A West Greenland Globule Dike

By

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Abstract.

A basalt dike, discordantly intruded into a Pre-Cambrian gneiss complex, is described with respect to its petrology and structure. The dike is composed of globules and short columns with mantles and interstitial fillings of tachylyte and sideromelane. Several possible explanations of this structure are discussed.

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Introduction.

During the field work of 1948 of the Geological Survey of Greenland, a dike of considerable extent and remarkable for its globule structure was discovered within the area of crystalline Pre-Cambrian rocks of West Greenland. Basic dikes are otherwise great rarities within the section in question of the West Greenland gneiss complex.

In the first half of the field season, the two southernmost exposures of the globule dike were discovered on the shores of Arferssiorfik Fiord (fig. 1 (7)) immediately west of Sarfartoq (i. e., The Rapids) (fig. 1 (8)), viz., on a small peninsula west of Inugssuk (fig. 1 (6)) on the southern shore of the fiord, and on the south side of Tugtulik Island (fig. 1 (5)) on the northern shore.

Later in the season, several other exposures of a dike were seen striking N.-S. across the peninsula of Tuarqap Inikasia (fig. 1 (4)), on the north and south sides of Nângissat (fig. 1 (3)), in a place a little south of Nivaq and in another place a little northwest of Nivaq (fig. 1 (2)). The last-mentioned occurrences have not been visited but have merely been observed from a motorboat at some distance from the shore. Consequently, nothing can be said about the structure of the dike at these exposures.

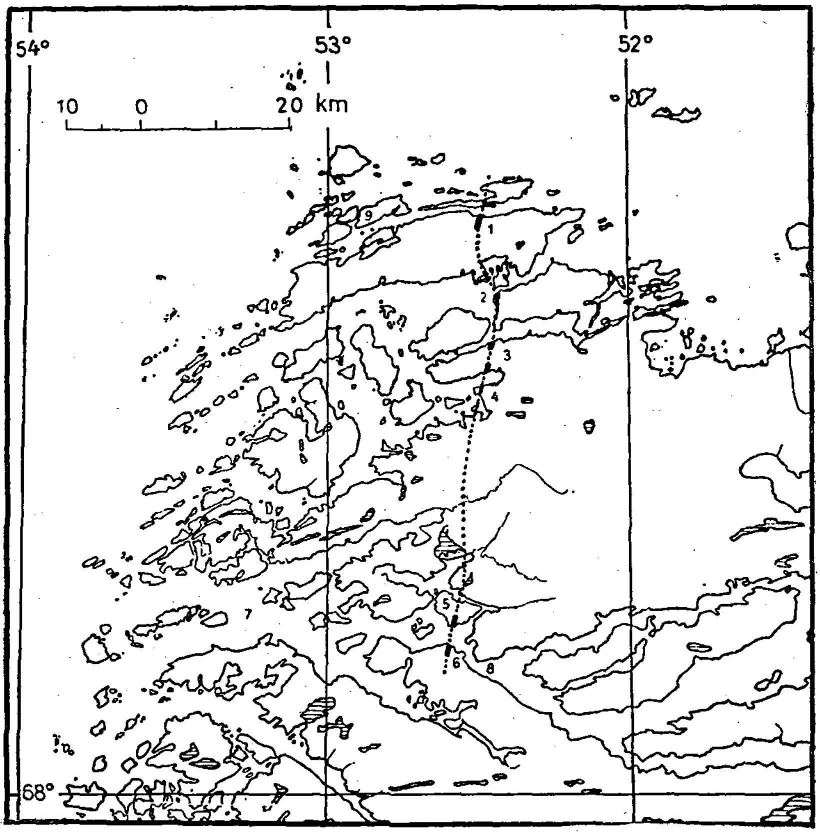

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Fig. 1. Index map of the area in which the globule dike occurs. 1: Langesund. 2: Nivaq. 3: Nângissat. 4: Tuarqap Inikasia. 5: Tugtulik. 7: Arferssiorfik. 8: Sarfartôq. 9: Egedesminde settlement.

In the second half of the field season, one more exposure of a dike was discovered on the south shore of Langesund (Ikerasarssuaq) (fig. 1 (1)). As it will be shown later on, the two exposures farthest north and farthest south are quite identical as to structure and composition. Undoubtedly it is the same dike that is exposed in the two localities. Although no examination has been made of the five other exposures, it may be said with a high degree of certainty that they are connected with the two first-mentioned occurrences. The great rarity of basic dikes in the area speaks in favor of this assumption. The coastal sections are to an unusual degree free of vegetation, and nearly all of them have been passed by boat at very short distances.

If the known exposures are assumed to belong to the same dike, the resultant intrusive body turns out to be of considerable size, the distance between the two extremes being about 58 kilometers.

Fig. 2. Tugtulik. Detail of a multiple globule dike. A small, younger dike (at the hammer head) cuts through the larger, older one. (Phot. K. E.-R.)

The thickness varies somewhat. On Tugtulik it is about 20 meters at the level of the sea, and at Langesund the thickness is probably much more than 50 meters.

At the localities visited, the dike is of a quite remarkable structure. It consists exclusively of spheres or globules of more or less flattened or pointed shapes. Every globule is covered by an aphanitic mantle, and many of them are surrounded by a glossy, black, pitchlike layer of glass. The size of the spheres varies somewhat, but the great majority of them are from 10 to 20 centimeters of diameter (fig. 2). The spheres are not mixed

Fig. 3. Tugtulik. The geologist is standing at a small multiple dike unit having a dense contact. The dike is composed of short columns and globules, one of which is lying on top of the dike. (Phot. K. E.-R.).

Fig. 4. Langesund. Lamellar structure characterized by parallel walls composed of globules with glassy mantles and interstitial material. (Phot. K. E.-R.).

chaotically but are arranged in small "brick walls", which together compose the dike. The individual walls vary in thickness, but the thickness probably never exceeds 1 meter. Such a wall is shown in figure 3. The exposed contact surface is dense, and in a few places it is glassy. One of the structure elements, a globule with its mantle of glass, has been worked free and lies on top of the wall. How the dike is composed of a large number of "brick walls" may be seen in fig. 4. At the exposure on Tugtulik (cfr. fig. 3), one gets the impression of a multiple dike as the first intrusions have been divided by repeated new ones. This impression is confirmed by the dense contact surfaces which coat the "brick walls". In figure 2, a small, younger dike, stretching in the long direction of the picture, may be seen at the hammer head. This dike is composed of a single layer of globules having dense outer shells.

As we are here concerned with an intrusive body built up of spheres or globules with glassy mantles, the term globules is used in stead of pillows, which term refers to extrusive bodies. This is in accordance with the usage by PEACOCK (1926, b) and NOE-NYGAARD (1940), both of whom use the word globular to describe spherical structures in a (subglacial) intrusive body in Iceland.

Petrology.

Under the microscope it is seen that the automorphic plagioclase and pyroxene phenocrysts are suspended in an aphanitic to microcryptocrystalline groundmass. The degree of crystallization of the groundmass is higher at the centers of the globules than in their peripheral parts. Basaltic glass is abundant in the outer layers of the globules, while its occurrence in their central portions is more sparse and scattered.

Table I. Plagioclase determinations in the peripheral portion of a globule. Tugtulik.

Specimen no.[1]		Twin Law[2]	Reinhard An. %.[3]	Angle Values $\alpha\alpha$	$\beta\beta$	$\gamma\gamma$	Low-temp. Opt. An %.[4]			High-temp. Opt. An %.[4]			Avarage of High-temp. Opt. An %.
35046	a	C	60–64 (–)	106	138	60	59	60	66	55	55	58	56.0
–	b	A-M	58–60 (+)										
–	c	C	50 (–)	94	118	52	50	52	56	50	50	46	48.7
–	d	C	45–60 (–)	98	112	65	53	50	73	52	48	68	56.0
–	e	C	60 (–)	102	134	61	55	58	67	53	54	59	55.3
–	f	C	53–58 (–)	99	128	57	53	56	62	52	52	52	52.0
–	g	{ M-A Ala	54–58 (+)										
–	h	A-C	47–58 (–)	85	87	32	49	52	63	50	51	49	50.0
–	i	A-C	54–63 (–)	96	85	34	45	52	65	48	52	53	51.0
–	j	C	52–63 (–)	111	141	58	66	61	64	60	56	54	56.7
										Total average			53.2 = 53.0

It may be seen from Table I that in most cases the results do not agree with the Reinhard curves. Either not all of the indices fall on the curves, or the results are very uncertain. It is quite remarkable that both of the

[1]) The letters a, b, c, etc., designate different phenocrysts.
[2]) C = Carlsbad. A-M = albite-Manebach. M-A = Manebach-acline. A-C = albite-Carlsbad.
[3]) (+) = reasonably good agreement with the curves, (–) = poor agreement.
[4]) Indicates the An-content corresponding to the angle values of $\alpha\alpha$, $\beta\beta$, $\gamma\gamma$.

two complex twins, the albite-Manebach and the Manebach-acline or Ala complexes, agree very well with the curves and give results of satisfactory accuracy. An examination of the values for high- and low-temperature optics shows that the H-values do not vary so much as the L-values. A couple of cases are, however, doubtful. It is, further, seen that the α- and β-values are not of decisive importance to the optical determinations, the large discrepancy falling on the γ-values. This is particularly true of the L-values. Only a single γ-H-value, namely *d*, deviates markedly. The better agreement is, in other words, found among the H-values, and it must therefore be assumed that the plagioclases in the outer layers of the globules in this part of the dike have high-temperature optical properties. It should at the same time be pointed out that zonal structure is absent or developed to a very small degree. In the diagram, an average value of An % has been given according to H. Tertsch (1942) (the values in the other diagrams are quoted from the same author) for the angle values $\alpha\alpha$, $\beta\beta$ and $\gamma\gamma$, valid for high-temperature optics of each single plagioclase. The composition varies between the extreme values of 48.7 and 56.7 % An. The average value of 53 % An corresponds to an acidic labradorite.

The plagioclase phenocrysts at the center of the examined globule in some cases have a marked zonal structure. Crystals occur in which a continuous extinction may be observed from their centers to their peripheries, but in many crystals sharp boundaries exist between their nuclei and their peripheral parts, boundaries that are quite as sharp as those between two individuals of a twin. One gets the impression that an early, interrupted crystallization has been started anew, the old crystals acting as grafting material. A few crystals have been found on which it has been possible to undertake double measurements of the optical properties of their central and outer parts, besides of the An-content.

Table II. Determinations of plagioclase in the central portion of a globule. Tugtulik.

Centers of phenocrysts.

Specimen no.	Twin Law	Reinhard An %.	Angle Values $\alpha\alpha$	$\beta\beta$	$\gamma\gamma$	Low-temp. Opt. An %.			High-temp. Opt. An %.			Average of High-temp. Opt. An %.
35046 k	?	58–60 (−)										
– l	C	64 (+)	113	156	63	—	68	70	—	61	64	62.5
– m	A	64–74 (+)	133	58	78	70	—	71	63	—	64	63.5
– n	A-C											
– o	A-C	97–75 (−)	32	59	45	82	75	86	80	72 (c. 60)		76,0
									Total average			67.3 = 67.0

Peripheries of phenocrysts.

Specimen no.	Twin Law[1]	Reinhard An %.	Angle Values $\alpha\alpha$	$\beta\beta$	$\gamma\gamma$	Low-temp. Opt. An %.			High-temp. Opt. An %.			Average of High-temp. Opt. An %.
35046 k	?	52–54 (+)										
– l	C											
– m	A	53–62 (+)	150	62	70	57	—	64	53	—	56	54.5
– n	A-C	52–55 (−)	82	90	34	50	49	65	50	51	53	51.3
– o	A-C	54–64 (−)	70	78	30	56	55	60	53	54	45	50.7
									Total average			52.2 = 52.0

[1]) A = albite.

The statistical material in Table II is a very slender basis for an evaluation of the conditions. If, however, one considers the only individual, *o*, on which it has been possible to make a complete determination, it may be seen that the L-values for the centers of the plagioclases show better agreement than do the H-values, while on the other hand the agreement with the Reinhard curves is poor. The interpretation of crystal *m* is doubtful, but here the agreement with the Reinhard curves is good. Also crystal *l* is doubtful, but the Reinhard curves may be applied and indicate the same An-content as do the H-values, while the L-values are somewhat higher. It is highly probable that also the centers of the plagioclase phenocrysts have high-temperature optics, corresponding to an An-content of 67 %. It is seen that the peripheral parts of the plagioclases show complete agreement with non-zonal crystals, having an An-content of 52 % and originating from the outer as well as from the central portions of the globule.

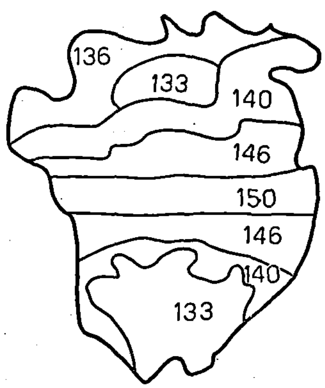

Fig. 5. Center of globule from Tugtulik. Actual length 0.4 millimeter. Showing pyroxene with hourglass-shaped extinction. The figures indicate the values in degrees, read on the microscope table, of the extinction of related zones. (G. G. U. 35046).

The size of the plagioclase phenocrysts as well as that of the plagioclases in the groundmass increase toward the center of the globule. In the peripheral portion, a few of the phenocrysts reach lengths of up to 1 millimeter, though most of them are much shorter. Here the plagioclase laths of the groundmass only reach lengths of 0.05 millimeter. At the center of the globule, a very large number of phenocrysts are of a length of 1 millimeter, while the individuals of the groundmass reach 0.1 millimeter.

In most cases, the cross-sections of the pyroxene phenocrysts are of the order of magnitude of 0.5 millimeter. Twins according to (100) are rather abundant, and zonal structures may commonly be seen. A wawy extinction, which is commonly very marked, is a general character of the pyroxenes, and the phenomenon has possibly been caused by rapid cooling. An hourglass-shaped, strongly irregular extinction is also of very common occurrence (fig. 5). The phenomena of extinction are in many cases so irregular that reliable optical measurements are unobtainable, but at the examination the best available individuals have been selected for measurement.

All measurements have been made on the universal stage, and $\gamma \wedge c$ determinations have been carried out with the aid of the stereographic projection.

Table III. Pyroxene determinations on the outer portion of a globule. Tugtulik.

Specimen no.	Twin Plane	$+2V_\gamma$	$\gamma \wedge c$
35046 d	(100)	I:52 II:50	I:44 II:46
– e	—	54	(39)[1]
– f	(100)	—	I:44 II:46
– g	(100)	I:56 II:—	I:46 II:—
	Average:	53.0	45.2 = 45.0

Table IV. Pyroxene determinations on the center of a globule. Tugtulik.

Specimen no.	Twin Plane	$+2V_\gamma$	$\gamma \wedge c$
35046 a	(100)	I:52 II:54	I:45 II:45
– b	—	56	43
– c	—	53	—
	Average:	53.8 = 54.0	44.3 = 44.0

It is seen from Tables III and IV that the optical conditions in the peripheral portion of the globule are quite identical with those at the center.

The conditions found at Langesund correspond exactly with those, just mentioned. Therefore, only the measured values are tabulated here.

In Table V, the one measurement that has been made on the center of a phenocryst agrees most closely with the low-temperature optics. As the phenocryst is very small and as the transition to the proved high-temperature optics of its outer layer is continuous, the writer has, nevertheless, considered it to be a case of high-temperature optical conditions. There is, moreover, some uncertainty as to the accuracy of the one measurement that has been made. The molecules of the peripheral portions of the plagioclases from Langesund are shown to contain less anorthite by a few percentages than those from Tugtulik.

Table V. Plagioclase determinations on the outer portion of a globule. Langesund.

Centers of phenocrysts.

Specimen no.	Twin Law	Reinhard An %.	Angle Values $\alpha\alpha$ $\beta\beta$ $\gamma\gamma$	Low-temp. Opt. An %.	High-temp. Opt. An %.	Average of High-temp. Opt. An %.
36691 a	C	60 (–)	111 142 56	66 62 61	60 56 51	55.7(=56.0)
– b	M[2])					
– c	C	48–64 (–)				

Peripheries of phenocrysts.

Specimen no.	Twin Law	Reinhard An %.	Angle Values $\alpha\alpha$ $\beta\beta$ $\gamma\gamma$	Low-temp. Opt. An %.	High-temp. Opt. An %.	Average of High-temp. Opt. An %.
36691 a	C	60 (–)	104 133 54	57 58 51	54 54 48	52.0
– b	M[2])		26 118 57	43 45 50	45 44 42	43.7
– c	C	48–64 (–)	102 100 56	43 45 52	45 45 51	47.0
					Total average	47.6 = 48.0

[1]) Plane of reference uncertain.

[2]) M = Manebach. The value of An % of this twin has been given according to VAN DER KAADEN, 1948.

Table VI. Plagioclase determinations on the center of a globule from Langesund.

Outer layers of phenocrysts.

Specimen no.	Twin Law	Reinhard An %.	Angle Values $\alpha\alpha$ $\beta\beta$ $\gamma\gamma$	Low-temp. Opt. An %.	High-temp. Opt. An %.	Average of High-temp. Opt. An %.
36690 a	C	54 (–)	105 132 54	58 58 51	54 53 48	51.7
– b	C	53–64 (–)	91 120 58	49 53 64	49 50 54	51.0
					Total average	51.4 = 51.0

As the centers of the phenocrysts, described in Table VI, rarely are regularly developed in both twin individuals so that it is difficult to reach a definite conclusion as to low- or high-temperature optical conditions, only the An-content has been determined. An acline or Manebach-ala twin turned out to contain about 60 % An, according to the Reinhard method.

Also in this case there is the better agreement between the high-temperature values, which in the case of the outer portions of the plagioclases indicate an An-content of 51 %. Here again, the centers are doubtful as to their optical properties, but if it is possible to base any conclusions on the poor agreement with the Reinhard curves, the figures should indicate high-temperature optics by an An-content of about 60 %.

Table VII. Pyroxene determinations on the outer portion of a globule. Langesund.

Specimen no.	Twin Plane	+ 2 Vγ	$\gamma \wedge c$
36691 a	—	53	—
– b	—	54	46
	Average:	53.5 = 54.0	46,0

In Table VII, complete agreement exists with the corresponding measurements on the Tugtulik globule.

Table VIII. Pyroxene determinations on the center of a globule. Langesund.

Specimen no.	Twin Plane	+ 2 Vγ	$\gamma \wedge c$
36690 a	(100)	I:50 II:—	I:46 II:—
– b	(100)	I:50 II:—	I:46 II:—
	Average:	50.0	46.0

Table IX. Compilation of the average results of measurements on globules from Tugtulik and Langesund.

	Plagioclase				Pyroxen			
	The central part of the globe. An %		The peri. part of the globe. An %		The central part of the globe.		The peri. part of the globe.	
	Ce. plag.	Pe. plag.	Ce. plag.	Pe. plag	+2V	$\gamma \wedge c$	+2V	$\gamma \wedge c$
Tugtulik	67	52	—	53	54	44	53	45
Langesund	ca. 60	51	56	48	50	46	54	46

Frequency of twin laws in plagioclases: C=11. A-C=4. A=1. M=1. A-M=1. M-A, Ala=1.

As all measurements of $\gamma \wedge c$ have been made by construction, the angle has in some cases been tested by means of monochromatic light (blue and red). The extinction angle turned out to be about 1° larger in the case of the blue light than when red light was employed. This identifies the pyroxene in question as an augite. Pleochroism is absent, and the mineral is in all directions of a light yellowish-brown color. The extinction is not always complete.

The figures show that good agreement exists between the two occurrences. In the case of the pyroxenes, the axial angles appear to be a couple of degrees larger in the outer portions than at the centers of the globules. At the centers of the globules, the peripheral plagioclase is constant as it has been developed in place. In the outer layers of the globules, the marginal portions of the plagioclases show a slight divergency, which may be due to local influences during cooling. The divergency of the central plagioclases may be due to the fact that the measurements were carried out on crystals at slightly different stages of development. Hence it must be assumed that the plagioclase of Tugtulik containing 66% An or a still more basic one represents the initial plagioclase. As all plagioclases measured have been phenocrysts, nothing is known about the plagioclases of the groundmass. It is, however, highly probable that these do not disagree much with the phenocrysts as the dike must have cooled very rapidly.

Table X. Geometric measurements on a globule from Tugtulik.

	Outer layer		Center	
	Vol. %.	Wght. %.	Vol. %.	Wght. %.
Opaque, aphanitic to cryptocrystalline groundmass	86.4	86.3	81.8	81.6
Yellowish-green glass	0.1	0.1	0.4	0.3
Plagioclase phenocrysts	8.0	7.3	10.2	9.3
Pyroxene phenocrysts	5.5	6.3	7.6	8.8
	100.0	100.0	100.0	100.0

Specific weight in aqua destill., 20° C. = 2.94, outer layer of globule.
Specific weight in aqua destill., 20° C. = 2.94, center of globule.

It may seem strange that more glass is present at the centers of the globules than in the outer layers (cfr. Table X). The reason is undoubtedly that much glass is hidden in the opaque substance of the outer layers.

The glass material and petrology of the glass mantles.

By the examination of a thin section of a glass mantle from the southern exposure, Tugtulik, a continuous transition could be traced from the finely crystalline center of the globule to the partly translucent glass mantle. Dark, reddish-brown tachylyte bodies with irregular outlines wind through the opaque material. The tachylyte is commonly very slightly anisotropic. A few sections are yellowish green and strongly devitrified. It is a characteristic feature of all the phenocrysts that they are surrounded by an opaque mantle of iron oxides (fig. 6, 1., 2., and 3. quadrant). This mantle must be the result of favorable conditions of oxidation acting in the presence of the pyroxenes. Besides in the outer layers of the globules, glass is also present at their centers. Fig. 7 shows a yellowish-green glass having a refraction slightly less than that of Canada balsam. Several sections of the glass are devitrified and show strong birefringence. The devitrification has penetrated along fissures. Perhaps it is a case of pala-

Fig. 6. Peripheral portion of globule, Langesund. Diameter of section: 2 millimeters. Opaque masses are shown in black. Yellowish-brown tachylyte with a few slightly anisotropic areas is marked by angle symbols. Yellowish-green devitrified anisotropic glass is shown by ruling. The pyroxenes commonly have opaque mantles. (G.G.U. 36691).

gonite formation, but because of the small size of the specimen no sure verdict can be reached. The centers of the glass grains commonly consist of a dark, only slightly translucent, pigmented material, in which distinct radiating crystal skeletons of ore (magnetite!) have grown from the circumference towards the center. At the centers of the globules from Langesund, phenomena quite identical with those, just described, have been observed.

A thin section of a sample from the northern occurrence shows a distinct boundary between a microcrystalline rock and a glass mantle. In this case, the material of the glass mantle is in its outer layers light yellowish-brown, translucent, isotropic, and completely free of ore particles. The refraction of the pure sections having the lightest color is very close to 1.580, and boiling for a short time in concentrated hydrochloric acid does not dissolve the material. The hardness is about 5. The material must thus be a sideromelane, according to Fuller and Peacock (1928). The glass is penetrated by fine fissures and is full of small plagioclase and pyroxene phenocrysts (fig. 8). Along the fissures and in spots the sideromelane has been changed into a palagonite. The palagonite of the purest color, namely dark yellow, occurs along the fissures, while an impure,

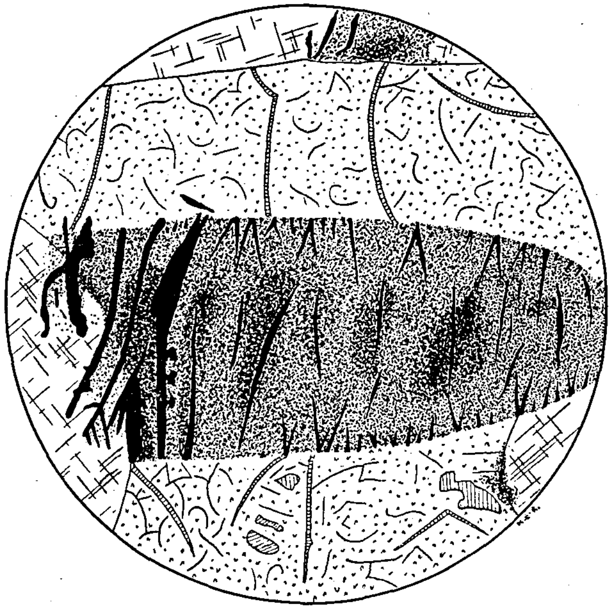

Fig. 7. Center of globule, Tugtulik. Diameter of section: 0.15 millimeter. Showing yellowish-green glass with an opaque-to-slightly-translucent nucleus. The black color is due to the presence of iron ore (magnetite?), which along the edges of the nucleus occurs as crystal skeletons with their long directions at right angle to the edges. The ruled areas are anisotropic sections (palagonite?) in the yellowish-green glass. A few crystal skeletons of iron ore have grown into the plagioclases. (G. G. U. 35046).

yellowish-brown palagonite is present as round spots in the glass. In many cases two zones may be seen within the palagonite spots, each zone with its own refraction, which in both cases is considerably lower than that of the sideromelane, and one zone being darker brown than the other. All of these alteration products are more or less birefringent. The palagonite shows the stronger birefringence along the fissures. In every case, the contact toward the sideromelane is quite distinct. A clear-cut classification of these palagonite varieties into fibro and gel palagonites, as f. inst. that but forth by Peacock (1926), Fuller and Peacock (1928) and Noe-Nygaard (1940), is probably not applicable in the present case. The impure, slightly brownish sections may be interpreted as fibro palagonite, while the pure-yellow isotropic sections should possibly be classified as gel palagonite. The alteration products of varying appearance should probably be regarded as so many stages of the process of palagonitization.

A single pore has turned out to be filled with a zeolite, which because of its small size could not be identified (fig. 8).

Fig. 8. Peripheral portion of globule, Langesund. Diameter of section: 2.5 millimeters. Showing sideromelane (not marked by symbols) with various alteration products. Along the fissures and in round spots may be seen orange-yellow, anisotropic materials (*marked by fine dots*). *Z symbols:* yellow, isotropic material (gel palagonite?). *Crescent symbols:* reddish-brown, anisotropic, irregularly diffused sections. *Cross symbols:* green, isotropic material. *Gamma symbols:* grayish-green, anisotropic material. *Angle symbols:* green, anisotropic material. *Dark areas:* almost opaque sections. The stellate mineral in the fourth quadrant is a secondary zeolite. The largest phenocryst consists of augite. In the lower part of the section, beautiful *fluidal structures may be seen. (G.G.U. 36694).*

Mechanism of intrusion.

Because of its remarkable structure, the globule dike presents a number of problems. Two phenomena are particularly conspicuous: (1) the composition by short columns and globules with aphanitic to glassy tachylyte mantles, which commonly consist of sideromelane, and (2) the subdivision of the intrusive bodies into lamellae parallel to the contacts.

Judging from the available literature, the generally accepted explanation of the formation of sideromelane seems to be that assuming a rapid cooling of a basaltic melt. Another, less prevalent theory, put forth in 1946 by T. EINARSSON, will be discussed later in the paper. If sideromelane can only be formed by a process of rapid cooling in the presence of water, one is forced to assume that water has played a rôle in the formation of the spherical bodies and the sideromelane of the globule dike. It is, however, difficult to determine with certainty where the water came from and how the globules were formed during the process of intrusion. In favor of the theory of rapid cooling speaks, besides the occurrence of sideromelane and the high-temperature optical properties of the plagioclases, the strongly wawy extinction of the pyroxenes, which may be the result of tensions created by precipitous cooling.

Various theories may be maintained with respect to the formation of the globules, f. inst. that of stress acting on a columnar structure created by a normal cooling process, or that of contraction centers formed by rapid cooling, but in the present case where sideromelane has formed outside of the globules, the theories mentioned may be discarded. Water must have been introduced either during the process of intrusion, the most plausible case, or after the intrusion, but how this has happened is, of course, very difficult to determine. In any case, the influx of water has evidently been very considerable, as large amounts of heat energy must have been carried away. How far into depth the globule structure extends is unknown. Neither is anything known about conditions above present sea level as both of the localities examined are situated at the beach, though the highest elevation attained by the dike along its unknown inland course probably lies around 200 meters above s. l. It seems to be beyond reasonable doubt, however, that the globule structure can only have developed at a level that nearly corresponds to the present level of the sea. It is difficult to imagine a large, yawning fissure filled with water, whether it be sea water or fresh water. Such fissures must be physical impossibilities. The presence of a zone of weakness without open spaces is, on the other hand, highly probable, and its strike would coincide completely with the north-south trend of numerous other zones of fracture in the area in question. The following two possibilities would then be present:

(1) A dike has forced its way through a partly open and water-filled fissure. The fissure has had connections upwards to the bottom of a lake or to the sea.

(2) A multiple dike has advanced along a zone of fissures and has steadily widened its openings. The fractured zone may have been the center of a larger, strongly aquiferous zone of fracture.

The first-mentioned assumption is difficult to accept. If a dike forces its way into a water-filled basin, the basalt will flow out onto the bottom of the basin, and the pressure would be too great to permit the penetration by water and the subsequent formation of globules at greater depths in the conduit. In the upper portion of the advancing dike, some pillows with sideromelane would possibly be formed and some of the pillows might become incorporated in the deeper portions of the dike. As will be shown later on, an Eocene age of the dike must be assumed, and large quantities of gneiss must, therefore, have been removed from higher levels after the intrusion has taken place. In other words, the present exposures represent a comparatively deep level of erosion. The large number of globules at this level thus excludes the first of the above-mentioned possibilities as the globules can not conceivably have been carried through a fissure as narrow as the one in question, down to large depths but still at the same level at two exposures lying at a distance of some 60 kilometers from each other.

If the dike, as mentioned, is of Eocene age, the above-mentioned assumption is made still more unlikely for the following reason. As far as we know, the area in which the dike occurs was in Eocene time above the level of the sea. The existence of a lake measuring at least 60 kilometers from south to north, i. e., across the regional strike, and occurring in a mountainous country the relief of which was much higher than it is today, is, however, most unlikely. The assumption of an Eocene age also speaks against a theory of the water being subglacial melt water.

The second of the two above-mentioned possibilities gives a more reasonable explanation of the various cooling phenomena. The dike has been a multiple one. Smaller "dike plates" have in the course of time penetrated into the strongly fissured and aquiferous gneiss complex. A cooling from the sides, as well at larger as at smaller depths, has thereby been possible with ensuing formation of globules and glass through a considerable range of depth. The creation of fissures in the first-intruded dikes, an event which must thus have happened immediately, has given access to water, which has acted on the later dikes. It is natural to assume that a certain amount of movement has taken place along the conduit, both in connection with the formation of the N.-S. trending fissures of the gneiss complex and in connection with the multiple intrusion. Such movements would give a reasonable explanation of the subdivision of the dike into lamellae parallel to its strike. Another phenomenon that appears to support the present explanation of the process of intrusion is the scarcity of vesicles in the rock. In other cases of globule and pillow structures, vesicles are very prominent. When, nevertheless, the vesicular structure is inconspicuous, it must be taken as a sign of a considerable pressure acting upon the dike during its cooling. Such a pressure would have been present if the dike advanced through and widened a zone of weakness in a pre-existing rock.

The strong cooling of the dike, which has penetrated to its very core, must, considering the considerable thickness of the dike, have demanded the carrying away of large amounts of heat. If this transportation has been due to cooling by water of the walls of the dike, the dike must have advanced slowly or the water would not have been able to carry away the necessary amounts of heat energy. Such a cooling mechanism would fit in with the theory of a multiple intrusion[1]).

[1]) As the observations in the field unfortunately were few and hasty, and as the dike was only rather accidentally chosen as the subject of investigation several years after the completion of the field work, additional field observations are needed in order to verify the theory of a multiple intrusion.

Whether the water carried into the zone of crushing has been of marine or of limnic origin is, as mentioned, very difficult to decide. The possibility that the water has not been salt water is, however, the more probable one. The water may even have been ordinary ground-water, which in this case has had ideal possibilities of access. Had sea water been active, it appears strange, in view of the large amounts of glass, which again presupposes considerable quantities of water, that no tendency toward the formation of spilites is discernible in the dike rock.

Though the last-mentioned explanation of the mechanism of intrusion and cooling sounds more plausible than the first one, it is by no means sufficient. It appears unlikely that the access of water to such a large dike over such a considerable distance should have been as good as the theory demands. As the dike is probably of Eocene age, the amount of material eroded away since then may have been quite considerable, and the present exposures may well be 2–3 kilometers below the surface of the ground as it was in Eocene time. It is difficult to imagine a fractured zone being strongly aquiferous at such a great depth, and introduction of water from a spring at the surface is probably out of the question. If the formation of sideromelane is due to the cooling effect of water, the amount of water present must, as mentioned, be assumed to have been very large, particularly if one considers that glass occurs in the center of the dike, in many cases 20–30 meters from the wall rock. In short, one must conclude that numerous favorable factors have worked towards the same goal, and that the above-mentioned explanation is an insufficient one. It would then be tempting to assume that the phenomena of short columns, globules, tachylyte, and sideromelane have originated *in situ* without the influence of outside factors.

With respect to this interpretation, the writer wishes to refer to a theory for the origin of glass in the palagonite formation of Iceland, put forth by T. Einarsson in 1944 (publ. 1946). Einarsson is of the opinion that the glass in the palagonite formation has not originated through rapid cooling in the presence of water, as previously assumed by several geologists, as f. inst. Peacock (1926 a) and Noe-Nygaard (1940), but that the ability to solidify as a glass is a primary property of a highly viscous magma which contains water, is of low temperature and stands under a high pressure. Einarsson maintains that formation of glass occurs in a molten magma that is so viscous that no crystallization can take place. The transportation of the glassy material from the magma chamber to the surface should, according to Einarsson, have taken place by explosive eruptions through which the pressure was released with concomitant liberation of vapors, the vapors carrying the glassy material with them. The formation of tachylyte and sideromelane is not explained as being due to moderate and rapid cooling, respectively, but as being the result of slow cooling. Einarsson further thinks that the presence of magnetite in the tachylyte is due to certain processes of oxidation, processes which have not affected the sideromelane, which is free of magnetite.

If Einarsson's theory is applied to the globule dike, two possibilities may be thought of: (1) A magma having the properties, mentioned above, and being in a state of initial crystallization, has been intruded under high pressure. If this be true, one would expect a completely chaotic mixture of crystalline and non-crystalline material. This possibility can thus be excluded. (2) The formation of globules and glassy material has taken place *in situ* after the intrusion. As the glass fills the interstices between the columns and globules, one is forced to assume that the present structure of the dike existed already before complete solidification had been attained. Solidification must then have started around centers of crystallization, but during the fall in temperature the glassy material has not had time to crystallize because of its high viscosity. According to this interpretation, slow, not rapid, cooling should have been the cause of the formation of glass. The circumstance that automorphic phenocrysts of plagioclase are present in the glassy material might also be regarded as a support of the theory of a slow process of cooling. As emphasized by EINARSSON, the difference between tachylyte and sideromelane may be due to different conditions of oxidation, an explanation which, of course, may also apply to the present dike material. As the rock is completely without pores, the pressure does not seem to have been released, and it is thus unlikely that the dike has ever penetrated to the surface. Fluidal structures in the glassy material may possibly have been caused by movements taking place in the dike during the formation of the parallel lamellae.

Also this interpretation has, however, inherent weaknesses. Thus, it does not explain the warped extinction figures in the pyroxenes. It is also difficult to understand how a highly viscous magma could be involved in a process of multiple intrusion, particularly because some of the intrusions are very small (fig. 2). It is, further, difficult to accept an initial crystallization around nuclei with a following peripheral segregation of glass, not least because the glassy material commonly forms thin mantles with distinct boundaries towards the crystalline nuclei. The high-temperature plagioclases are of minor importance in this connection as no definite figures are on hand. The same is true of the conditions of viscosity as far as the mechanism of intrusion is concerned.

A final conclusion as to the mechanism of intrusion and the general character of the globule dike can hardly be arrived at on the basis of the few field observations on hand. There are, however, phenomena which speak in favor of applying T. EINARSSON's theory of segregation of glass during a process of slow cooling to this remarkable globule dike, but many more field observations must be secured in that remote region of West Greenland before the problem can be solved.

Time of intrusion.

The thought lies close at hand of connecting a basic dike, occurring in a region where such dikes are very rare, with the near-by complexes of plateau basalts of Disko, Nugssuaq and Svartenhuk, the southern limit of which lies only some 50 kilometers north of our dike. According to NOE-NYGAARD (1942), the conduits of these large complexes have probably been fissures trending north-south, i. e., in the same direction as the globule dike. This agreement as to trend may, of course, be purely accidental, and not too much weight should be placed on it, but on the other hand one should remember that the globule dike represents a fissure at least 60 kilometers long. The absence of olivine from the materials of the globule dike corresponds to what one finds in the youngest extrusive members of the basalt sequence (NIELAND, 1931, and NOE-NYGAARD, 1942). The fact that the glassy mantles have not become devitrified points toward a young age of the dike. Furthermore, the Eocene basalts constitute the only trace of volcanic activity in the neighborhood of our area. Only in South and North Greenland does one find basic intrusives of similar compositions, and these intrusives are, moreover, supposedly of Paleozoic or Pre-Cambrian age and generally somewhat altered. In short, a great many things point toward a close connection between our globule dike and the complex of plateau basalts, which would mean that the dike is of Eocene age.

RESUMÉ

I sommeren 1948 fandtes under Grønlands Geologiske Undersøgelses arbejde paa Grønlands vestkyst (fig. 1) en n-s-strygende basaltisk globulardyke. Dyken er diskordant med strukturen i det omgivende gnejskompleks og lodretstaaende, samt har en minimumslængde paa ca. 60 km. Dyken opbygges af en række lamelzoner parallelt med kontakten (fig. 4). Hver af disse lamelzoner, der er murværklignende, sammensættes atter af afstumpede korte søjler og kugler, der i mange tilfælde har glaskappe eller glasmellemmasse (fig. 2). Lamelopdelingsstrukturen understreges yderligere af multipel intrusionsmekanik (fig. 3). I hvor udstrakt grad, der er tale om multiple intrusioner, hersker der dog stor usikkerhed om.

Plagioklaserne i den basaltiske dykebjergart er labrador med højtemperaturoptik. Maaleresultaterne er hensat i tabel IX, af hvilket skema pyroxenmaalingerne ogsaa kan aflæses. Augitindividerne har ofte uregelmæssig timeglasstruktur (fig. 5), og undertiden er de »mekanisk« deformerede, hvilket menes frembragt ved spændinger i bjergarten under dennes afkøling. Glasmaterialet paa kuglernes og søjlernes overflader er tachylyt (fig. 6) og sideromelan (fig. 8). Det sidste er noget palagonitiseret. Den mineralogiske sammensætning er ganske identisk i begge ender af dyken, det samme gælder storstrukturen.

Ud fra de i øjeblikket herskende teorier om basaltisk glasdannelse diskuteres dykens strukturudformning. Den i almindelighed herskende opfattelse for glasdannelse af basaltisk smelte er en hastig afkøling ved vands medvirken. Anlægges denne teori paa globulardyken, menes globularstrukturen at være opstaaet ved vands afkølende effekt fra dykens sider over horisontal og vertikal udstrækning. Vandet tænkes tilført gennem en opknusningszone og borttransporten af varme menes lettet ved, at dyken langsomt med multiple intrusioner har udkilet intrusionsspalten. Opspaltning af de ældste intrusioner har lettet vandtilførslen til de yngste med central beliggenhed i dyken. Den mulighed, at det kan dreje sig om vand tilført spalten enten fra en hav- eller søbund under dykens fremtrængen til denne, usandsynliggøres. Det samme gælder for vand tilført fra en subglacial opsmeltning. Om oprindelsen af det eventuelle vand, der har været aktivt afkølende fra siderne i spalten, er det vanskeligt at sige noget sikkert. Det maa dog have været ferskvand, da der ikke er fundet spilittendens i bjergarten. En anden og mindre udbredt opfattelse m. h. t. glasdannelse er i 1946 fremsat af T. EINARSSON, der mener, at dette er dannet ved langsom afkøling, med primær aarsag i et højviskost, vandholdigt magma under højt tryk ved lav temperatur. Anlægges dette synspunkt paa dykestrukturen, maa denne være udformet *in situ* af et magma med ovennævnte egenskaber. Ingen af de iagttagne egenskaber taler absolut imod denne forklaring. Da der imidlertid mangler mere indgaaende feltiagttagelser, er en endelig tolkning næppe mulig.

Alderen for intrusionen henlægges til Eocæn. Der synes at være overensstemmelse mellem dykens mineralogiske sammensætning og nogle af de yngste extrusivled i det vestgrønlandske plateaubasaltkompleks lige nord for dyken. Det drejer sig saaledes muligvis om en perifer tilførselskanal, der maaske aldrig har naaet jordens overflade. En saadan antagelse støttes ogsaa af det forhold, at hovedudbrudsspalterne i basaltkomplekset (Noe-Nygaard 1942) menes at forløbe nord-syd ligesom omtalte globulardyke.

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