Rb/Sr whole rock age determinations from the western part of the Østfold basement complex, SE Norway

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Rb/Sr whole rock age determinations on granitic orthogneisses in the western part of the Østfold basement complex have yielded ages in the range 1380–1015 m.y. The ages obtained indicate that the regional multiple fold structures, formed by superimposition of folds with E–W trending, vertical to steeply northwards dipping axial surfaces on older folds with N–S axial surfaces, are younger than 1320 m.y. Intrusion of basic dykes (the Kattsund dykes), and the subsequent ductile high strain deformation in the Oslofjorden region are younger than 1225 m.y. It is suggested that the last amphibolite facies metamorphism in the area, which is associated with the high strain deformation, occurred about 1015 m.y. ago.

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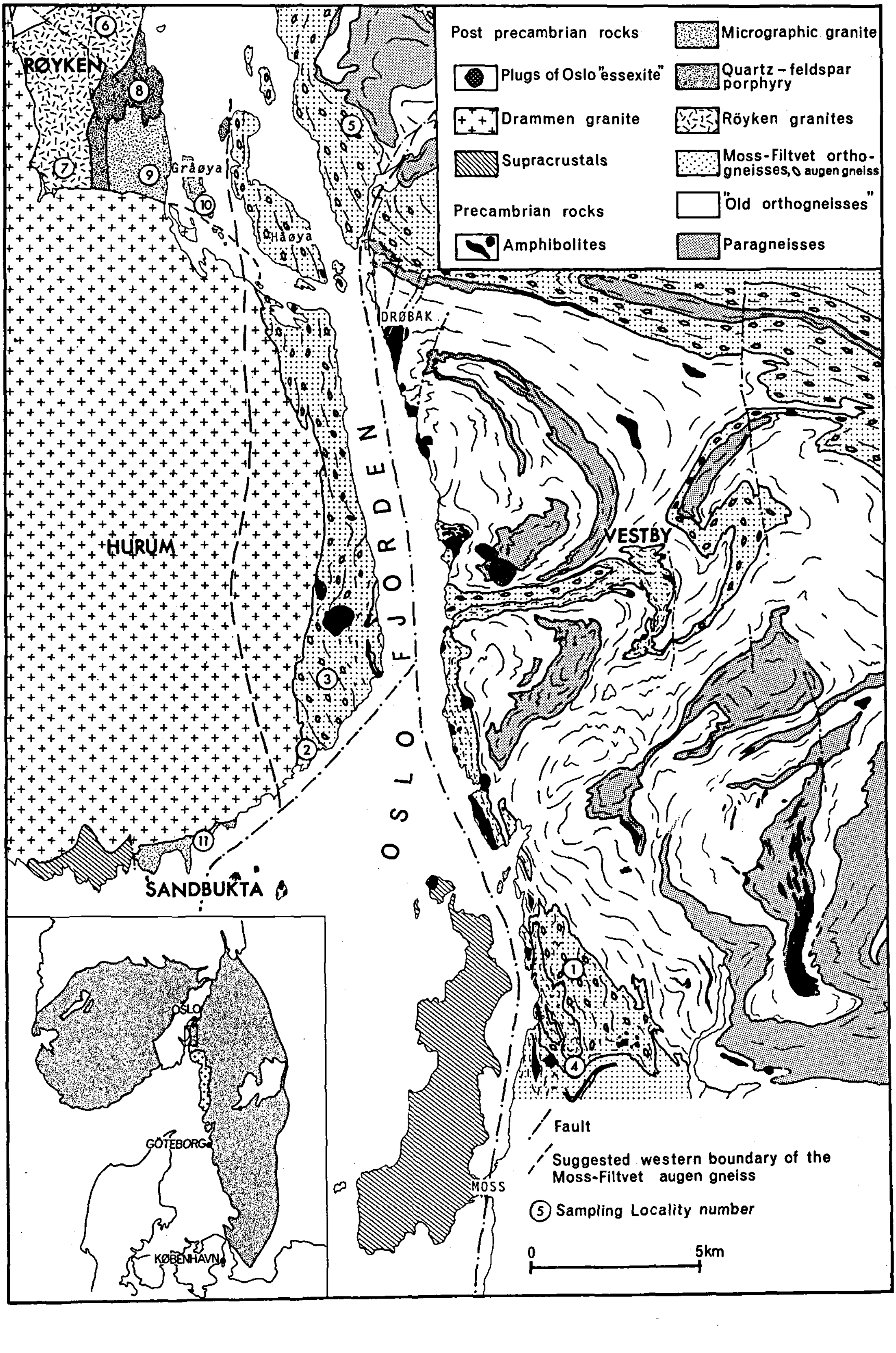
The Østfold basement complex, SE Norway, is situated within the 1200–900 m.y. old Sveconorwegian K/Ar age province of the southwestern part of the Baltic Shield, fig. 1, (Magnusson 1960, Kratz et al. 1968). Geological, structural and geochronological investigations indicate that deformational, metamorphic and magmatic activity affected the province in the period 1200–850 m.y. (Magnusson 1960, Touret 1968, Starmer 1972, 1977, Pasteels & Michot 1975, Versteeve 1975, Berthelsen 1978, Pedersen et al. 1978, Demaiffe & Michot 1979). These events are referred to as Sveconorwegian events.

The Østfold basement complex has earlier been believed to be composed essentially of the classic pre-Sveconorwegian elements, i.e. the Pregothian, the Stora Le-Marstrand Formation, and the Gothian (Gledisch 1952a, Magnusson 1963), which together form the bulk of the crustal material of the SW Swedish part of the province (cf. Magnusson 1963). Recent geochronological investigations in SW Sweden have yielded Rb/Sr ages for the Pregothian and the Gothian (or the so-called Åmål Mega-unit, Gorbatschev 1975) of 1700–1200 m.y. (Gorbatschev & Welin 1975, Skiöld 1976, Welin & Gorbatschev 1976a, b, c, Welin & Gorbatschev 1978). These ages agree with Rb/Sr ages obtained for orthogneisses in SE Norway (Pedersen et al. 1978) and imply that most intrusive activity occurred in this interval. Only the supracrustals of the Dal Formation, the post-kinematic Bohus-Iddefjord granite batholith and minor granitic bodies, and some basic dykes are of Sveconorwegian age (Skiöld 1976, Welin & Gorbatschev 1976b, Pedersen et al. op.cit.).

The Rb/Sr age study presented in this paper has been carried out on gneissified acid igneous rocks from the westernmost part of the Østfold basement complex. The rocks under consideration occur in the Precambrian areas of Sandbukta, E Hurum, Røyken and Vestby (fig. 1). The three first-mentioned areas are separated from the Vestby area by Oslofjorden, and are separated from each other by the Permian Drammen granite. Due to these relations and to the complex Precambrian geology, the establishment of a general event chronology covering all the areas mentioned is not easy. The rocks studied are the Moss-Filtvet augen gneiss, a gneissified quartz-feldspar porphyry, and granites from Røyken.

The western part of the Østfold basement complex has previously been investigated by Gleditsch (1952a, b), Berthelsen (1970) and Hageskov (1978), but since the recent geological and structural investigations are largely unpublished a summary of the geology is given in the next section.


Post precambrian rocks
Plugs of Oslo "essexite"
Drammen granite
Supracrustals
Precambrian rocks
Amphibolites
Micrographic granite
Quartz – feldspar porphyry
Röyken granites
Moss-Filtvet ortho-gneisses, augen gneiss
"Old orthogneisses"
Paragneisses
RØYKEN
Gråøya
Håøya
DRØBAK
HURUM
VESTBY
OSLO FJORDEN
SANDBUKTA
MOSS
OSLO
GÖTEBORG
KØBENHAVN
Fault
Suggested western boundary of the Moss-Filtvet augen gneiss
5 Sampling Locality number
0
5km

The geology of the westernmost part of the Østfold basement complex

Vestby area

The oldest known rocks in the area are monotonous grey, usually fine-grained and banded biotite-muscovite paragneisses of psammitic to semipelitic composition. Lenses of calcsilicates are fairly common in the unit and are thought to represent concretions. Thin pelitic bands are occasionally found, sometimes with a little sulphide and graphite. Garnet, sillimanite and kyanite occur, but nearly all the sillimanite and kyanite are altered to phyllosilicates. It is suggested that the paragneiss is derived from a greywacke formation and it is equivalent to the Stora Le-Marstrand Formation of SW Sweden (Larsson 1956, Lundegårdh 1958, Park et al. 1979). These paragneisses are now seen complexly interfolded with orthogneisses which in the western part of the Østfold basement complex are the most widespread rocks.

The orthogneisses may be divided roughly into the mega-unit "old orthogneisses" and the Moss-Filtvet orthogneisses.

The "old orthogneisses" are only seen in W Østfold. These original intrusives form a heterogeneous rock mass composed of different types of grey gneisses of calc-alkaline affinity that carry biotite, garnet and, less commonly, hornblende. The most widespread types are granitic augen gneisses of varying fabric, but the augens are always formed of megacrysts or aggregates of microcline perthite which are prekinematic in relation to the oldest deformation seen. Other types are granodioritic to tonalitic in composition.

The Moss-Filtvet orthogneisses consist of an intimate association of augen gneiss and fine-grained homogeneous gneisses derived from coarse-grained porphyritic and leucocratic even-grained granites respectively. The Hobøl granite (gneiss) of Rekstad (1921) belongs to the augen gneiss of this unit. East of Oslofjorden the Moss-Filtvet orthogneisses appear in a folded dyke-like body which can be followed across the area. This orthogneiss body has sharp contact against the host gneisses, which trends parallel to both the foliation in the host gneiss and that in the orthogneiss body. The body is nevertheless discordant to the pre-existing complex of paragneisses and "old orthogneisses". Dykes of the homogeneous type are found in the host gneisses as well as in the Moss-Filtvet augen gneiss and it is therefore believed that at least part, if not all, of the even-grained granitic material was injected later than the coarse-grained, porphyritic type. The field relations (e.g. sharp discordant contacts, dyke shape, minor dykes) suggest that the granites were injected into a brittle crust. The granites were later subjected to orogenic deformation and metamorphism as seen in table 1, which shows the event stratigraphy of W Østfold.

The Precambrian areas west of Oslofjorden

The Precambrian areas west of Oslofjorden (E Hurum, Røyken and Sandbukta) are situated within a ductile deformed N–S trending belt of high strain called the Fjordzone (Hageskov 1971), table 1, in which the deformation took place under amphibolite facies conditions. The youngest rock unit submitted to the Fjordzone deformation consists of the basic Kattsund dykes (Hageskov 1978). The dykes, which are now amphibolites, form a dense swarm in the Sandbukta area, but are also seen sparsely distributed in E Hurum and Røyken.

The Precambrian geology of E Hurum is easily correlated with the geology of the Vestby area as E Hurum is built up largely by the Moss-Filtvet augen gneiss. Since this augen gneiss does not appear in the Sandbukta and the Røyken areas, it is suggested that the original boundary of the augen gneiss runs N–S just west of the Precambrian of E Hurum, parallel to the main structural N–S trend of the Fjordzone. To the north the augen gneiss mass continues on the islands, and part of the western boundary is seen on the island of Håøya. The suggested western boundary of the Moss- Filtvet augen gneiss is shown on fig. 1.

According to Gleditsch (1952b) the Precambrian rocks in Røyken belong to a northern and a southern field of leptites separated by younger anatectic granites. The very fine-grained,

Fig. 1. Geological sketch map of the western part of the Østfold basement complex compiled from Hageskov & Jorde (1980), A. Berthelsen, T. Haaland, P. Nielsen and C. Zetterstrøm. The inset map shows the Sweconorwegian province of the Baltic Shield (in grey).

TABLE 1

THE EVENT STRATIGRAPHY OF W ØSTFOLD

ROCKS	CRUSTAL CONDITIONS	METAMORPHISMS
Postkinematic pegmatite dykes and Bohus/Iddefjord granite (Rb/Sr ages: 891 m.y.[1]) 923 m.y.[2])		
	Late folds Fjordzone deformation. Formation of reclined folds with N-S axial surfaces and moderately W-plunging axis in the westernmost part of Østfold. Local folds with steep N-S axial surfaces and N plunging axis in the Sandbukta area. Transposition of older structures towards the N-S axial surfaces. Formation of strong stretch fabric and minor shears	Greenschist facies Middle to low amphibolite facies (1015 m.y.)
Intrusion of the Kattsund dykes, (stratigraphic position uncertain but postdated by the Fjordzone deformation)		
	Folding, Regional Southward facing folds with steep E-W axial surfaces and W plunging axis	Low to middle amphibolite facies
Intrusion of basic magma The Moss globuliths[3])	Anorogenic conditions	
	Folding. Regional folds with N-S axial surfaces. First foliation in the Moss-Filtvet granites	High amphibolite facies. Migmatisation
Intrusion of layered gabbros, basic dykes, Intrusion of the Moss-Filtvet granites (1320 ± 22 m.y.)	Brittle crust, anorogenic conditions	
Intrusion of granitoids of granitic to tonalitic composition "Old orthogneisses" Rb/Sr ages: (1525, 1485, 1480 m.y.)[2])		
	Deformation	Metamorphism
Deposition of greywackes. Basement unknown		

1) Skiöld (1976); 2) Pedersen et al. (1978); 3) Berthelsen (1970)

homogeneous leptite in southern Røyken, which carries scattered small relic phenocrysts of quartz and feldspar, grades north- and westwards into a micrographic leptite and a micrographic granite. Graversen (1972) remapped the area and grouped the micrographic leptite and the micrographic granite into a micrographic granite unit. Both this unit and the anatectic granites (the Røyken granites), are interpretated as being of intrusive origin (Graversen op. cit.). Graversen agreed with Gleditsch that the northern leptite (now called fine-grained granitic gneiss) is older than the Røyken granite, but he found no field evidence to support Gleditsch proposition that the southern leptite is also older than the Røyken granites (O. Graversen, pers. comm.). The excellent exposures on Gråøya have enabled one of us (Hageskov) to demonstrate that the southern "leptite" is intrusive into fine-grained streaky gneisses of unknown affinity. This leptite is renamed gneissified quartz-feldspar porphyry.

In the Sandbukta area, a very fine-grained granitic gneiss occurs (Hageskov 1978). This rock is very silimar, although a little coarser, than the gneissified quartz-feldspar porphyry from South Røyken. The chemical composition of the Sandbukta rock, the occurrence of assumed relict phenocrysts (feldspar megacrysts and quartz aggregates) within the unit and the position directly south of the gneissified quartz-feldspar porphyry in Røyken suggest that this rock is a more recrystallised southwards continuation of the Røyken quartz-feldspar porphyry.

The relationships discussed in the foregoing leave the chronological problem of the age relations between the Røyken granites and the "gneissified quartz-feldspar porphyry – micrographic granite" unsolved. Furthermore the age relations between the Røyken – Sandbukta rocks and the Moss-Filtvet rocks are unknown. It is only known with certain from field relations that the Røyken – Sandbukta rocks are older than the Kattsund dykes as well as the Fjordzone deformation which postdates the dykes.

Rb/Sr dating

Sampling and description of localities

The analysed samples were, with a few exceptions, selected from localities where the rocks apparently had suffered very little deformation. Most samples weighed between 8 and 15 kg. Smaller samples of quartz-feldspar porphyry were analysed due to the very fine-grained and homogeneous nature of these rocks.

14 large speciments of the Moss-Filtvet orthogneiss were collected from five localities within a distance of 30 km in the Oslofjorden region (fig. 1). No leucosome was detected in any of the samples and in only one of the localities is migmatisation visible. The samples from locality no. 2 (Bispen) and no. 1 (Fylkegrensen) are of special interest.

The Bispen locality is the only known locality where largely undeformed porphyritic Moss-Filtvet granite can be studied. The development of augen gneiss in minor zones within this granite and the gradational transformation of the granite to augen gneiss by increasing deformation provide an excellent example of the formation of augen gneiss from prophyritic granite. Five samples were collected from the granite.

At the Fylkegrensen locality two phases of deformation have been established. The older phase is defined by an almost vertical E–W trending foliation; superimposed on this is the younger Fjordzone deformation, which has given rise to N–S striking and moderately westwards dipping younger foliation. Minor shears parallel to the younger foliation have developed gleitbrett structures. Leucocratic material resulting from mobilisation in amphibolite facies is located in these shears and in thin veins subparallel to the younger foliation. The mobilisation is thus related to the Fjordzone deformation. Four samples without mobilisate were collected from this locality.

In the Røyken and the Sandbukta areas samples from four rock types have been collected for a reconnaissance Rb/Sr study. The gneissified quartz-feldspar porphyry has been collected in the Sandbukta area (3 samples) and in southern Røyken (5 samples). Furthermore the micrographic granite (4 samples) and a grey and red type of Røyken granite have been sampled (4 samples).

Analytical technique

The analytical work was carried out at the Institute of Petrology, University of Copenhagen. The Sr-isotope ratios were determined on unspiked samples on a Varian MAT TH–5 mass spectrometer. All values in the following refer to an Eimer & Amend value for the $^{87}Sr/^{86}Sr$ ratio of 0.7080 normalised to a $^{88}Sr/^{86}Sr$ value of 8.3752. The errors quoted were calculated from suites of 20 double determinations (including the chemistry) carried out a different times during the investigations in the laboratory. Determinations of the Rb/Sr ratios were carried out on a Philips pw-1410 XRF spectrometer on two pellets from each sample. Errors were calculated from the counting statistics and from the differences between the standards used. GSP-1 and G-2 were used as standards with assumed Rb/Sr values of 1.093 and 0.355 respectively (Pankhurst & O'Nions 1973). While measuring the samples with high Rb/Sr ratios the NBS–70A K-feldspar was also analysed. A value of 8.11 ± 0.07 was obtained. Three of the samples with high Rb/Sr ratios were also analysed at the isotope laboratory at Oxford. The results agree within experimental errors.

Analytical details are given in Table 2 and Table 3. Ages were calculated with the help of the programme by McIntyre et al. (1966) using a decay constant of 1.42 × 10^{-11}/year (Steiger & Jäger 1977). Errors are given at the 2σ – level.

Results and discussion

Samples from the augen gneiss unit within the Moss-Filtvet orthogneisses, apart from those from the Fylkegrensen locality, define an isochron of 1320 ± 22 m.y. (fig. 2). The initial $^{87}Sr/^{86}Sr$ ratio is 0.7174 ± 20. When calculated on their own, the samples from the Bispen locality and from the Kaltenbak locality define ages of

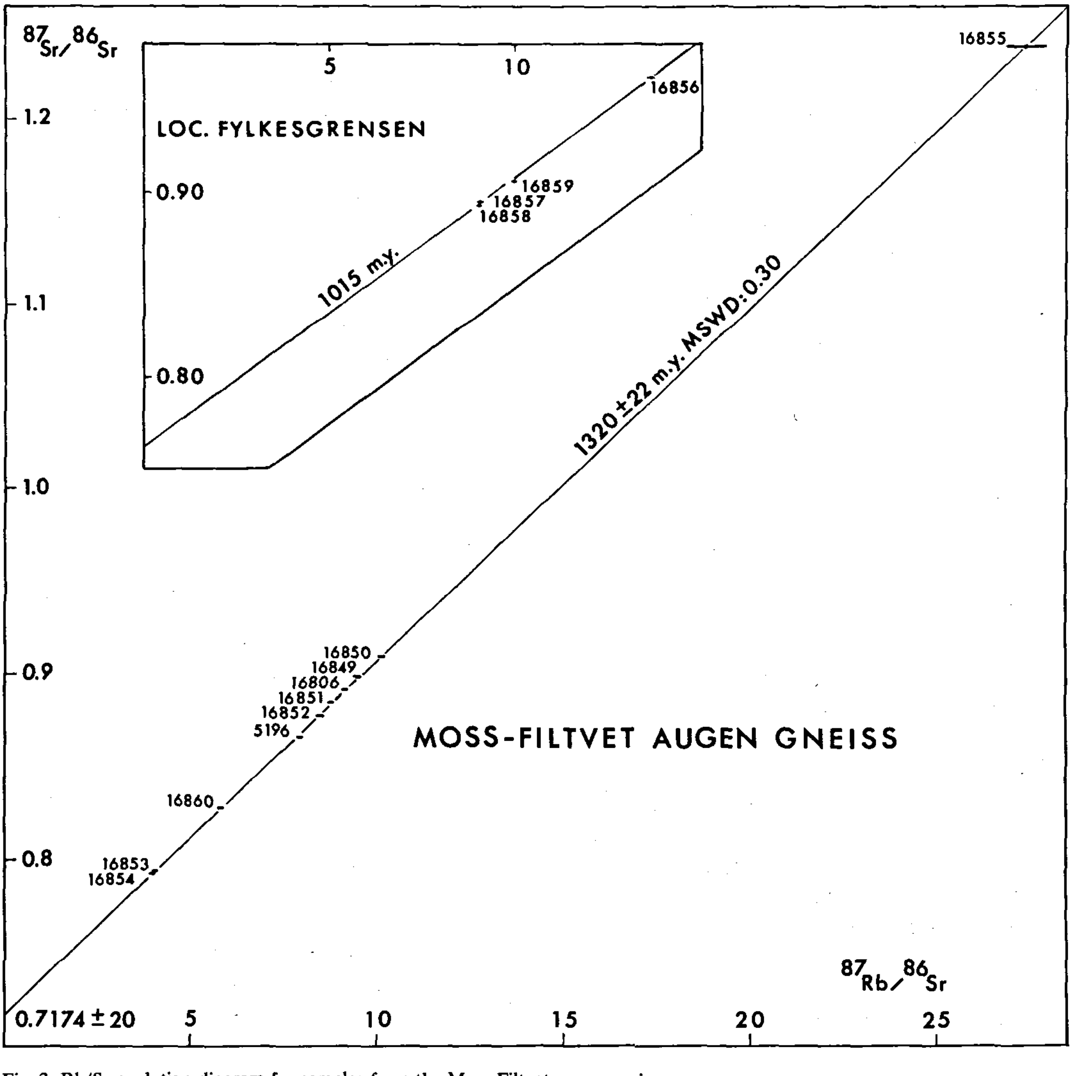


Fig. 2. Rb/Sr evolution diagram for samples from the Moss-Filtvet augen gneiss.

TABLE 2. ANALYTICAL DETAILS OF SAMPLES FROM THE MOSS-FILTVET AUGEN GNEISS.

LOC.NO.	SAMPLE NO.	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
1	16858	9.00 ± 9	0.8932 ± 2
1	16857	9.05 ± 8	0.8951 ± 3
1	16859	10.00 ± 9	0.9063 ± 3
1	16856	13.66 ± 14	0.9616 ± 3
Age, loc. 1 (Fylkesgrensen): 1015 m.y. $(^{87}Sr/^{86}Sr)_o$: 0.763			
2	16852	8.46 ± 8	0.8768 ± 2
2	16851	8.78 ± 9	0.8842 ± 2
2	16809	9.18 ± 9	0.8908 ± 2
2	16849	9.47 ± 9	0.8978 ± 3
2	16850	10.13 ± 10	0.9089 ± 2
Age, loc. 2 (Bispen, Hurum): 1350 m.y. $(^{87}Sr/^{86}Sr)_o$: 0.714			
3	16854	3.98 ± 3	0.7928 ± 3
3	16853	4.03 ± 4	0.7936 ± 3
3	16855	27.4 ± 5	1.2393 ± 5
Age, loc. 3 (Kaltenbak): 1340 m.y. $(^{87}Sr/^{86}Sr)_o$: 0.707			
4	16860	5.81 ± 5	0.8276 ± 2
5	5196	7.92 ± 7	0.8657 ± 3

Age, loc. 2, 3, 4, 5: 1320 m.y. ± 22 m.y.
$(^{87}Sr/^{86}Sr)_o$: 0.7174 ± 20, MSWD: 0.30

TABLE 3. ANALYTICAL DETAILS OF SAMPLES FROM THE SANDBUKTA AND RØYKEN AREAS.

LOC.NO.	SAMPLE NO.	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Røyken granites			
Grey type			
6	16879	6.60 ± 4	0.8408 ± 3
6	16880	6.89 ± 6	0.8434 ± 3
Red type			
7	16877	36.4 ± 4	1.4362 ± 5
7	16878	40.5 ± 5	1.5043 ± 5
Age: 1380 m.y. $(^{87}Sr/^{86}Sr)_o$: 0.709			
Micrographic granite (Røyken)			
8	16871	55.0 ± 9	1.6994 ± 5
8	16870	56.9 ± 9	1.7332 ± 5
8	16872	66.0 ± 1.1	1.9000 ± 5
8	16873	71.9 ± 1.2	2.0364 ± 5
Model age calculation with a fixed initial $^{87}Sr/^{86}Sr$ of 0.705: 1270 m.y.			
Quartz-feldspar porphyry			
Røyken			
9	16876	7.38 ± 8	0.8752 ± 3
9	16875	7.95 ± 9	0.8829 ± 3
9	A	8.13 ± 14	0.8814 ± 3
9	16874	8.15 ± 9	0.8817 ± 3
10	10814	14.2 ± 3	0.9540 ± 3
Sandbukta			
11	10829	9.59 ± 18	0.9125 ± 3
11	16804	11.1 ± 2	0.9292 ± 3
11	16803	14.9 ± 3	1.0033 ± 3

Age (loc. 8-11, minus 10): 1225 ± 22 m.y.
$(^{87}Sr/^{86}Sr)_o$: 0.742 ± 0.003 MSWD: 2.32

Age (loc. 8-14, minus sample 16874, A, 16804, 10814): 1224 ± 22.m.y.
$(^{87}Sr/^{86}Sr)_o$: 0.745 ± 0.003, MSWD: 0.70

1350 m.y. and 1340 m.y. respectively. The Fylkegrensen locality yields an age of 1015 m.y. (fig. 2).

We believe that the age of 1320 ± 22 m.y. is the age of intrusion of the porphyritic granite which later became the Moss-Filtvet augen gneiss, and that, in spite of the initial $^{87}Sr/^{86}Sr$ of 0.7174, it does not reflect resetting. In our opinion resetting in this case is unlikely as it demands either a perfect homogenisation of the Sr isotope system over a distance of 30 km or a small scale homogenisation within restricted areas with uniform mean Rb/Sr ratios. This would result in a secondary isochron as discussed by Roddich & Compston (1977), but is excluded here due to the spread in the Rb/Sr ratios within the area. Moreover, Rb/Sr age determinations on other plutonic rocks in the same area yield higher apparent ages of 1480, 1485 and 1525 m.y. (Pedersen et al. 1978), which implies that any resetting in the Moss-Filtvet augen gneiss would

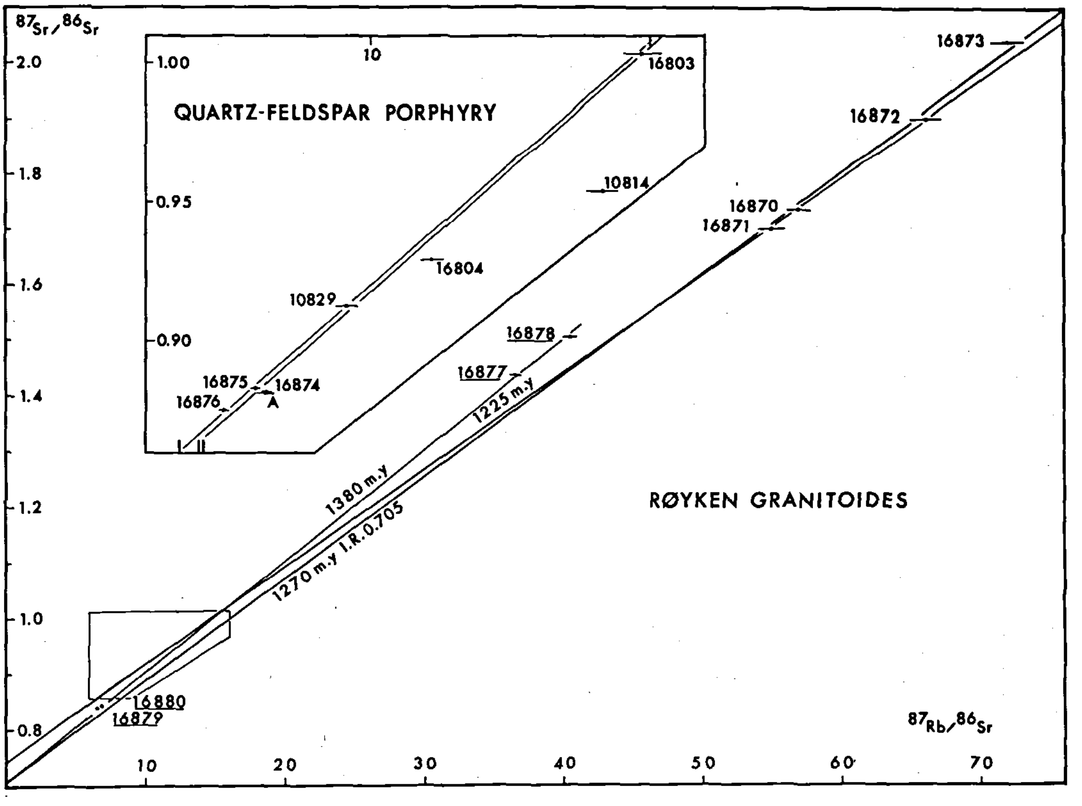


Fig. 3. Rb/Sr evolution diagram for samples from the Røyken granitoids. The age of 1380 m.y. refers to the age of the Røyken granites (underlined). The regression line I in the insert is the isochron calculated from the micrographic granite and the quartz-feldspar porphyry samples unaffected by shearing (1224 ± 22 m.y., MSWD: 0.70). Regression line II is the isochron including all samples of micrographic granite and quartz-feldspar prophyry – except 10814 (1225 ± 22 m.y., MSWD: 2.32). The age of 1270 m.y. is a model age for the micrographic granite assuming an initial Sr isotope ratio of 0.705.

have to have been confined to this single lithological unit. The initial Sr isotope ratio of 0.7174 suggests a derivation from older crustal material.

The age of 1015 m.y. obtained from the Fylkegrense locality indicates that a local resetting and homogenisation has taken place. We suggest that this process should be correlated with the metamorphism and leucosome formation that accompanied the Fjordzone deformation.

The samples from the micrographic granite and the gneissified quartz-feldspar porphyry from the Røyken area, which may be related, yield some scatter around an isochron of 1225 ± 22 m.y. with a MSWD of 2.32 (cut-off value: 2.40) (fig. 3). One of the samples of the quartz-feldspar porphyry (10814) is strongly sheared by the Fjordzone deformation, and falls far to the right of the isochron. This could be due to Rb addition during the shearing as the Rb content of the sample is higher than in the other samples (217 ppm versus 146–172 ppm). Although lacking good evidence, we suggest that some of the other samples of the quartz-feldspar porphyry were either enriched in Rb or depleted in ^{87}Sr during the Fjordzone deformation giving rise to the observed scatter in the Rb/Sr evolution diagram. A calculation of the common age for the samples of the micrographic granite and the quartz-feldspar porphyry which have not been affected by the shearing (i.e. the samples which fall to the right of the isochron) yields an isochron age of 1224 ± 22 m.y. with a MSWD of 0.70 and an initial Sr isotope ratio of 0.745 ± 0.003. The age is considered to be intrusion age, and the high initial Sr isotope ratio indicates, as for the Moss-Filtvet augen gneiss, a derivation of the rocks from older crustal material.

The preliminary age determination of the grey and red Røyken granites yields an apparent age of 1380 m.y. (fig. 3), which could mean that the Røyken granites are slightly older than the Moss-Filtvet augen gneiss.

Conclusions

The consequences of the Rb/Sr investigations presented in this paper are in summary:

1) The coarse-grained porphyritic Moss-Filtvet granite (the augen gneiss) was intruded into a complex of paragneisses and old orthogneisses about 1320 m.y. ago.

2 The intrusion of the micrographic granite and the quartz-feldspar porphyry from southern Røyken and from Sandbukta took place about 1225 m.y. ago.

3) The Røyken granite seems to be older than the quartz-feldspar porphyry and the micrographic granite and possibly as old as 1380 m.y. Consequently the northern leptite of Gleditsch (1952b) should not be correlated with the quartz-feldspar porphyry in south Røyken and Sandbukta as the geological evidence indicates that the northern leptite is older than the Røyken granite.

4) The granitic rocks are derived from older sialic crustal material.

5) The N–S folds and the succeeding E–W folds, which form the regional fold structures in W Østfold, are younger than 1320 m.y. and older than the Fjordzone events.

6) The Kattsund dyking and the initial deformational and metamorphic events associated with the Fjordzone deformation are younger than 1225 m.y., as the Kattsund dykes cut the quartz-feldspar porphyry.

7) Syn-deformational amphibolite facies metamorphism in the Fjordzone probably took place 1015 m.y. ago.

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Dansk sammendrag

Rb/Sr-aldersbestemmelser på granitiske orthognejser fra den vestlige del af Østfoldområdet giver aldre fra 1380 til 1015 mill. år. Aldrene viser, at de regionale interferensmønstre, der er dannet ved overprægning af folder med Ø–V forløbende, vertikal til stejlt nordligt hældende aksialflader på ældre folder med N–S aksialflader, er yngre end 1320 mill. år. Intrusionen af basiske gange (Kattsund gange) og efterfølgende ductile 'high strain' deformation i Oslofjordområdet er yngre end 1225 mill. år. Den sidste amfibolitfacies metamorfose i området, der er associeret med 'high strain' deformationen, antages at være omkring 1015 mill. år gammel.

References

Berthelsen, A., 1970: Globulith. A new type of intrusive structure, exemplified by metabasic bodies in the Moss area, SE Norway. *Norges geol. Unders.* 266: 70–85.

Berthelsen, A., 1978: Himalayan and Sveconorwegian tectonics – a comparison. *Tectonic Geology of the Himalaya: ed.* Saklani, P. S., 287–294.

Demaiffe, D. & Michot, J., 1979: Petrology, geochemistry and geochronology of the Precambrian complex of South Rogaland: A review (abstract). *ECOG* VI, Lillehammer 1979.

Gleditsch, C. C., 1952a: Oslofjordens prekambriske områder I. *Norges geol. Unders.*, 181.

Gleditsch, C. C., 1952b: Oslofjordens prekambriske områder II. *Norges geol. Unders.*, 182.

Gorbatschev, R., 1975: Fundamental subdivisions of Precambrian granitoids in the Åmål mega-unit and the evolution of the south-western Baltic Shield, Sweden. *Geol. Fören. Stockh. Förh.* 97, 107–114.

Gorbatschev, R. & Welin, E., 1975: The Rb–Sr age of the Ursand granite and the boundary between the Åmål and "Pregothian" mega-units of southwestern Sweden. *Geol. Fören. Stockh. Förh.* 97, 379–381.

Graversen, O., 1972: Geological map 1814 I Asker: 1:50.000 (Precambrian division). *Norges geol. Unders.* Unpublished.

Hageskov, B. 1971: *Grundfjeldets tektoniske udvikling og strukturel beskrivelse af metabasiter i det nordvestlige Moss-område.* Unpubl. thesis, University of Copenhagen.

Hageskov, B. 1978: On the Precambrian structures of the Sandbukta-Mølen inlier in the Oslo Graben, SE Norway. *Nor. Geol. Tidsskr.*, 58, 69–80.

Hageskov, B. & Jorde, K. 1980: DRØBAK, berggrundsgeologisk kart 1814 II – M. 1:50.000. Foreløbig utgave. *Norges geol. Unders.*

Kratz, K. O., Gerling, E. K. & Lobach-Zhuchenko, S. B., 1968: The isotope geology of the Precambrian of the Baltic Shield. *Cand. Jour. Earth Sci.* 5, 657–660.

Larsson, W., 1956: Beskrivning til kartbladet Vårvik. Berggrunden. *Sver. geol. Unders.* Ser. A, 187: 10–127.

Lundegårdh, P. H. 1958: Göteborgstraktens berggrund. *Sver. geol. Unders.* Ser. C, 553.

Magnusson, N. H., 1960: Age determinations of Swedish precambrian rocks. *Geol. Fören. Stockh. Förh.* 82: 407–432.

Magnusson, N. H. 1963: *in:* Magnusson, N. H., Lundqvist, G. & Regnéll, G.: *Sveriges Geologi,* Svenska Bokförlaget/Norsteds.

McIntyre, G. A., Brooks, C., Compston, W. & Turek, A., 1966: The statistic assessment of Rb–Sr isochrons. *J. Geophys. Res.* 71: 5459–5468.

Pankhurst, R. J. & O'Nions, R. K., 1973: Determinations of Rb/Sr and $^{87}Sr/^{86}Sr$ ratios of some standard rocks and evaluation of X-ray fluorscence spectrometry in Rb/Sr geochemistry. *Chem. Geol.* 12: 127–136.

Park, G., Bailey, A., Crane, A., Cresswell, P. & Standley, R., 1979: Structure and geological history of the Stora Le-Marstrand rocks in western Orust, southwestern Sweden. *Sver. Geol. Under.* Ser. C, nr. 763: 1–36.

Pasteels, P. & Michot, J., 1975: Geochronologic investigations of the metamorphic terrain of southwestern Norway. *Nor. Geol. Tidsskr.*, 55: 111–134.

Pedersen, S., Berthelsen, A., Falkum, T., Graversen, O., Hageskov, B., Maaløe, S., Petersen, J. S., Skjernaa, L. & Wilson, J. R. 1978: Rb/Sr-dating of the plutonic and tectonic evolution of the Sveconorwegian Province, Southern Norway. *ICOG Denver, U.S. Geol. Surv. Open-File rep.* 78, 701: 329–331.

Rekstad, J. 1921: Eidsberg: De geologiske forhold innen rektangelkartet Eidsbergs område. *Norges geol. Unders.* 88: 1–76.

Roddick, J. C. & Compston, W. 1977: Strontium isotopic equilibration: A solution to a paradox. *Earth Planet. Sci. Lett.* 34: 238–246.

Skiöld, T., 1976: The interpretation of the Rb/Sr and K–Ar ages of late Precambrian rocks in south-western Sweden. *Geol. Fören. Stockh. Förh.* 98: 3–28.

Steiger, R. H. & Jäger, E., 1977: Subcommission on Geochronology: Convention on the use of decay constants in geo- and cosmochronology. *Earth Planet. Sci. Lett.* 36: 359–362.

Starmer, I. C., 1972: The Sveconorwegian regeneration and earlier orogenic events in the Bamble series. *Norges geol. Unders.* 277: 37–52.

Starmer, I. C., 1977: The geology and evolution of the south-western part of the Kongsberg series. *Nor. geol. Tidsskr.* 57: 1–22.

Touret, J. 1968: The Precambrian metamorphic rocks around the Lake Vegår (Aust–Agder, southern Norway). *Norges geol. Unders.* 257: 1–45.

Versteve, A. J., 1975: Isotope geochronology in the high-grade metamorphic Precambrian of southwestern Norway. *Norges geol. Unders.* 318: 1–50.

Welin, E. & Gorbatschev, R., 1976a: A Rb–Sr geochronological study of the older granitoids in the Åmål tectonic mega-unit, south-western Sweden. *Geol. Fören. Stockh. Förh.* 98: 374–377.

Welin, E. & Gorbatschev, R., 1976b: The Rb–Sr age of the Hästefjorden granite and its bearing on the Precambrian evolution of south-western Sweden. *Precambrian Res.* 3: 187–195.

Welin, E. & Gorbatschev, R., 1976c: Rb–Sr age of granitoid gneisses in the "Pregothian" area of south-western Sweden. *Geol. Fören. Stockh. Förh.* 98: 378–381.

Welin, E. & Gorbatschev, R., 1978: Rb–Sr age of the Lane granites in south-western Sweden. *Geol. Fören. Stockh. Förh.* 100: 101–102.