

SOGGENDALITE (C. F. KOLDERUP), A SPOROPHITIC DOLERITE

BY
PAUL ANTUN

In his paper on the anorthosites of Egersund (SW-Norway), C. F. KOLDERUP (1896, pp. 152—159) has given a short petrographic description of the dolerite dikes dissecting the Precambrian basement of that region. He distinguished normal dolerites, so-called bronzite-dolerites, olivine-dolerites and, finally, a rock-type called diabase-pyroxenite or soggendalite.

KOLDERUP claimed that this soggendalite differed from the other dolerites by two facts: First, the rock does not have a "typical diabase structure", i.e., there is no continuous meshwork of plagioclase laths. Secondly, the rock was said to consist mainly of clear-red augite in large and allotriomorphic individuals, and of ilmenite, the other components being plagioclase in the form of small laths and a trifle of biotite and apatite. No modal or chemical analysis was given to support the description, but the features of the rock were well illustrated by a pen-drawing after a thin section (KOLDERUP, 1896, Pl. II, fig. 1). To indicate its parental relationship to diabase, as well as its richness in augite, the rock was, first, termed diabase-pyroxenite. But, since pyroxenite is reserved to abyssal rocks, KOLDERUP proposed to name it soggendalite, after the township crossed by the dike.

It appears that the term soggendalite has never been used in petrographical practice since it was created, but it survives, nevertheless, in several important textbooks: According to A. HOLMES (1920, p. 212), it is a meladolerite rich in augite. A. JOHANNSEN (1937, p. 332) uses the description of Kolderup and places soggendalite under the heading meladiabase. More recently, E. E. WAHLSTROM (1947, pp. 315, 318)

expressed the suspicion that soggedalite might be a gabbro lamprophyre.

As shown below, soggedalite is, in fact, a normal dolerite with sporophitic texture.

Description of the Soggedal dolerite

The almost vertical Soggedal-dike stretches in a general ESE direction from Odden, where it crops out on the shore of the North Sea with a maximum thickness of 30 meters, to a point east of Lundevatn, some 35 km from Odden, where it pinches out. The massive, grey rock is uniform in macroscopic and microscopic appearance over the whole length of the dike. In hand specimens, it is characterized by the spot-like distribution of equant, dark pyroxene grains, one to two mm across, in a lighter feldspathic matrix. The distance between individual pyroxene spots is about equal to their own diameter.

The rock is composed of plagioclase, augite, olivine, ores and subordinate alkali-feldspar, biotite, apatite, and quartz in the following proportions:

TABLE 1.
Modal composition of the Soggedal dolerite
Volume %

	Nr 756 h	Nr 832	Nr 108	A.
Plagioclase and				
Alkali-Feldspar	64.7	66.6	60.7	60.4
Augite	24.2	19.9	21.7	36.2
Olivine	5.8	6.8	9.5	
Ore	3.9	4.6	3.5	3.4
Apatite	1.0	1.0	1.0	
Biotite	tr.	0.6	2.1	
Quartz	0.4	0.5	1.5	

Specimen No. 756 h from the center of the dike at Odden.

» No. 832 » » » » » at Soggedal.

» No. 108 » » » » » at Elve.

A = Point-counter analysis of drawing Pl. II, fig. 2 in KOLDERUP.

A chemical analysis of specimen No. 108 gave the results listed in Table 2.

TABLE 2.

Chemical Composition of Soggendal dolerite (specimen 108).

	Weight %	Mol. Prop.	Cation %	NORM C.I.P.W.										
SiO ₂	49.86	831	47.60	q 0,04 or 5.00										
TiO ₂	2.37	30	1.72	ab 26.78 an 24.44	Sal 56.26									
Al ₂ O ₃	15.13	148	16.79	di 14.26	<table border="0"> <tr> <td>{</td> <td>CaSiO₃</td> <td>7.26</td> </tr> <tr> <td>{</td> <td>MgSiO₃</td> <td>3.94</td> </tr> <tr> <td>{</td> <td>FeSiO₃</td> <td>3.06</td> </tr> </table>	{	CaSiO ₃	7.26	{	MgSiO ₃	3.94	{	FeSiO ₃	3.06
{	CaSiO ₃	7.26												
{	MgSiO ₃	3.94												
{	FeSiO ₃	3.06												
Fe ₂ O ₃	2.04	13	1.49	hy 18.89	<table border="0"> <tr> <td>{</td> <td>MgSiO₃</td> <td>10.61</td> </tr> <tr> <td>{</td> <td>FeSiO₃</td> <td>8.28</td> </tr> </table>	{	MgSiO ₃	10.61	{	FeSiO ₃	8.28			
{	MgSiO ₃	10.61												
{	FeSiO ₃	8.28												
FeO	9.05	126	7.22	mt 2.97										
MnO	0.20	3	0,17	il 4.56										
MgO	5.82	144	8,25	ap 1.15	Fem 41.83									
CaO	9.08	162	9.28		+ H ₂ O 2.13									
Na ₂ O	3.17	51	5.85	III,5,3,4,(5) Camptonose (Ornose)	100.32									
K ₂ O	0.84	9	1.03	Mol or/ab/an = 8,65/49.1/42.25										
P ₂ O ₅	0.50	3,5	0.40	Mol ab/an = 53.75/46.25										
				Mol FeSiO ³ /MgSiO ³ = 37.12/62.88										
H ₂ O(+)	1.98			NIGGLI VALUES										
H ₂ O(-)	0.25			al 22.2	si 124									
Sum	100.29		100.00	fm 44.6	k 0.15									
DENSITY = 2,975				c 24.2	mg 0.48									
Analyst P. ANTUN				alk 9. —	c/fm 0.54									

As is immediately seen from tables Nos. 1 and 2, the rock of the Soggendal dike is not meladolerite. On the contrary, for an aphyric rock it is rather somewhat high in feldspar if we compare it with the micrometric data of a considerable number of olivine dolerites and tholeites furnished by F. Walker (1957, pp. 8, 11).

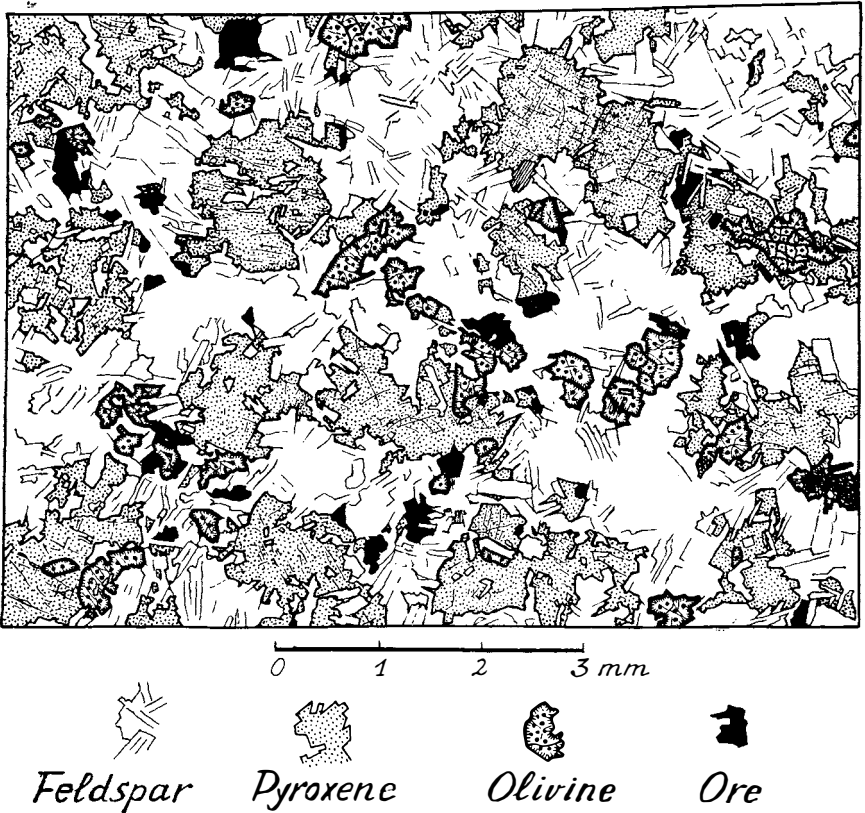


Fig. 1. Soggedal dolerite. Specimen 756 h. Dike-center. The drawing shows the segregation of the early tiny plagioclase laths into feldspatic areas, where they are cemented by their own acid rims. The late, massive pyroxenes form sporophitic grains.

As mentioned above, the plagioclases form a considerable number of relatively small plates throughout the dike. The crystals are always strongly zoned and the anorthite content decreases from 67% in the cores to 25% in the most acid rims. Since the cores are everywhere of the same composition, they must have been precipitated at about the same moment. This, in turn, implies that the magma became strongly oversaturated in feldspar during a small cooling interval.

The olivine (45% mol Fa. $-X=1$, 720, $Y=1$, 753, $-2V = 76^\circ$) began to crystallize shortly after the basic plagioclase. It is seen associated in small microphenocrysts (0,3 mm) to the microporphyritic

feldspar laths of the chilled border rocks. In the central parts of the dike, the olivine forms hypidiomorphic grains which may occasionally grow into pore spaces of adjacent plagioclase tablets and which may sometimes include entirely such tablets. The latter are then always very small. As is often the case in dolerites, the olivine is relatively more abundant in the feldspathic, than in the pyroxenic areas of the rock. It may, however, be completely surrounded by augite.

The pyroxene assumes the form of coarse monocrystalline grains, one to two mm in diameter, i.e., three to seven times the length of the plagioclase crystals. The cores are pink, the intensity of the color increasing towards the rims. Simultaneously, $2V$ (+ in OIO) decreases from $42,5^\circ$ in the cores to 38° in the rim. The plates often include small basic plagioclase laths and on their borders, they are ophitic.

The ore is formed of titanomagnetite and of ilmenite. Especially the latter may show ophitic growth. Minute specks of pyrrhotite and chalcopyrite are here and there attached to the oxides.

In the feldspathic areas of the rock, the pores between the plagioclase laths are occupied by larger acid rims and by alkali-feldspar and a trifle of quartz, both pierced by slender apatite needles. Biotite, chlorite a.s.o. are in part late autometamorphic products.

Genesis of sporophitic texture

If the foregoing description tells us the general course of the crystallization, it is, nevertheless, not very explicit concerning the genesis of the texture. As indicated, the latter is somewhat special because of the strong segregation of the components into feldspathic and pyroxenic areas and it is typically sporophitic (F. WALKER, 1957, p. 2).

In the writers opinion, this segregation is governed by the following factors:

- (1) Attention is first called to the fact that some differentiation is brought about in nearly all doleritic rocks carrying olivine because of the tendency of the first crystalline phases, plagioclase and olivine, to cluster together in the liquid. This is easily seen in chilled rocks, where the microphenocrysts are sharply set against the groundmass, but it can still be seen in the more equigranular central rocks, where olivine is often more abundant in the plagioclastic, than in the pyroxenic areas.

(2) A second important factor causing segregation is the differential diffusion of the magma-components to already existing crystallization centers. This operates, of course, in every crystallization process and it leads to greater heterogeneity only when, as a consequence of the composition of the liquid, as well as of the kinetics of the crystallization, one solid phase takes systematically greater dimensions than other phases. Be this particular phase an early precipitating mineral, it then takes the form of porphyric grains. Be it a mineral appearing only later in the solidification process, it must grow in the spaces between already existing crystals as is the case of pyroxene in ophitic dolerites. Now, this peculiar growth-form of pyroxene, on which attention is readily centered, causes a segregation which is not so apparent and which is easily overlooked. It consists in the fact, displayed in the writer's experience by the great majority of ophitic dolerites, that the ophitic pyroxene is not continuous through the meshwork of earlier plagioclase laths, but that pyroxenic areas have their counterpart in other areas, where the pores of the basic feldspar laths are cemented by acid plagioclase, and alkali-feldspar. As these are oriented on the older laths, they do not call attention. It may suffice here to stress the reality of the segregation thus brought about, without entering into a discussion of the relative quantity of the coprecipitated feldspar and pyroxene.

(3) Pursuing in this line of thought, we may then characterize the sporophitic texture not, by insisting unilaterally on the concentration of augite in massive individuals, but by calling the attention as well to the fact that here, the plagioclase meshwork is discontinuous. Not only are the acid plagioclase and the alkali-feldspar segregated from the pyroxene-filled pores, but the earlier plagioclase laths themselves are concentrated, together with the later feldspar, in areas apart from the massive pyroxene plates.

That there is no question of early formed pyroxene causing this segregations is obvious from the descriptions given above. Plagioclase was the first solid phase and a necessary premise to its later concentration is, that the laths, already formed when augite started its precipitation, were small enough and had such a form that they could freely move in the remaining melt.

In the case of the Soggendal dolerite, the great number of seeds of basic plagioclase throughout the dyke indicates that undercooling

of the melt played a part in the formation of the small feldspar laths. The composition of this magma, expressed in molecules of An, Ab, Hy and Di is such that, in the corresponding system, it lies in the plagioclase field, but close to the cotectic plane plagioclase-pyroxene as defined by T. BARTH (1936, pp. 328—334), $f(\text{Ab}' + 2\text{Di}' + 2, 3\text{Hy}')$ being 117 as against 123 for the plane in question. Furthermore, a look at experimental data shows that this system should crystallize in a range of temperature not greater than 100°C . Pronounced undercooling in this magma devoid of phenocrysts could thus originate by a limited drop in temperature.

The massive plagioclase crystallization starting suddenly through the dike must have caused a slow-down of the cooling-rate so that, when pyroxene came into being, it formed only a few seeds able of rapid growth. The plagioclase tablets, remaining free to move, were trapped in a limited amount only by the augites. Instead, they were fixed and cemented together in areas apart, where the local melt was oversaturated in feldspar because of the continuous diffusion of augite components towards a few distant crystallization centers.

Chemical composition played thus certainly a part in the genesis of the sporophitic texture. It may, however, be added that, in the marginal rocks, the plagioclase assumes more elongated forms and had not the time to concentrate, so that the augite becomes more and more dissected by feldspar-laths, the whole texture changing thus from the sporophitic type to a more normal ophitic variety. Such changes of texture are quite common in the Egersund dolerite dikes because the relative crystallization velocities and the resulting crystallographic habits of the different components do not vary in the same sense with varying cooling rates. Chemical composition alone cannot explain the wide variety of textures.

In conclusion, it may be repeated that the dolerite of the Soggendal dike is neither of an exceptional composition, nor of an exceptional texture. It is therefore recommended to discard the term *soggendalite*.

REFERENCES.

- BARTH, T., 1936. The crystallization process of basalt. — *Am. J. Sc.* 5th ser., vol. 31.
- JOHANNESSEN, A., 1937. A descriptive petrography of the igneous rocks. Vol. III. Chicago.
- HOLMES, A., 1920. The nomenclature of petrology. London.
- KOLDERUP, C.F., 1896. Die Labradorfelse des westlichen Norwegens I.-Bergens Mus. Aarbok.
- WAHLSTROM, E.E., 1947. *Igneous minerals and rocks*. New York.
- WALKER, F., 1957. Ophitic texture and basaltic crystallization. *J. of Geol.*, vol. 65.

Manuscript received March 19, 1962.

Printed September 1962