No. 7. — *The Great Dike at Hough's Neck, Quincy, Mass.* By John Eliot Wolff.

This dike is situated some two and a half miles northeast from Quincy Depot; rising, when first seen, as an irregular ridge, and continuing, with interruptions, for about a mile in an easterly direction.

Mr. Crosby has mentioned this locality in his "Contributions to the Geology of Eastern Massachusetts": * — "On Hough's Neck, in Quincy, the amygdaloid is a green, slaty rock; it is sometimes amygdaloidal, and sometimes porphyritic, and includes masses which resemble felsite. It occupies the axis of an anticlinal in the conglomerate; and also cuts the latter rock very freely, after the manner of an eruptive." (p. 176.) Again: — "On Hough's Neck, in Quincy, along the north side of Rock Island Cove, there are prominent ledges of conglomerate flanking a large mass of amygdaloid, and the latter rock crops through the former in isolated bands, due to extravasation or faulting. The conglomerate strikes about east-west, and shows nearly vertical dips to the north and south, dipping away from the amygdaloid. It holds unmistakable pebbles of Shawmut breccia. This is clearly a faulted anticlinal fold. Toward the north, over the area marked as slate, the rocks are all concealed by drift; but on the south the conglomerate shows very plain indications of a passage to slate." (p. 209.) The amygdaloid, constituting a member of Crosby's Shawmut group, is regarded by him as older than the overlying Primordial conglomerate, and as a sedimentary rock in general, though sometimes presenting evidence of intrusion.

The country rock of the dike is a coarse conglomerate, with occasional interbedded layers of red sandstone and slate. At the eastern end it is bordered on both sides by the conglomerate. After running for a quarter of a mile as a ridge, the dike suddenly loses its ridge character, and occasional exposures only are found in the field to the east, among the outcropping conglomerate ledges. It can be traced thus for a quarter of a mile; then for some hundred feet no outcrop of dike is found until a small creek is reached. Crossing this, however, we again find a dike continuing as a ridge in the same direction for some hundred yards, when it disappears under the drift of a headland. This exposure, how-

* Occas. Papers, Bost. Soc. Nat. Hist., III., 1880.

ever, is not in the line of strike of the main, or westerly part of the dike, but lies some hundred feet to the north. Whether this change is due to a horizontal throw, or to a fresh outbreak of dike along a parallel line, does not appear.

At the western end, on the southern side, the junction with the conglomerate and red sandstone is very irregular, — large and small tongues of the dike penetrate into the conglomerate, this rock having a strike N. 60°–80° W., and a dip 70° south. The junction between the two rocks is sharp and well marked : the dike seems often amygdaloidal near the junction. Sections of the contact of the two rocks show that the dike is composed of a mass of very small feldspars, having a beautiful fluidal arrangement, while they are often bent when in contact with the line of the conglomerate. On the northern side, a fine vertical exposure of the junction is obtained, which is seen to stand almost vertical ; the dike cutting the slate and conglomerate a little irregularly, but standing nearly parallel to the stratification. The conglomerate here is nearly vertical, but may be said to dip to the north very steeply ; if, however, we pass east along the strike, a few hundred yards, to the exposures in the field, we find that all the conglomerate, both north and south of the line of the dike, dips steeply in one direction, i. e. south. I cannot, therefore, agree with Mr. Crosby, that " this is clearly a faulted anticlinal fold." It may equally well be an intrusion of the dike into the vertically standing strata, causing irregularities of the dip. More detailed study is required. In the western ridge the dike has a width of about three hundred feet from contact to contact.

The rock is generally of a greenish color, approaching a greenish red in the fresher portions ; it is irregularly jointed. In texture there is great variation between coarse, fine, porphyritic, and amygdaloidal. Masses of quartz, and yellowish-green epidotic material frequently occur. These greenish masses are often very irregular, occasionally vertically banded, and resembling fragments of a stratified rock, and often lined on the exterior with a band of reddish substance. Microscopic sections of some of them give a mixture of quartz, calcite, epidote, and a whitish opaque substance (kaolin ?), and show that they are in part areas in the rock of decomposition, or segregation.

Although at first sight this dike appears to be a homogeneous mass of rock, yet it is in reality composed of rocks belonging (in all probability) to at least three separate eruptions, forming, instead of one, numerous dikes. To this fact is largely due the noticeable variations in the area of rock. First in order comes the amygdaloid, forming the principal

mass of the rock, and eruptive through the conglomerate. In the second place, a close study of the great area of this rock shows that it is cut by a large number of narrow diabase dikes, generally but a few feet in width (e. g. three feet), which do not have a marked amygdaloidal structure. In many cases they run almost parallel with the trend of the amygdaloid; in other cases they run obliquely, while others again may cut almost transversely across it, in parallelism with a third dike to be mentioned. These dikes show generally well-marked contacts with the amygdaloid: they are fine-grained at the junction, but coarse-grained in the centre; in some cases they have melted the amygdaloid at the contact, so that it is difficult to find the actual line. Some of them are easily distinguished from the amygdaloid, under the microscope, by the large amount of augite which they contain, but in others this mineral cannot be found as such, for all trace of it (if originally present) has been lost in the alteration products. Lastly, about the middle of the large western exposure of the amygdaloid there is found a large dike (at least seventy feet wide) running transversely across it, in a direction N. 5°–10° W. On the south side it is seen breaking through the conglomerate and sandstone, and can be traced from that locality across the amygdaloid. No exposure was found giving the actual contact of this rock with any of the others, although it can be seen at a distance of a foot or two from them. Judging from its direction, which cuts directly across the trend of a great number of the small dikes, it would seem to be the latest rock of all. Some of the small dikes to the east of it are, however, nearly parallel with it. While, therefore, there seem to be at least two periods of eruption subsequent to that of the amygdaloid, yet some of these small dikes may cut the others, thus complicating the phenomena still further. I have not been able to find evidence of this beyond the difference of direction; and to settle the question by the discovery of the actual contacts will be difficult, on account of the lithological similarity of all the eruptive rocks, and the thick covering of lichens, which conceals everything, and makes any work there laborious.

The amygdaloid sometimes loses its amygdaloidal character, so as to resemble greatly the later dikes; but in such cases the passage is gradual.

The microscopic descriptions which follow show that all these rocks are altered basalts, and, together with the field relations, prove that they are all truly eruptive rocks, breaking through the conglomerate, while the later eruptive rocks cut the earlier ones.

[1.] *From Western End of Dike, North Side, near the Road, — one of the small Dikes in the Amygdaloid.*

Lens. A greenish-gray, felty-looking rock, containing minute grains of pyrite, and small feldspar crystals. Traversed by veinlets of epidote. — *Section.* White opaque feldspar crystals, and masses of opacite, magnetite, and pyrite, in a green chloritic groundmass. The feldspars have generally the long ledge form of the basaltic triclinic feldspars, but occasionally the form of Carlsbad twins of sanidin. They are entirely altered to a fibrous and scaly aggregate, polarizing with yellow and blue colors, — often with the brilliancy of talc. Colorless needles with cross fracture (apatite) occur occasionally in the feldspars, and also aggregate quartz. Between the feldspars lies a mass of green fibrous products, — chlorite, viridite, etc., considerable epidote, magnetite, quartz, etc., — rarely hematite and biotite. The magnetite often has the form of a grating, reminding us of decomposed olivine. The feldspars occasionally have a fluidal arrangement.

[2.] *Contact of Amygdaloid and Conglomerate at Southeast Corner.*

Section. A mass of small feldspar crystals, having a well-marked fluidal arrangement, and surrounding decomposed crystals of olivine and masses of magnetite and opacite. The olivine crystals have the characteristic lozenge shape, blackened border, and irregular fissuring, while the small parallel feldspars of the groundmass separate and flow around the crystals. Some are altered within the black border to a light green serpentine with fibrous polarization ; in others, while the centre shows the brilliant polarization and the pitted surface of olivine (though the greenish color is evidence of some alteration), the exterior zone of the crystal has been altered to a bluish-gray substance, which in polarized light is seen to contain fibres with brilliant polarization, and may perhaps represent a stage in the alteration to talc. Some of the olivines are wholly or partially altered to ferrite and talc, the latter polarizing very brilliantly. Some of the magnetite and opacite in the section is derived apparently from the complete alteration of grains of olivine. The feldspars have generally the long ledge character of the basaltic feldspars, though some have the form and optical properties of Carlsbad twins. Occasionally there is found a crystal sufficiently fresh to show the multiple twinning, but generally they are filled with greenish or transparent scales, while along the centre of the ledge crystal there runs a line of green chloritic material, containing generally less opacite

than the similar substances lying outside the crystal, but often continuous with them. Some of the crystals are more than half filled in the centre by a rectangular mass of this chlorite, often extending through to connect with that outside. The space between the feldspars is occupied by chloritic materials, opacite, etc., together with some quartz. Epidote and quartz occur in the groundmass as alteration products, and transparent needles, frequently broken across, which are probably in part apatite. Along the line of the conglomerate some of the feldspars are bent.

[3.] *West End of Amygdaloid very near* [1]

Lens. A gray-colored groundmass, containing white and greenish feldspar crystals, spots and crystals of epidote, occasional quartz and epidote amygdules, and reddish areas of decomposition. — *Section.* Composed principally of feldspars, with considerable epidote, chlorite, opacite, etc. The feldspars are mainly plagioclase, but there are occasional Carlsbad twins of sanidin. Some of the large porphyritic feldspars are broken and fragmentary; an effect, apparently, of the flowing base, for the small feldspars diverge, and flow around the large crystals. In some cases they are seen to have been pushed into the large crystals a certain distance on opposite ends along the central line, while a line of base passed through the crystal connecting the two tongues. This base, however, is now altered to calcite, chlorite, epidote, etc. Occasionally two feldspars interpenetrate each other. The products of their decomposition are the same greenish or colorless scales (which often have a brilliant polarization), epidote, chlorite, calcite, quartz, and colorless needles. The smaller feldspars seem less decomposed than the larger ones. Between the feldspars lie masses of chlorite, epidote, opacite, calcite, magnetite, etc.; often in the form of wedges between the diverging feldspars. One grain of altered olivine is seen in the section, identified by the shape and the previously described motion of the groundmass and base around it. The exterior consists of reddish ferrite, penetrating along the fissures; the interior of quartz.

[4.] *West End of the Amygdaloid near* [1] *and* [3], *but nearer in the Centre of the Mass.*

Lens. Similar to [3]. — *Section.* The large feldspars are broken by the base, as described above. Plagioclase and sanidin occur. True amygdules occur here, recognized as such by the regular shape, and by the fact that the small feldspars of the groundmass flow around the

cavity and are distinctly separated from it. They are filled with epidote, chlorite, calcite, quartz, and a fibrous chalcedonic (?) material: the epidote is generally on the outside, the chlorite inside. Considerable epidote is scattered through the section, generally outside of the feldspars, and also talc, calcite, and quartz. These decomposition products often occur in the groundmass in rounded areas, but are not true amygdaloids. Patches of reddish opaque ferrite also occur in a similar manner, constituting the red spots seen macroscopically.

[5.] *Western Ridge of the Dike on the West Side of a Road which crosses it, — taken towards the Centre of the Mass.*

Lens. A greenish groundmass containing porphyritic feldspars, reddish and greenish areas of alteration, and rounded masses of quartz. The groundmass has intruded into some of the large feldspars. — *Section.* Crystals of feldspar and areas of decomposition or infiltration surrounded by a greenish chloritic mass. The large feldspars are occasionally Carlsbad twins; the small ones of the groundmass principally plagioclase, although some are twinned sanidin crystals. The (original) base, carrying small feldspars, has bent some of the large feldspars, and pushed into them. Others contain in the centre square zonal inclusions of the greenish mass, while the outer zone of the crystal is free from it. These phenomena are similar to those so frequently observed in the unaltered basalts with a glassy base. Many of the larger feldspar crystals are partly filled with epidote grains, chloritic material, and light-green needles, which have a yellowish-white polarization. Rounded areas, composed of greenish chloritic fibres, with sometimes a deep violet blue color between crossed nicols, occur in the groundmass, mingled occasionally with talc, and bordered by epidote. Some of these areas, enclosing the remains of the small feldspars, arise from the decomposition of the groundmass; others are either true amygdules, as described above, or some might be pseudomorphs after some mineral, — for instance, olivine. Between the feldspars lies the green mixture of chlorite, viridite, and greenish needles similar to those described in the feldspars, beside some epidote, calcite, and quartz.

[6.] *Western Ridge of the Amygdaloid, about fifty feet east of a Road crossing it, — the Specimen taken from a long Dike crossing the Amygdaloid obliquely to its Main Trend.*

Lens. A grayish-green groundmass, holding crystals of greenish feldspar and grains of pyrite. The groundmass has pushed into some of

the long crystals. Powder feebly magnetic. — *Section.* Much decomposed. The feldspars retain their outline, but are filled with chloritic material, — kaolin, epidote, and calcite. Magnetite is very plentiful in crystalline and irregular forms, having often a whitish, decomposed surface (leucoxene), which, in connection with the reticular or branching shape of the masses, shows the presence of menaccanite. Pyrite occurs in occasional grains and square crystals, generally close to or mingled with the magnetite or decomposed menaccanite, and is therefore probably an alteration product. The remaining portion of the rock is a confused mixture of chlorite, epidote, quartz, viridite, hornblende, calcite, and colorless needles, in part probably apatite, — all products of alteration. This rock is the most coarsely crystalline and the most decomposed of any examined.

[7.] *From the Exposure of the Dike in the Field midway between the extreme Eastern and Western Ridges.*

Lens. Similar to the preceding hand-specimens, but rather reddish in color, and somewhat more amygdaloidal. — *Section.* A much fresher rock than those already described. The few porphyritic feldspars are generally plagioclase, and exhibit the same proof of an early crystallization mentioned above (i. e. the feldspars of the groundmass flow around them, etc.). The feldspars of the groundmass are principally plagioclase, but some Carlsbad twins and unstriated crystals can be found. All these feldspars are comparatively fresh, and the formation of the greenish scales and other products of decomposition has not progressed far. The frequent inclusions of the original base, however, are entirely altered to chloritic products and magnetite. The feldspars contain occasional large rounded or irregular fluid inclusions, with bubbles, and immense numbers of extremely small similar inclusions (requiring the use of powers of from 700 to 900) characterized also by occasional moving bubbles. Grains and crystals of epidote occur in the feldspars, and occasionally quartz. Chloritic products and magnetite represent the original base. Epidote occurs in the groundmass in patches; calcite is rare. True amygdules occur, filled with chlorite, quartz, and epidote.

[8.] *From the Ridge constituting the extreme easterly Exposure of the Dike, and not in Line with the Western Half, though trending parallel with it.*

Lens. A reddish groundmass, containing feldspar crystals, amygdules of greenish chlorite, and red spots resulting from the decomposi-

tion of the rock. — *Section.* The least decomposed rock of any examined. It has a groundmass composed of small ledge-shaped feldspars, magnetite, chlorite, epidote, etc., enclosing porphyritically a few large feldspars. The majority of the crystals are plagioclase, but there is a considerable number of Carlsbad twins. The small feldspars of the groundmass show the flowing of the base around the large crystals, as described previously. The larger feldspars contain very characteristic inclusions of a base in irregular, reticulated, or cylindrical forms. They often fill a large part of the crystal; may be zonally arranged; and are absolutely identical in shape and other characteristics with the inclusions of glass or base in the unaltered basalts. These inclusions are now altered to magnetite and greenish chloritic or viriditic products. Besides these dark inclusions of base, the feldspars are filled with almost colorless microliths and scales, — the products of the incipient decomposition of the feldspathic substance, — and very minute fluid inclusions, rounded, cylindrical, or branching. Some epidote and calcite occur in the feldspars. True amygdules are found, filled with calcite, epidote, and chlorite. Irregular masses of epidote occur as areas of alteration in the groundmass, — the magnetite often in large masses, enclosing the small feldspar crystals of the groundmass, and mixed with considerable ferrite. One decomposed crystal may perhaps be referred to olivine.

[Q. 8′.] *The Large Dike running nearly at Right Angles across the Trend of the Amygdaloid.*

Lens. A coarse-grained, dark green rock, containing crystals of feldspar, pyrite, magnetite, and hornblende, in a dark green groundmass. — *Section.* Contains (comparatively speaking) large-sized feldspar crystals; fibrous, greenish, dichroic hornblende; crystals of magnetite and pyrite; decomposed crystals of olivine; epidote; and viridite, quartz, apatite, etc. The feldspars are to a great extent kaolinized. The hornblende occurs in irregular masses, shows strong dichroism and brilliant polarization, and contains a great deal of epidote in rounded grains. Some of the feldspar crystals lie imbedded in the hornblende, or cross it, just as they do in the case of the augite of the less decomposed diabases, so that this and the whole character of the hornblende indicate that it is (in part at least) a product of the decomposition of the original augite. The olivine occurs generally in shattered crystals, with the usual blackened border. The interior is altered to greenish serpentinous products; but little spots still show the polarization and other characteristics of

the unaltered olivine. The magnetite is found in extremely irregular forms, while the pyrite grains often contain magnetite, and therefore arise probably from its decomposition.

[Q. 1′.] *One of the Narrow Dikes running parallel with the Trend of the Amygdaloid.*

Lens. A compact greenish rock containing crystals of feldspar. — *Section.* Contains feldspar crystals, augite, magnetite, pyrite, and decomposition products. The feldspars are kaolinized, or else decomposed to white fibres, and contain considerable epidote, viridite, etc. The augite occurs in irregular masses; it is reddish and has well-marked cleavage; the decomposition to viridite, hornblende, and epidote is seen to be well advanced, these substances forming along the cleavage lines. The magnetite often shows the white decomposition characteristic of menaccanite. The pyrite is probably derived from the magnetite. No traces of olivine were seen.

[9.] *Section of Two Pieces of the Greenish vein-like or irregular Masses found in the Rock.*

One of the fragments is composed of epidote, calcite, quartz, and an opaque gray substance, perhaps kaolin, — mixed with the remains of feldspar crystals. The other fragment, from one of the banded veins, is composed of the same substances arranged in bands. Both are probably areas of decomposition in the rock.

Summary.

From the details given we obtain the following generalized description of the amygdaloid proper. In the hand specimens the groundmass varies in color from green, through gray, to red, — the last color characteristic of the rock that is least decomposed. It sometimes encloses large green or white feldspar crystals, often indented by the groundmass, or the feldspar crystals may be comparatively minute; grains and crystals of epidote are occasionally seen. The rock generally contains greenish spots of epidote and of chloritic material, in part true amygdules, and spots of reddish decomposition. There are also amygdules of calcite and quartz.

The specimens from which the eight sections were made differ chiefly in the degree of decomposition, the presence or absence of olivine, and the coarse or fine texture. The specimens from the eastern end are much less decomposed than those from the western end.

As seen under the microscope, the rock is composed of large and small feldspar crystals, magnetite, epidote, calcite, and a mass of chlorite, viridite, and opacite. The large porphyritic feldspars are twinned plagioclase, and occasionally Carlsbad twins of sanidin. The minute feldspars of the groundmass flow around them, encroach upon, and sometimes break them. Rarely, the groundmass, holding small feldspars, has pushed into a crystal, a little distance on either side, and a tongue of the (original) base, alone, without the small feldspars, passes through the crystal and connects the two intrusions, — this connecting tongue now altered, however, to calcite, chlorite, and epidote. The small feldspars, when sufficiently fresh, show the triclinic twinning; but some Carlsbad twins of sanidin and unstriated crystals occur, the former of which cannot be referred to the plagioclase that, owing to the alteration, does not show its multiple twinning.

The degree of decomposition that the feldspars have undergone varies in the different sections: in the freshest rock they contain immense quantities of minute fluid inclusions, characterized by moving bubbles, and occasional larger ones, rounded or irregular in shape, together with inclusions of the base. The latter are cylindrical, or irregularly reticulated in form, often zonally arranged in the interior or exterior parts of the crystal; they are absolutely identical in shape, and in their relations to the enclosing crystal, with the inclusions of glass or base of the fresh basalts; they are now altered to magnetite, viridite, and other products. In the smaller feldspars these intrusions generally run through the centre of the crystal, parallel with the twinning-plane. Even in the freshest specimens, the substance of the feldspars is filled with minute microliths, and scales either colorless or of a light greenish color, with occasionally some epidote, calcite, or quartz, — generally products of the decomposition of the feldspathic substance proper. In the more decomposed specimens these products multiply, so that the crystals become a mass of these viriditic scales and fibres (often polarizing with the brilliancy of talc, or in red and yellow colors), or even of opaque kaolin, while calcite, epidote, quartz, and colorless needles with cross fracture, in part apatite, appear to a greater or less extent. The epidote occurs generally in the large feldspars in grains: some of it may originate from the alteration of included minerals; but of this there is no proof. Occasionally two feldspars interpenetrate each other.

The only other original mineral, unless it be part of the magnetite and apatite, is olivine. This was found in well-marked, large, and undecomposed crystals only near the contact of the amygdaloid with the con-

glomerate (described with section [2]); though what seemed to be the remains of olivine crystals were found in one or two other sections. Their relations to the groundmass prove an anterior origin: some of the magnetite and opacite in the sections have probably been derived from the alteration of small fragments of olivine.

Between the large and small feldspar crystals lies a mass of greenish alteration products, — chlorite (often dichroic), viridite, magnetite, opacite, considerable epidote, quartz, and calcite. When some of the large feldspar crystals diverge, the triangular space between them is filled with very small feldspar crystals, lying in this greenish mass; showing, as has been often remarked, that it is merely an original, glassy base, much altered, for we find this same relation in the unaltered basalts. Calcite, quartz, epidote, hornblende, biotite, apatite, etc., in the decomposed base, seem to belong to the more advanced state of decomposition.

Magnetite is always present. A large part of the magnetite arises from the decomposition of the base, and it is generally difficult to say what part of it is original.

While in some sections true amygdules are wanting, yet they generally occur, characterized by their sharp boundary, and the arrangement of the feldspars of the groundmass parallel to their outline. They are filled by epidote, chlorite, viridite, calcite, or quartz; the epidote generally on the outside, when other minerals occur with it. Besides these true amygdules, areas of decomposition occur in the groundmass, consisting either of opaque ferritic material, constituting the macroscopical red spots, or of epidote, chlorite, viridite, etc., enclosing the small feldspars.

Assuming that all the specimens described belong to the same rock-mass, this rock, according to the classification used, would be referred to both the Diabase and Melaphyr sections of the Basalts* (according to the specimen examined), or again might be called a Diabase and Olivine-diabase.† It is found by study to be a rock which, in the original state, was composed of the feldspars, olivine, magnetite, a base (glassy, microlithic, etc.), and probably some augite (though this cannot be identified now), all in varying proportions, and that these original constituents have been largely replaced by secondary products. It is therefore an altered basalt, as has been previously shown by others for similar rocks of this region.‡

* M. E. Wadsworth "On the Classification of Rocks," Bulletin Mus. Comp. Zoöl., Vol. V. No. 13.

† Rosenbusch, Mikros. Phys. der Mass. Gest., etc.

‡ M. E. Wadsworth, Proc. Bost. Soc. Nat. Hist., Vol. XIX. p. 217 *et seq.*, 1877. E. R. Benton, Ibid., Vol. XX. p. 416 *et seq.*, 1880.

The examination of the sections made from some of the narrow dikes which cut the amygdaloid seems to show, in general, a similarity to either [Q. 1′] or [6] — one series containing undecomposed augite, the other none that can be identified. The great cross dike is described under [Q. 8′]. All of these later eruptive rocks seem in a more advanced stage of decomposition than the amygdaloid.

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