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GENESIS OF LATE-MAGMATIC DIABASE DIKES

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With 1 figure.

Ascutney Mountain, Vermont.

Abyssic rocks occur as (R. A. Daly 1903): gabbro, diorite, acid essexite, nordmarkite, alkali granite, monzonite, and alkalic biotite granite. These rocks have been cut by diabase dikes, that occur even outside the district of the igneous rocks mentioned (loc. cit. p. 88).

British Isles.

Parts of the British Isles (Harker 1904 and Bailey 1924) have been cut by dike swarms of tertiary age which show the highest frequency of dikes in the vicinity of the igneous centers. The dikes mentioned may be acid as well as basic, but basic ones are by far the most abundant. The acid dikes are concentrated around the igneous centers, this fact indicating a consanguinity with the igneous rocks occurring here. The dikes are partly older than the ring-dikes and the cone-sheets of the centers, whereas the greater part of them are younger. Hence, the breaking up of the bedrock leaving room for the dike swarms has taken place approximately at the same time as the breaking up leaving room for ring-dikes and cone-sheets, tending, however, to be somewhat later.

Essex County.

Some diabase dikes in this district (Washington 1899) are younger than gabbro, esexite, foyaite, diorite, quartz-syenite, and granite. Excerpt: "As regards their (diabases') relations to other rocks it may be noted that they cut, and are hence later than, all the other types." The diabases in Essex County are of one type.

Okanagan Batholith.

In this region (R. A. Daly 1906) malignites, syenites, and granites (partly with natronmonzonite and quartz-diorite as border facies) are cut by olivine basalt dikes.

Sudbury district.

Here olivine diabase dikes have cut the following rocks of Keweenawan age: gabbro, norite-pegmatite, granite, and trap dikes. (C. W. Knight 1917.)

Oslo region.

As recently demonstrated by Tom. F. W. Barth (1944), the igneous rocks of this region belong to two rock series: the Oslo-essexite-series consisting of modumites, olivine-gabbros, hyperites, kauaites, akerites, hurumites, windsorites, and husebyites -and the kjelsåsite-larvikite-nordmarkite-ekerite-series with a satellitic branch of lardalite.

These two rock series are different in regard to geological occurrence, as the Oslo-essexites, which is the oldest series, occur in volcanic bosses, while the rocks of the younger series occur in subvolcanic plutonites.

As a third series diabase dikes appear, cutting through all the rocks mentioned above, thus being the very youngest rocks of the Oslo region. The dikes are to be found in great numbers practically all over this region (Brøgger 1933, p. 115), and are relatively common even in the environments. Usually the diabase dikes attain a width of ½ to 2—3 meters, occasionally even 6—7 meters.

This third series of rocks shows but a slight tendency to differentiate, varying in SiO_2 contents from 42.32 % to 55,82 % (ref. analyses Brøgger 1933 pp. 116—117). After all, a characteristic of the dikes must be said to be their similarity, in spite of their widespread occurrence in very different bedrocks. This similarity applies to texture as well, even if differences may be found, as f. inst. porphyritic types occur side by side with non-porphyritic ones.

The genetic correlation between these dikes and the other igneous rocks of the Oslo area has always been difficult to interpret. As against the idea of Barth (loc. cit.), Brøgger considered all igneous rocks of the Oslo region as belonging to a single series with the

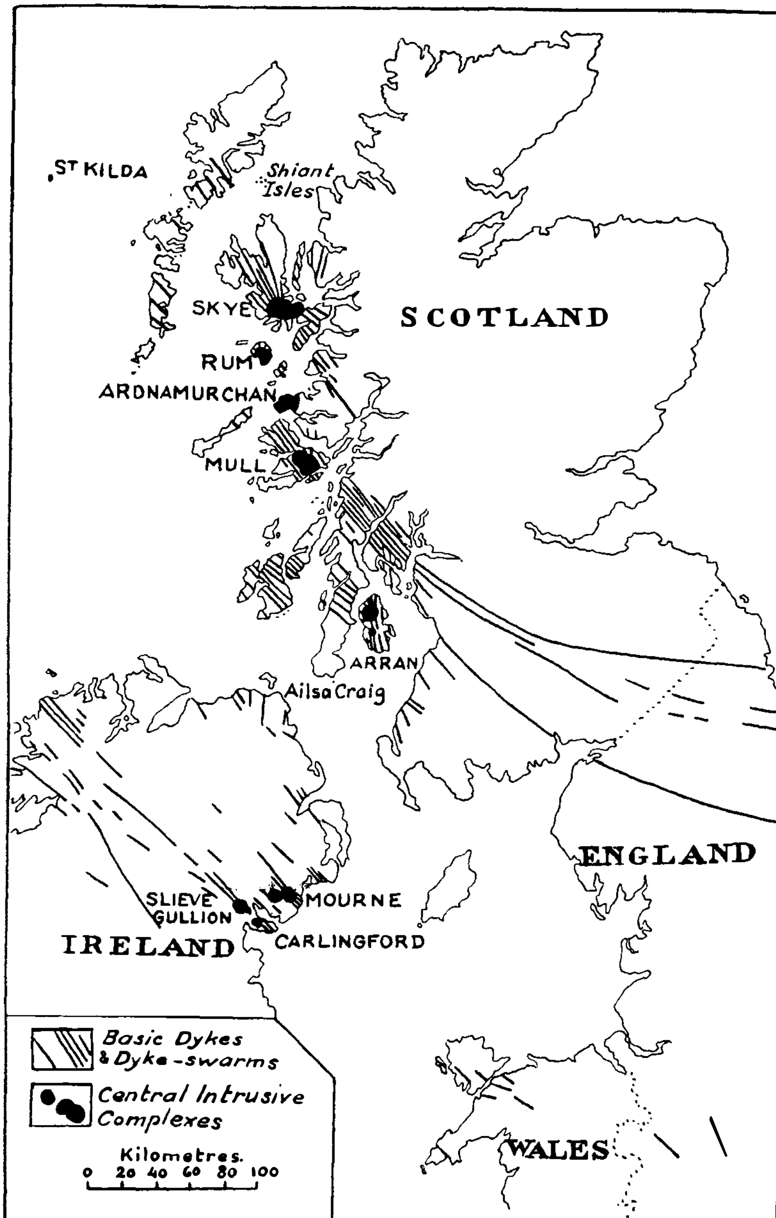

Fig. 1. Map showing distribution of tertiary north-west basic dikes in relation to tertiary central intrusive complexes of the British Isles. NB. Number of dikes is greatly reduced. After Mem. Geol. Surv., Scotland, 1930, p. 53.

kauaitic (by Brøgger erroneously termed essexitic) magma as the parental magma of a differentiation series which through ever more acid stages ended in ekeritic and granitic magmas. It is hardly natural to consider the youngest diabase magma as a result of this process, and our understanding of the matter is not at all furthered by Barth's demonstration of two rock series with different parental magmas, the older one being kauaitic, the younger syenitic. Brøgger has pointed out the great similarity in the chemical relationships between the oldest rocks in the area, the kauaites, and the youngest ones, the diabase dikes, and has contended that the diabase dikes represent a renewed eruption of the oldest mother magma, still partly undifferentiated (Brøgger 1932 pp. 86—88). Excerpt: »Die nahe Übereinstimmung der mittleren chemischen Zusammensetzung der Diabase, der jüngsten Eruptivgesteine des Oslogebietes, mit der mittleren chemischen Zusammensetzung der Gesteine der Essexitreihe, der ältesten Eruptivgesteine desselben, deutet darauf, daß das ursprüngliche Magma des Oslogebietes eben ungefähr dieselbe chemische Zusammensetzung gehabt hat, und somit, nach der ersten Eruptionsepoche der Essexite, selbst zum Boden des Magmabassins gesunken ist. Durch stetig fortsetzende Differentiation durch die fortgesetzte Auskrystallisation der schwersten, am meisten basischen Mineralien (Pyroxen, Erze etc.), die zuerst zu Boden sinken mußten, mußte das Magma in ihrer oberen Schicht nach und nach immer saurer und leichter werden, immer reicher an Alkalien und SiO_2, und umgekehrt immer ärmer an CaO, MgO und Fe-Oxyden werden. Das stetig in seiner Zusammensetzung sich ändernde, in seiner oberen Schicht immer saurer werdende Magma mußte somit dementsprechend immer saurere, alkalireichere Magmen nach oben ergießen. Schließlich ist aber das tief eingesunkene, ursprüngliche basische Magma wieder von größerer Tiefe aufgepreßt und hat dabei die zahlreichen Gangspalten gefüllt, und somit die Diabasgänge hinterlassen.«

The view that a smaller part of the original magma in the magma chamber has escaped the differentiation process undergone by the remaining part of the magma, and later has been intruded into fissures around the magma chamber, is hard to maintain, being rather artificial. It seems to me that Brøgger, who has rendered so many important contributions to the understanding of the formation of igneous rocks, has missed the correct interpretation of the genesis of the young diabases.

General considerations.

These late-magmatic diabase dikes cutting the other rocks of a petrographic province are usually somewhat sparingly referred to, probably because they have failed to fascinate the petrographers: The various members of the ever-present diabase family resemble each other closely, and it is difficult fitting them into the picture of the evolution of the rock suite in question. Thus I suspect that this phenomenon of igneous rock suites closing their history of evolution with intrusions of basic dikes are more commonly met with than the reading of petrographic literature would indicate.

Let us now consider the thermal relations in and around a province of igneous rocks immediately after the consolidation of the magma. The heat content of the original magma chamber plus the crystallization heat of the magma will be so distributed that the igneous rocks themselves represent the warmer part, while the heat in the surrounding rocks slowly decreases as the distance from the igneous rocks increases.

On consolidation the magma will be welded to the surrounding rocks, with the result that the igneous rocks and their environments are to be considered a unity not only thermically, but even mechanically. This unity will however, not have attained stability merely by the consolidation of the magma: thermic stability will be attained only when the heat equals that average in the depth of the earth's crust where the rocks are located. During further cooling the volume will decrease, as a hot rock will be more voluminous than a cold one. The resulting tensions will have to be compensated for by formation of fissures (provided the tension effect will not be ruled out by other effects, caused, f. inst., by orogenic forces).

The fissure frequency must be supposed to be highest where the original temperature was greatest, that is within the igneous rocks and in their immediate surroundings, while the frequency will decrease further away from the plutonite. The relations described from the British Isles (Fig. 1) is a god affirmation of the correctness of this presumption.

The fissures formed will be filled by fluids at hand. The pegmatite magmas, still unconsolidated, will presumably fill the oldest fissures, while hydrothermal solutions will deposit mineral veins in the younger ones. —

No.	A	B	C	D	E	F	G
SiO_2	50 80	50.59	49.47	47.00	47.49	49.70	48.42
TiO_2	2.23	1.71	1.79	3.60	3.29	2.23	3.60
Al_2O_3	16.30	14.58	13.09	16.44	14.54	14.24	15.59
Fe_2O_3	3.91	2.91	4 18	3.31	3.36	3.66	3.70
FeO	6.95	8.22	9.95	12.34	11.80	9.96	7.69
MnO	0.19	0.17	0 29	0.04	n. d.	0.17	0.12
MgO	4.31	7.39	6.78	3.32	6.10	6.82	6.43
CaO	7.21	9.46	9.91	9.57	9.70	9.55	8.69
Na_2O	4.02	2.52	3 08	3.38	2.60	2.64	3.52
K_2O	2.17	0.17	1 07	0.67	1.12	0.70	1.70
P_2O_5	0.94	0.25	0.24	0.33	n. d.	0.33	0.54
CO_2	0.97	1.39	0.15	n. d.	n. d.		
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Molecular Norms[2].							
Q	0.4	2.6	—	—	—	0.7	—
Or	12.9	4.2	6.4	4.0	6.9	4.3	10.1
Ab	36.3	18,0	28 0	30.9	23.9	24.1	32.0
An	20.1	28.1	19.0	28.7	25.2	25.5	21.8
Wo	1.4	4.0	11.4	7.2	9.6	8.2	7.2
En	12.0	21.6	13.7	5.7	10.4	19.2	5.7
Fs	5.3	11.5	7.6	7.4	7.0	10.3	1.5
Ol	—	—	6.1	6.5[3]	8.7[4]	—	11.6
Il	3.1	2.5	2.5	5.2	4.7	3.2	5.0
Mt	4.1	3.2	4.5	3.6	3.6	3.8	3.9
Ap	1.9	0.7	0.5	0.8	—	0.7	1.2
Cc	2.5	3.6	0.3	—	—	—	—
Σ Sal	69.7	52.9	53.4	63.6	56.0	54.6	63.9

Table 1. Analyses[1] of diabase dikes and basalts with corresponding molecular norms.[2]

A. Diabase dikes. Oslo region. Average of 11. (W. C. Brøgger, 1933, p. 117.)

B. Diabase dike. Ascutney Mountain, Vermont. Hillebrand analyst. (R. A. Daly, 1903, p. 88.)

C. Basic dikes. Skye and Mull swarms, Great Britain. Average of 5. (Alfred Harker, 1904, and E. B. Bailey, 1924.)

D. Big diabase dike near Muray Mines, Sudbury. Walker analyst. (T. L. Walker, 1897, p. 63.)

E. Diabase dike. Rockport, Essex County. Washington analyst. H. S. Washington, 1899, p. 289.)

F. Plateau basalts. Average of 43. (R. A. Daly, 1933, p. 17.)

G. Basalts. Gough Island and Saint Helena. Average of 8. (Tom F. W. Barth, 1942, and R. A. Daly, 1927.)

[1] All analyses are recalculated as water free.
[2] Ref. Niggli, 1936, and Barth, 1944, pp. 10—13.
[3] Ol probably too high as CO_2 is not determined.
[4] Normative Ol is too high as P_2O_5 and CO_2 are not determined.

I shall now offer for consideration the view that under favourable geological circumstances some of these fissures will extend so far into the depths of the earth's crust as to give way for the eruptible basaltic substratum, and so explain the genesis of the late-magmatic diabase dikes.

In table I I have presented analyses and corresponding molecular norms of diabase dikes from the petrographic provinces mentioned above. For comparison I have added average analyses of plateau basalts (F) and basalts from Gough Island and Saint Helena (G) which should both of them be considered representatives of the basaltic substratum.

It will appear that these rocks demonstrate a high degree of mutual resemblance in support of the hypothesis presented, which, if accepted, will allow us to consider the late-magmatic diabase dikes a natural stage in the evolution of a petrographic province, without necessarily implying their consanguinity with the remaining igneous rocks of the province considered.

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