ZIRCONS FROM SOME METAMORPHIC ROCKS IN THE STAVANGER AREA (SOUTHERN NORWAY)

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Abstract: Albite-porphyroblasts-schists and feldspar-rich gneisses in the Stavanger area contain more and bigger zircon crystals than the surrounding phyllites. This indicates that the feldspar bearing rocks did not originate through metasomatism of phyllites, but that they were formed from more coarse grained sediments with higher silica and sodium contents than the phyllites.

It is supposed that zircon crystals are not or but slightly affected by metamorphism (POLDERVAART & V. BACKSTRÖM 1950). Therefore zircon grains in metamorphic rocks may give valuable information concerning the original material from which the rocks in question were formed (see e.g. PRESTON 1954; ECKELMANN & KULP 1956; VERSPYCK 1960; KALSBEEK 1962). The present author studied the zircons from a number of metamorphic rocks from the Stavanger area to test the hypothesis of GOLDSCHMIDT (1921) that the feldspar-rich rocks in the area developed through metasomatism of phyllites.

According to GOLDSCHMIDT (l.c.), influx of silica and sodium during metamorphism changed phyllites through biotite-garnet-schists and albite-porphyroblasts-schists into feldspar-rich gneisses. Table I lists the chemical composition of these rocks, recalculated to 100 % and omitting SO_2, H_2O etc. As shown in table II, a same type of variation in chemical composition may be due to differences in the original sediments, e.g. due to differences in grain size. Table II gives the chemical composition of average shale (a), average graywacke (b) and different layers of a varved clay: winter clay (c) and summer silt (d).

It is seen that the phyllites from the Stavanger area are chemically

Table I.

	I	II	III	IV	V	VI	VII
SiO_2	61.4	60.2	62.5	64.3	65.7	66.4	67.0
TiO_2 ...	1.0	1.0	0.8	0.8	0.7	0.6	0.6
Al_2O_3 ...	21.0	21.7	19.1	16.8	16.9	15.9	15.0
Fe_2O_3 ..	2.1	2.5	1.4	1.5	2.3	1.4	1.9
FeO	5.3	5.8	5.8	6.0	4.0	4.3	4.0
MnO ...	0.2	0.4	0.1	0.4	0.1	0.1	0.1
MgO ...	2.0	1.9	2.5	2.3	2.1	1.5	0.7
CaO	0.7	0.4	1.7	2.1	2.1	3.0	1.8
Na_2O ...	1.3	1.5	1.9	2.4	2.0	3.2	3.3
K_2O	4.7	4.5	4.1	3.3	3.9	3.5	5.5
P_2O_5 ...	0.2	0.1	0.1	0.2	0.2	0.2	0.1

Tab. I: Chemical composition of metamorphic rocks from the Stavanger area after GOLDSCHMIDT (1921). The analyses have been recalculated to 100%. BaO, CO_2, S, H_2O, C, Cr_2O_3 and V_2O_3 have been omitted.

I 18 quartz-muscovite-chlorite-phyllites.
II 8 quartz-muscovite-chlorite-garnet-phyllites.
III 1 quartz-muscovite-biotite-garnet-phyllite.
IV 6 brown quartz-muscovite-biotite-garnet-schists.
V 4 gray quartz-muscovite-biotite-garnet-schists.
VI 6 albite-porphyroblasts-schists.
VII 1 augengneiss, rich in mica.

comparable with average shale. More coarse grained sediments tend to be more rich in silica and sodium than shales. An alternative hypothesis to explain the higher silica and sodium contents in the feldspar-rich rocks may thus be that these rocks did not derive from shales by metasomatism, but from more coarse grained sediments by a more or less isochemical metamorphism.

Fig. 1 shows the localities where samples for zircon concentration have been collected, plotted on the geological map of the Stavanger peninsula. Table III lists the statistical data concerning size, shape and amount of zircons from the investigated rocks.

It is seen that the zircons found in the phyllites are relatively small. Further the phyllite zircons have a relatively stubby shape. Finally, the phyllites generally contain very little zircon. The higher metamorphic, feldspar-rich, rocks generally contain more and larger and more elongate zircons.

Table II.

	a	*b*	*c*	*d*
SiO_2	63.9	→ 67.4	55.3	→ 61.8
TiO_2	0.7	0.5	1.2	1.3
Al_2O_3	16.9	15.4	21.1	16.8
Fe_2O_3	4.4	1.6	7.1	4.5
FeO	2.7	4.1	2.8	3.4
MnO	—	0.1	0.1	0.1
MgO	2.7	2.3	4.1	3.3
CaO	3.4	3.2	1.6	2.6
Na_2O	1.4	→ 3.2	2.0	→ 4.0
K_2O	3.6	2.0	4.4	2.1
P_2O_5	0.2	0.2	0.2	0.2

Tab. II: Chemical composition of some sediments.
a) average shale after CLARKE, 1924 (PETTIJOHN, 1957 Tab. 61 A, pag. 344).
b) average graywacke (PETTIJOHN l.c. Tab. 52 A, pag. 307).
c) winter clay, varved clay, Leppakosi, Finland,
d) summer silt, belonging to c.
c and d after ESKOLA, 1932 (PETTIJOHN l.c. Tab. 62 A and B, pag. 345).

To test the significance of these differences Wilcoxon's two-sample test has been applied. The test has been used to compare the zircon data from the phyllites (No.'s 16, 17, 18, 19, 34, 21) with those from the rocks which could be supposed to have developed through metasomatism of phyllites (No.'s 22, 23, 24, 27, 28, 29, 30, 31). Two quartzitic rocks (No.'s 32 and 33) have been excluded from the tests, since it can hardly be assumed that they were formed from phyllites. Wilcoxon's two-sample test involves the calculation of a test statistic W. To find W for $\bar{I}$, one must note for every phyllite the number of feldspar bearing samples with a lower or equal $\bar{I}$. The sum of these numbers for all of the phyllites equals W. The lower the value of W, the smaller is the probability that the phyllites and the feldspar bearing rocks are in reality not different in their values of $\bar{I}$, and that the apparent differences are obtained by accident. Statistical text-books (e.g. VAN DER WAERDEN 1957) give tables in which is shown how big the probability is, to find a certain value for W just by accident. A comparison of 6 phyllites with 8 feldspar bearing rocks shows that for $\bar{I}$, $W = 1$. Statistical tables indicate that the probability to get such a low value by accident, P = 0.2 %. In table III the values for W (together with the numbers of values which have been compared) and for P have been given for the listed zircon data.

Size. There is more than 99 % chance that the mean length, $\bar{l}$, of the zircons in the phyllites is really lower than that of the other rocks. There is 97 % chance that the two rock groups differ in the median value of the length, l_{50}, and there is about 99 % chance that their values for l_{90} are different. We may thus state that the zircons in the feldspar bearing rocks are definitely larger than those in the phyllites.

Elongation. There is approx. 95 % chance that the zircons in the phyllites are really less elongate than those in the other rocks.

Number. There is more than 99 % chance that the feldspar bearing rocks contain really more zircon crystals than the phyllites.

Now there does not exist a clear relation between the size, the elongation and the amount of zircons in the different samples. In no. 21, e.g., a low value for $\bar{l}$ goes together with a rather high value for $\bar{l}/\bar{b}$; in no. 17 a relatively high $\bar{l}$ and l_{50} occur together with a low N; in no. 16 a fairly high N is combined with a low $\bar{l}$. Therefore, the combined chance that the zircons in both rock groups are in reality equal, and that just by accident we found both more, and larger, and more elongate zircons in the feldspar-rich rocks, is negligible.

Two explanations for these differences in the zircon content of the two rock groups may be forwarded:

1) Together with silica and sodium also zirconium has been added to the original phyllites.
2) The more silica and sodium rich rocks did not form from phyllites, but from other sediments which did contain more and bigger zircon crystals.

There are several reasons to reject the first explanation. The zircons in the feldspar bearing rocks have all the characteristics of a sedimentary origin. Most of them are well rounded, but a number of them have irregular shapes. Further the investigated zircon concentrates are often not homogeneous; one and the same sample may contain different types of zircon grains, e.g. clear ones and metamict ones. Finally, it is known that zircon is a very stable mineral during metamorphism, and it is very improbable that zircon could be formed during the rather low-grade metamorphism (greenschist-

Table III.

	rock-type	$\bar{l}$	l_{50}	l_{90}	$\bar{l}/\bar{b}$	N
		mm	mm	mm		
112 016	phyllite	0.054	0.049	0.071	1.60	3,800
17	—	0.075	0.070	0.113	1.54	70
18	—	0.054	0.048	0.073	1.55	160
19	—	0.060	0.049	0.087	1.61	25
34	—	(0.069)	—	—	(1.32)	15
21	garnet-phyllite...........	0.045	0.040	0.062	1.70	1,200
24	garnet-schist	0.075	0.068	0.100	1.61	15,500
22	albite-porph.-schist.......	0.079	0.070	0.125	1.67	7,900
23	—	0.101	0.093	0.147	1.64	500
27	—	0.080	0.072	0.132	1.78	20,000
28	light coloured gneiss	0.076	0.069	0.106	1.57	20,000
29	—	0.077	0.069	0.104	1.62	4,300
30	—	0.088	0.082	0.121	1.85	2.200
31	—	0.077	0.067	0.116	1.71	11,600
32	muscovite-quartzite	0.113	0.102	0.157	1.57	2,700
33	quartzite................	0.120	0.116	0.178	1.54	600
	W =	1(8/6)	5(8/5)	3(8/5)	8(8/6)	3(8/6)
	P =	0.2‰	3%	1%	4.3%	0.5%

Tab. III: Statistical data on zircon grains separated from metamorphic rocks from the Stavanger area. $\bar{l}$, l_{50} and l_{90} relate to the size of the zircons, $\bar{l}/\bar{b}$ relates to the shape, and N to the amount of zircon crystals in the different rocks. The data concerning length and breadth are based on the measurement of approx. 200 grains per sample, if the concentrates contained enough crystals. The small number of crystals in no. 34 permitted only rough estimates of $\bar{l}$ and $\bar{l}/\bar{b}$.

$\bar{l}$: mean (= average) length.

l_{50}: median length. 50% of the measured grains have a smaller, 50% have a bigger length.

l_{90}: 90 % of the measured grains have a smaller, 10 % have a bigger length than this value.

$\bar{l}/\bar{b}$: ratio between mean length and mean breadth of the measured crystals; a measure for the elongation of the grains.

N: estimated number of zircon crystals per 100 gram of rock sample.

W: test statistic (see text) calculated to decide whether there exist significant differences between the zircons of 8 feldspar bearing rocks and those of 6 (or 5) phyllites.

P: probability that the listed values for W had been found if no real differences between the zircons of the two rock groups existed.

The investigated rock specimens are kept by the State Museum of Geology and Mineralogy, Leiden (Netherlands). The specimens number are the numbers under which the specimens are enscribed in the books of the Museum. Only the last two figures of the numbers have been referred to in the text.

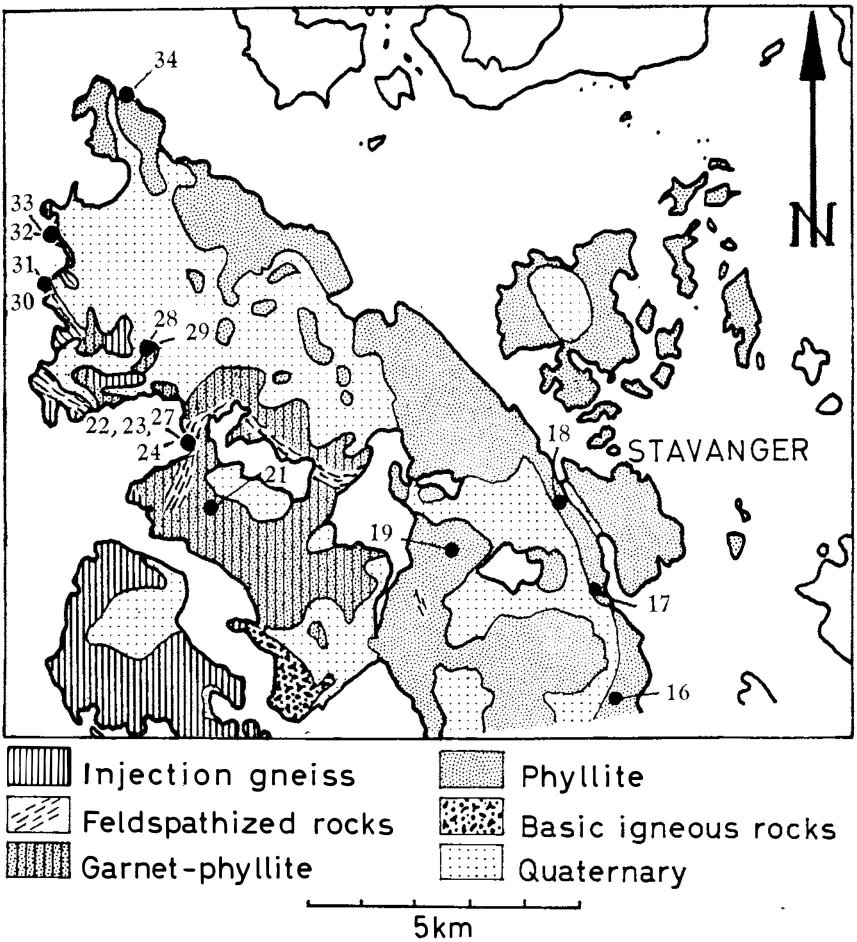

Fig. 1: Geological map of the Stavanger peninsula after GOLDSCHMIDT (1921) with the localities where samples for zircon concentration have been collected. Black dots show location of samples. 16, 17, 18, 19: phyllites. 21: garnet-phyllite. 22, 23, 27: albite-porphyroblasts-schists. 24: garnet-schist. 28, 29: feldspar-rich light coloured gneisses. 30, 31: feldspar-rich light coloured gneisses (interbedded with schists). 32: muscovite-quartzite. 33: quartzite.

facies to epidote-amfibolite-facies) which prevailed in the Stavanger area. In the opinion of the writer there can hardly be any doubt that the second explanation is the correct one.

Very little is known about the characteristics of zircons in different types of sediment. Shales hardly contain any zircon (TRUEMAN 1912. POLDERVAART 1955). Zircons seem to be restricted to more coarse grained sediments — in fact most of the zircon grains are larger than 64 μ, that means that they are sand grains. Probably the feldspar-rich rocks derived from sandy shales or graywacke-like sediments.

Although the zircons indicate that the feldspar bearing rocks did not originate from phyllites, this does not necessarily mean that metasomatism did not take place at all. If, however, metasomatism did contribute to the formation of these rocks, it was almost certainly of less importance than GOLDSCHMIDT thought, since more coarse grained rocks are already more rich in silica and sodium than phyllites.

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