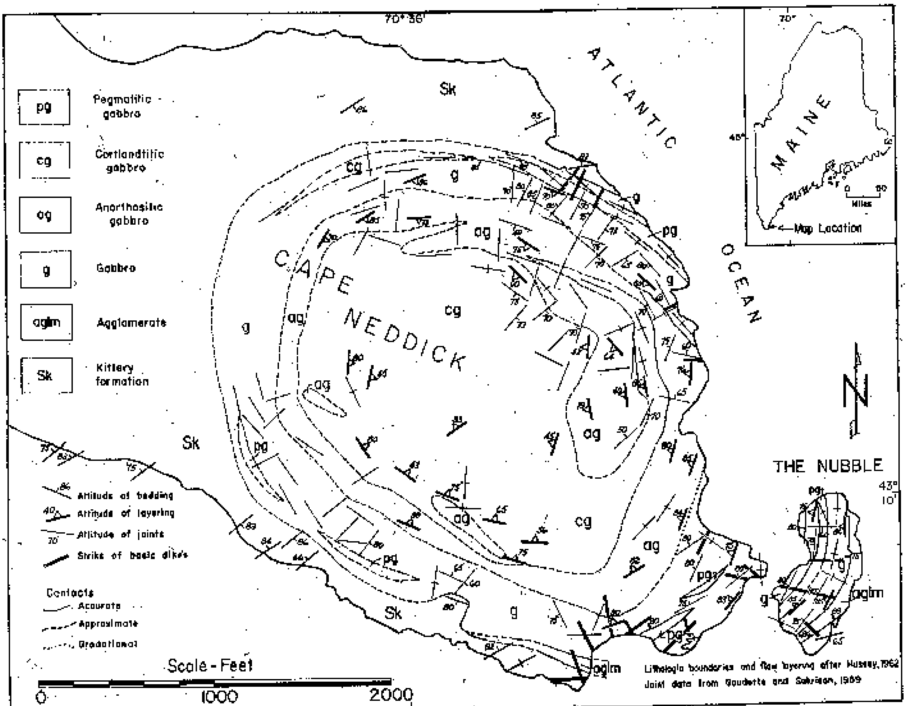

FIGURE 1.—Geologic map of Cape Neddick, Maine.

and lamination in the rocks of this first phase. Initially inward dipping planar structures may have been steepened by partial withdrawal of magma from below.

In the second phase forcefully intruded magma entered cone fractures in the gabbro and anorthositic gabbro and filled the space vacated by a funnel-shaped block near the center of the complex. Upon crystallization this magma formed the cortlandtitic gabbro. Subsequent withdrawal of magma from below may have caused steepening of layers in the cortlandtitic gabbro. Emanations associated with this second injection may have followed cone fractures and caused the earlier gabbro to be recrystallized to pegmatitic gabbro.

The sequence of rock formation was, therefore: (1) gabbro, (2) anorthositic gabbro, (3) cortlandtitic gabbro, and (4) pegmatitic gabbro.

In the light of Hussey's (1962) more recent detailed work, certain structural studies made several years earlier by Gaudette and Sakrison (1959) take on a slightly different and more significant meaning.

The structural features with which we are primarily concerned here are the joints. A plot of the joints as originally measured by Gaudette and Sakrison is shown in

Figure 1. It should be noted that nearly all readings lie within the gabbro and anorthositic gabbro phases. In spite of the fact that the central cortlandtitic gabbro is poorly exposed, it is felt that the much greater concentration of joints in the marginal phases of the complex is, in general, a correct representation.

The joint pattern as expressed in Figure 1 may be considered as constituted by two joint systems, one radial and one tangential. Two such systems in combination, if ideally developed, should give rise to a spider web pattern. In the Cape Neddick complex the web pattern appears incomplete because the central portion is so poorly developed.

Other structural features of the complex, recently investigated by the present authors but not mentioned by the earlier workers, are the few small basic dikes which cut the Cape Neddick complex. Only 18 such dikes were located, and of these all but one are less than a foot in thickness.

Microscopically the dike material appears to have been basaltic in composition. It consists of about 55% plagioclase (An_{45-65}), 15% red-brown biotite, 10% opaques, and roughly either 15% of clinopyroxene or 20-25% red-brown hornblende. The original rock textures were subophitic to intergranular. Fluidal structure with well-oriented plagioclase laths is common throughout the smaller dikes and near the contacts of the large one.

Recrystallization and alteration of the dike material appear as extensive phenomena. Locally original textures remain; but due to recrystallization, grains have become rounded and mutually embayed so the rock takes on a hornfelsic texture. Clinopyroxene is the principal primary mineral, but much has been converted to hornblende and biotite. Considerable hornblende has also been changed to biotite. Biotite is generally more abundant where the content of pyroxene plus hornblende is lower.

Closely associated with some of these basic dikes are intermediate to granitic phases and the relationship between different types may be of a simple or complex nature. The microscopic features of the dikes in this association resemble those of certain dikes at Mount Desert Island, Maine (Chapman 1962).

When plotted on the map (Fig.1) the basic dikes appear to present a radial pattern. It is possible that their restriction to the marginal portion of the pluton is more apparent than real because of the better exposures in this region, however, the radial pattern and basaltic composition suggest they are genetically related to the Cape Neddick complex. The dikes are obviously younger than the gabbro and anorthositic gabbro; but, because of their petrographic character, they are probably not related to the cortlandtitic gabbro. It seems logical, however, to consider them contemporaneous with or younger than the radial joints.

The history of development of the web joint pattern may have been rather complex. The joints are obviously all post-gabbro and post-anorthositic gabbro in age, and some at least must be post-cortlandtitic gabbro in age.

Hussey (1962, p. 48) considered that the arcuate masses of cortlandtitic gabbro in the outer part of the complex are cone sheets, which formed as the central mass of cortlandtitic gabbro was emplaced. Some of the tangential joints in the outer part of the complex may represent cone fractures, formed during this same explosive phase, which never opened sufficiently to admit the mafic magma. Had most of the tangential joints formed at this time, it would seem that cone sheets should be numerous in this area. Since radial fissures filled with cortlandtitic material have never been found here, it seems likely that the cone fractures were adequate to relieve the stress and that few if any radial joints formed at this time. Furthermore, Hussey's (1962, p. 48) conclusion that considerable recrystallization of the gabbro to form pegmatitic gabbro may have taken place along principally one cone fracture due to rising emanations, and the fact that such recrystallization is not known to have occurred along any radial joints would also indicate that few if any radial joints had formed. It appears, therefore, that nearly all the radial joints and most of the tangential joints formed after the cortlandtitic gabbro was emplaced.

The web pattern, therefore, may be ascribed to a still later but relatively minor explosive phase. Such an impulse may have been not only less violent; but it may have occurred more as a sudden, mild doming action accompanied by the injection of only a few thin mafic dikes. A doming movement would help explain the numerous radial joints and the small, radial basic dikes. The tangential joints would represent cone fractures which did not open sufficiently to admit the new magma.

In most other areas where cone sheets have formed, there is a paucity of these fractures in the vicinity of the intrusive center. Instead the cone sheets tend to cluster in a ring-like zone a short distance from the eruptive epicenter. This characteristic of cone sheet formation may explain the small number of tangential joints in the cortlandtitic gabbro, which occupies the central portion of the complex, and the clustering of these joints in the marginal portion.

The scarcity of radial joints in the cortlandtitic gabbro may be accounted for if it is assumed that the central portion of the complex moved upward more or less as a single conical block isolated by cone fractures. Such movements would have created little or no stretching in this central region and consequently few if any radial joints in the cortlandtitic gabbro.

In summary, it may be said that the present study of joints and dikes in the Cape Neddick complex tends to corroborate Hussey's (1962) findings. The sequence of events that led to the development of the complex and the web joint pattern in its outer portion is as follows:

1. Intrusion of gabbroic melt into a funnel-shaped opening (volcanic vent).

2. Crystallization and formation of the layered gabbro and anorthositic gabbro.

3. Slumping of the crystal mush or nearly solid rock along steep

fractures to partially obliterate, to tilt, and to partly reform the layered structure (recrystallization).

4. Sudden forceful intrusion of cortlandtitic gabbro melt to form steep cone fractures in the nearly completely crystallized earlier phases. Influx of magma into some cone fractures to form cone sheets. Upward displacement of a central cone-shaped block to form the central mass of cortlandtitic gabbro. Perhaps some recrystallization of gabbro and anorthositic gabbro occurred at this time.

5. Slumping of the cortlandtitic mass and steepening of its layered structure.

6. Sudden doming action in the solid complex, during a late and minor explosive phase, produced the web pattern of radial and tangential joints and the small radial dikes of basaltic composition.

Literature Cited

Chapman, C. A. 1962. Diabase-granite composite dikes, with pillow-like structure, Mount Desert Island, Maine. Jour. Geol. 70:539-564.

Eldridge, W. F. 1960. A petrographic study of the Cape Neddick gabbro pluton. B. A. Thesis, Univ. of New Hampshire.

Gaudette, H. E. and H. C. Sakrison. 1959. A structural study of the Cape Neddick gabbro stock. B. A. Thesis, Univ. of New Hampshire.

Haff, J. C. 1939. Multiple dikes of Cape Neddick, Maine. Geol. Soc. Amer., Bull. 50: 465-514.

———. 1941. Contaminated complex dike at Cape Neddick, Maine. Jour. Geol. 49: 835-853.

———. 1943. Alkaline vitrophyre dike at Cape Neddick, Maine. Amer. Miner. 28: 426-436.

Hussey II, A. M. 1961. Petrology and structure of three basic igneous complexes, southwestern Maine. Ph.D. Thesis, Univ. of Illinois.

———. 1962. The geology of Southern York County, Maine. Maine Geol. Sur., Spec. Geol. Studies Series No. 4, 67 p.

Wandke, A. 1922. A petrologic study of the Cape Neddick gabbro. Amer. Jour. Sci. 4: 295-304.

Woodard, H. H. 1957. Diffusion of chemical elements in some naturally occurring silicate inclusions. Jour. Geol. 65: 67-84.

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